

Sphere of Sustainability: Lessons from the University of Utah's Global Changes and Society Course

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Abstract: Global challenges increasingly require interdisciplinary approaches to problem solving. This need should be facilitated by institutions of higher education. With increasing climatic and anthropogenic changes, graduate students must gain collaborative experience communicating and working across disciplines. The evolution of multidisciplinary problem-solving and global, sustainability-minded education provides the impetus for universities to reframe researchers' understanding of the environment and reimagine the spheres of curriculum, research, teaching, outreach, culture, and management. This paper describes a successful multidisciplinary approach at the University of Utah, centered on the project-based Global Changes and Society course. This method has brought about changes within the university and improved linkages to the greater community. Of particular importance is the development and implementation of the course framework, which transitions over time to address region-specific sustainability objectives. The results, pitfalls, and recommendations from this evolving venture are highlighted through a series of universal examples, with the potential to be applied at any institution of higher education focused on adapting the culture, environment, and structure to facilitate multilevel sustainability. DOI: 10.1061/(ASCE)WR.1943-5452.0000514. © 2015 American Society of Civil Engineers.

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Introduction

Society faces broad environmental and sustainability challenges that will be best addressed with interdisciplinary assessments and solutions. Across the globe, humans are altering climate, hydrological cycles, natural resource availability, wildlife habitat, air quality, species diversity, and numerous other complex systems. These environmental issues are strongly related to societal changes. Changes in social systems drive and respond to changing environmental conditions. Achieving a sustainable way of life is imperative (so that future generations can enjoy the same opportunities and natural resources as the current generation) and requires diverse inputs.

The nature of a sustainable world requires fundamental changes in human thought and action, and therefore fundamental changes to

the education system. Yet, how does society go about making those changes? An interdisciplinary approach to sustainability education is often suggested, with a variety of methods presented, including case studies and systematic adjustments to curriculum, research, teacher training, institutional practices, research funding, and community relations (Cortese 2003; Moore 2005; Summers et al. 2005; O'Brien et al. 2013). Steiner and Posch (2006) emphasize the importance of courses addressing so-called real world problems, identification of and cooperation among stakeholders, and a departure from traditional roles (such as professors as providers of information and students as consumers of information). The sustainability field has been home to many experiments in education. Some of these experiments have been more successful than others, as evidenced by the observation that neither higher education nor society has fundamentally transformed (Jones et al. 2010). Still, these areas are in noticeable flux and researchers must continue experimentation if an envisioned sustainable future is to be achieved. As Feng (2012) notes, "The key to interdisciplinarity is an open attitude, a willingness to learn and an ability to engage with different ways of thinking about issues we face in common."

No longer can higher education attempt to address global-scale, regional-scale, or local-scale sustainability challenges from solitary perspectives, and hope to institute long-term solutions. Instead, university engagement and collaboration with stakeholders and workers in other germane fields should occur to develop effective solutions. This is an important step in transitioning graduate training so that students are as well-grounded in working as part of an interdisciplinary team as they are experts in their specialized fields. In a review of issues facing sustainable cities, Shmelev and Shmeleva (2009) highlight (1) energy, (2) transportation, (3) landscape and architecture design and planning, (4) green space, and (5) human-urban interactions. These foci are pertinent to the foundation for courses targeting students' abilities to collaborate across disciplinary boundaries. Similarly, cities must rely upon individuals from diverse intellectual and cultural backgrounds to

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make progress in each of these focus areas. As the conceptualization of sustainability expands, integrative studies are increasingly used to assess the vulnerabilities and adaptation potential of urban environments (Shmelev and Shmeleva 2009).

Addressing such broad environmental and social issues requires research and framing of results, such that broader stakeholder education and satisfaction is achieved (Krizek et al. 2012). An interdisciplinary approach can greatly contribute to this goal. By working together, economists, chemists, sociologists, engineers, and members of other fields can develop robust solutions to global, regional, or local problems. The Intergovernmental Panel on Climate Change (IPCC) is a prime example, comprised of researchers from numerous fields collaborating on broad, complex issues. To successfully develop common solutions, these researchers require excellent communication skills and the ability to understand or work with unfamiliar research, and relate it to their own. This format of collaborative science and research reflects the future of how students should be educated, to maximize their experience and training within this paradigm (Sankar et al. 2007). Universities and high schools in the United States will benefit by engaging with the sustainability megatrend (Lubin and Esty 2010), by cultivating students who are well-prepared to address the social and environmental issues of the current generation. Without consistent and concerted effort, American universities risk falling behind corporations and foreign countries that have embraced sustainability efforts for decades (van Weenen 2000).

Efforts aimed at improving sustainability competencies in higher education are increasingly documented, lending insight to any institution willing to change (Krizek et al. 2012; Sims and Falkenberg 2013). Prominent themes include experiential, interdisciplinary, and interinstitutional learning; problem-based or project-based courses that incorporate nearby communities and natural environments; and partnerships between multiple stakeholders such as students, academics, community members, and government organizations (de la Harpe and Thomas 2009; Thomas 2009; Sims and Falkenberg 2013). Wagner et al. (2012) and Vale et al. (2012) provide multiple examples of specific courses aimed at improving individuals' interdisciplinary education. Individual university-level courses are only one step in the process of securing long-term shifts. Other successful applications have stressed that changes in existing university structures, towards a so-called universal knowledge network, must also be provided (van Weenen 2000). As such, the education and incorporation of sustainability in higher education has become an imperative for institutions globally, with increasing examples of theoretical and practical frameworks.

Recognizing coordination amongst individuals, emphasis of community-based participatory research (CBPR) has permeated modern research and funding sources. Community-based participatory research is an iterative process in which research questions are driven by end results satisfying community needs and a broader understanding of the produced knowledge, extending beyond both the individual and discipline. The U.S. Agency for International Development (USAID) is an example of an organization that has increasingly relied on crowd-sourcing for creative solutions to the Grand Challenges for Development (Wible 2012). This democratization of science and technology relies on local experience and knowledge to produce low-cost, less-destructive alternatives to the status quo (Wible 2012). However, major hurdles of such initiatives include language barriers (Bracken and Oughton 2006) and the need for a stable partnership base in a transient student body. Broadening stakeholder education and action must be at the center of any sustainable education mission to provide experience to students in solving problems beyond academia.

The question then is how do academic institutions synthesize and sustain the process of educating students within a sustainability framework? What curricula can be created and implemented that substantively address sustainability issues at the postsecondary level? What outcomes should be expected? If interdisciplinary work will yield better solutions, then students need interdisciplinary training. Historically, once a student's major had been selected, coursework and research were often constrained by discipline. When students pursue a more advanced degrees, this disciplinary focus often intensifies. To lower these barriers, the emergence of honors colleges has facilitated both educational and social external engagement. While a strong disciplinary base is essential for students, interdisciplinary and transdisciplinary training is becoming a new standard for a high-quality education (Lozano et al. 2013). For this reason, it is vital that successful models for training students to work within interdisciplinary environments enter the common space. Still, the question of how to shift the secondary-education paradigm to improve interdisciplinary connections, education, and research remains elusive.

This paper introduces a pedagogical model that incorporates students in an integrative framework essential to solving problems within this evolving paradigm of higher-education sustainability. The Global Changes and Society (GCS) course at the University of Utah is explored as a successful case study in sustainability education. This action-oriented, project-based course exposed students to working with students in other departments on a project devoted to improving sustainability. Students elected to focus on a local issue on which they could have a positive impact, and learned about the complexities associated with implementing institutional change and addressing global issues. The course is described and the success of the course is established by describing outcomes from two semesters of this course at the student, department, university, community, and regional levels. Finally, successful features of the course are discussed, as well as lessons and suggestions for faculty, students, and administrators wanting to integrate interdisciplinary sustainability learning into their own institutions. This paper highlights the understanding of complex socioecological systems and how interdisciplinary coursework prepares students for the types of collaborative research and practice they may encounter after graduation.

Background

The Global Change and Sustainability Center (GCSC) includes faculty affiliates from eight colleges across the entire campus, and facilitates faculty-led sustainability leadership at the University of Utah. As a consortium of nearly 100 faculty representing over 15 departments, the GCSC provides a hub to coordinate, promote, and accelerate interdisciplinary research and training on natural and human-built systems, the dynamic interactions and interconnections that exist in those systems, and the role of humans in the environment (GCSC 2014b). The GCSC attracts motivated incoming graduate students and provides first-year fellowships with a focus on facilitating interdisciplinary activities, and fostering working relationships. It does this by hosting a year-long seminar series by faculty presenting on topics of broad environmental and interdisciplinary interest, facilitating and promoting cross-disciplinary collaborations, and offering a GCS class. The epitome of future sustainability education, the GCS course is summarized in this paper to inform others that may embrace this model.

The three-credit GCS course consists of a cohort of both first-year fellows and nonfellows (Masters and Ph.D. students), and is

Table 1. Global Changes and Society Course Composition by Students' Departmental Affiliations, Interests, and Research Backgrounds

Discipline	College	General research interests and backgrounds
Civil and environmental engineering	Engineering	Urban hydrologic cycle, green infrastructure implementation and design, and hydrologic/hydraulic modeling
Mechanical engineering	Engineering	Earth-atmospheric interactions, atmospheric turbulence's role on the surface exchange of water, turbulence-enhanced PM10 particulate deposition in vegetative canopies, and low-cost atmospheric turbulence measurement system(s)
Geography	Social and behavioral science	Climate change, forest disturbances and fires, remote sensing, and long-term sediment records
City and metropolitan planning	Architecture and planning	Sustainable principles of architecture, urban environmental policy, urban sprawl, transportation, housing affordability, residential energy consumption, and walkability
Biology	Science	Terrestrial biogeochemistry, ecohydrology, disturbance ecology, natural history, and effects of NO _x air pollution on plant chemistry
Mathematics	Science	Interface between real-world phenomena and mathematics, and analysis of numerical approximations of partial differential equations
Geology and geophysics	Mines and earth science	Climate change, nutrient cycling, human impacts on the environment, hydrology, earth systems, paleoclimatology, and isotope biogeochemistry
Atmospheric science	Mines and earth science	Atmospheric modeling, anthropogenic and natural impacts on air quality, and meteorological impacts of climate change
Professional Masters of Science and Technology	Science	Technology and methods for improved communication of science and environmental change issues with the public

Note: To create an interdisciplinary project, students moved beyond their specific research areas to work in tandem in pursuit of the overall objectives of sustainability and the course.

open to all disciplines (Table 1). As of September 2014, the composition of GCS classes (i.e., typically 10–14 students per semester) has been 45% women and 55% men, and 30% Master's and 70% Ph.D. students. The GCSC faculty created the project-based course in 2012 as a response to the growing need for interdisciplinary training and does so by offering “an interdisciplinary introduction to research related to global changes” (GCSC 2014a). Participating students are given the freedom and directive to collectively identify a semester-long project on which to work as a class. The professor serves as a guide, facilitator, mentor, and resource throughout the iterative process of project development and implementation. Outside speakers are invited to present research and community needs and opportunities to the class as well as to develop broader community relationships. Students are concurrently enrolled in a one-unit seminar series that exposes them to lectures on a diverse set of topics closely related to the GCSC's mission and the themes underpinning the GCS course.

The professor and class participants explore unfamiliar areas in graduate student education by integrating project-based learning, interdisciplinary collaboration, and connections between global and local change. To identify a problem addressed with an action-oriented project over the course of a semester, students from distinct academic disciplines began by describing their research backgrounds and general interests to identify potential overlaps (Table 1). The two semesters of GCS described in this paper chose to focus their projects on issues related to water along the Wasatch Front, specifically focusing on Red Butte Creek (RBC), which passes through the University of Utah campus. Thus, reading and guest speakers focused on the issue of place-based, community-driven research, and targeted topics related to Red Butte Creek and its relationship with the University of Utah. Awareness of the creek had recently increased due to two unrelated oil spills, from a pipeline that crosses the creek, in 2010.

Originating in a pristine research natural area (RNA; <http://redbuttecanyon.net>) in the Wasatch Mountains just to the east of the University of Utah, RBC flows first through campus prior to entering residential zones (Fig. 1). As a result of being the first

institution to encounter the stream after it leaves the RNA, the University of Utah is the ultimate upstream steward. The RBC connects both undeveloped and developed watershed areas within a relatively short distance. Scientific research has been a highlight in the RNA since its formation in 1969, although few efforts have been made downstream. The wealth of knowledge (institutional and technical) regarding the RNA established a vast baseline upon which future education and research could be built. In combination with the direction and faculty resources of the GCSC, the applied project's goal was to bring to light the numerous opportunities for research, education, community, and stewardship inherent in the lower, urban portions of RBC.

Both classes focused on issues in the RBC riparian corridor that were intimately tied to global phenomena, i.e., water resources and environmental degradation under the weight of urbanization and global climate change. The goal of the year 2012 GCS (GCS1) was to identify university opportunities for stewardship improvement. Retention of the creek's pristine upstream qualities while balancing its long-term sustainability was of primary importance. This project became known as the Red Butte Creek Project, which included a compilation of existing data, a survey of students, faculty, and staff perceptions of RBC, research needs, and outreach and education opportunities. The GCS1 presented recommendations to university administration with the expressed goal of improving education, research, and outreach, and proposed adding RBC to the campus master plan. Students in the 2013 GCS course (GCS2) built on these initial efforts and focused on connecting disparate on-campus and off-campus activities related to the creek through improved outreach, engagement, and education. These efforts were eventually materialized through the formation of the group, Friends of Red Butte Creek (FORBC; redbuttecreek.utah.edu). The GCS1 and GCS2 students became intimately aware of the numerous ongoing projects and stakeholders along various stretches of RBC. Moreover, it became evident that RBC was a small component of a larger effort addressing water sustainability along the Wasatch Range metropolitan area (WRMA),

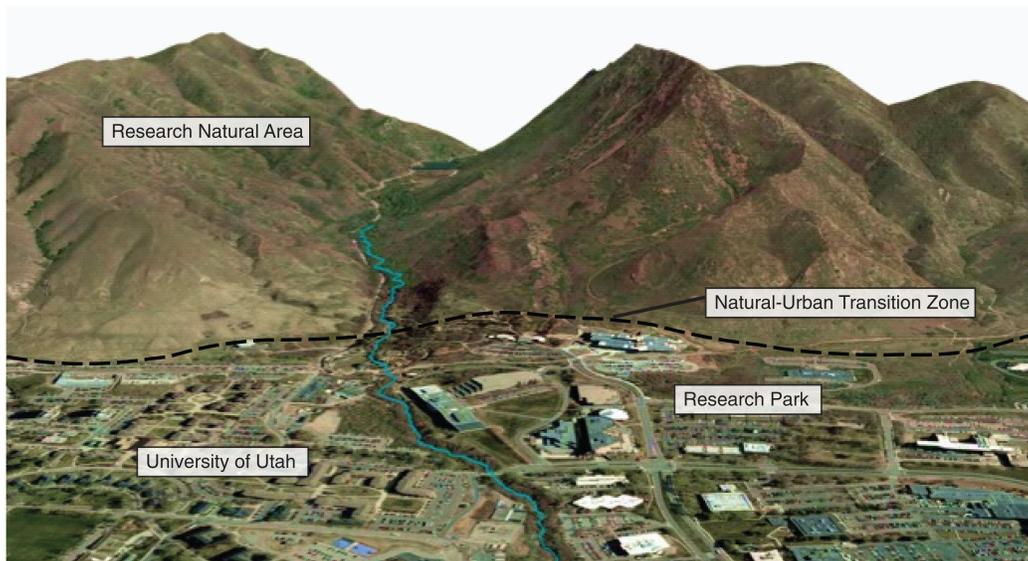


Fig. 1. Oblique aerial view of Red Butte Creek at the transition from the research natural area to the University of Utah; numerous management entities exist within the RBC watershed, including the National Forest Service, University of Utah, State of Utah, Salt Lake County, and the City of Salt Lake; Jordan Valley Water Conservancy District (JVWCD) manages the reservoir, as part of the Central Utah Project [CUP; image courtesy of Dudley (personal communication, 2013), with permission]

including the state of Utah, universities, and the broader Colorado River basin.

Objectives

Measuring the success of a sustainability-focused interdisciplinary course can be difficult with dynamic outcomes, but it is argued that the GCS model has been successful based on both the actual and potential outcomes at the individual, educational, and institutional levels.

Individual

Based on feedback, students finished the course with a more nuanced understanding of complex socioecological systems and those specific to RBC in particular. Beyond scientific understanding, students gained insight to the process of working across disciplinary lines and in creating and directing institutional change to improve sustainability. A feeling shared by many was the importance of the institutional process, as described by a GCS1 student, as presented next.

“At the beginning of the project I was very interested in developing better measurements of the health of the Red Butte Creek riparian corridor. By the end of the project, I really came to understand and appreciate the vital relationship between stewardship and governing entities like the University of Utah, Salt Lake City, and the County and State level administrations. Data is only one aspect to producing meaningful change, the rest is produced by concerned people raising concerns and working together to achieve a more sustainable future.”

On a more personal level, a network of students, researchers, and mentors was fostered that enhanced and enriched participant experiences after the course’s conclusion. Such networks have exhibited career benefits, including expanded applicability of results and methods to policy or management improvements (Goring et al. 2014). Post-GCS relationships have resulted in an extension of some student work to previously unfamiliar and nondiscipline-specific

arenas. The expanded mentor base and awareness of research provided students with access to methods, datasets, and resources far beyond their departmental scope. These relationships were noted by some as a highlight of their experience in the project-based seminar. As with the GCS, interdisciplinary projects can be an essential bridge between science, technology, policy, and action for broader issues and goals, as they encourage many disciplines to actually work together.

The GCS participants also noted improved abilities to communicate and work with other disciplines and stakeholders. To successfully navigate amongst these stakeholders, students were forced to adapt their vocabularies when discussing a common topic. This improved each individual’s ability to distill information and reduce jargon. This language hurdle represents a microcosm of the challenges facing universities and the future of sustainability education. Communication is the key to an understanding, acceptance, improvement, implementation, and long-term operation of the sustainability framework at the university level and beyond.

Finally, GCS participants described a deeper understanding of how other disciplines identified project components that addressed the larger issues or questions (e.g., thought process). This awareness of others’ processes of problem identification, which inevitably led to the range of proposed solutions, allowed for the overall project to shift according to the collective thought process. In GCS2, this became evident when students were asked to construct models of the RBC system. The words system and model were subject to debate between disciplines, harkening back to the discussion of language and communication. As to be expected, many of the system’s core elements were represented in each model; however, each was uniquely different along disciplinary lines. For instance, a geology student’s conceptual model of the RBC system uniquely included groundwater cycles, whereas a civil engineering student’s provided a primarily surface-flow-driven hydrologic cycle. This difference, despite dealing with the same issue, was a useful example illustrating both disciplinary thought processes and opportunities where interdisciplinary work improved solutions.

Educational

The University of Utah is working to embrace the so-called campus as a living laboratory approach to environmental and sustainability education. The GCS course established a precedent for interdisciplinary graduate education focused on issues related to global change and sustainability at the University of Utah. This movement has also motivated changes in undergraduate courses across many departments. The GCS outcomes aided the improved communication between departmental leaders, faculty members, and students, resulting in research advising and curriculum development centered on the creek and its riparian corridor. Multiple upper-level undergraduate courses have since incorporated RBC explicitly as a case-study project or to reinforce fundamental concepts and issues related to course objectives. Courses linking to RBC were taught in the Biology, Honors College, City and Metropolitan Planning, Geology and Geophysics, and Civil and Environmental Engineering Departments. Specific content included urban ecology and hydrology, water use, supply and demand, urban impacts on water quality, hydrological cycles, hydraulics, and ecological planning. The RBC's accessibility allowed for data collection that translated into semester-long research projects, homework assignments, and lecture content. These products increased the potential for future collaborative projects, recognition of the inherent benefits (e.g., monetary, recreational, educational, and research) of the creek system, and highlighted the fact that a representative body of students can serve to initiate change on campus.

University Administration

The GCS's influence also reached the university administration, with meetings and plans aimed at explicitly incorporating RBC and the riparian corridor into the university mission through improved education, research, and outreach centered on RBC. While the importance of this outcome cannot be overstated, the attitude and actions the university takes regarding RBC continue to evolve. The fact that GCS's goal of improving research, education, and outreach (described in a subsequent paragraph) related to RBC sustainability was achieved is clear evidence that this educational framework can improve sustainability. Along with collaborative potential, the ability of students to navigate administrative policy and politics was equally improved.

If institutions of higher learning are to play a leading role in global change and sustainability research, addressing the unsustainable realities inherent to their campuses is an important step. In part because of the work done by the GCS, the University of Utah has begun laying the groundwork for long-term change both in policy (e.g., establishment of a Riparian Corridor Steering Committee to inform the Campus Master Plan) and culture (e.g., implementing drought tolerant vegetation, xeriscaping, and green infrastructure on campus) that may improve the school's impact on the environment. The GCS students were successful in initiating small changes at the administrative level, which has translated into first steps of changes at the physical level.

Research

The GCS class helped to establish a foundation for future research related to RBC sustainability by identifying research needs and acknowledging the unique balance between ecological needs and human impacts for the urban-natural transition zone. Subsequent research activity within the RBC watershed has provided answers to research questions as well as education and investment in the sustainability of the creek. Some research even focuses on how to best improve environmental conditions of RBC.

The research questions established by the GCS class have been addressed by several research projects ranging from studies on vegetative use of groundwater, climate data monitoring, isotope hydrology, data synthesis and visualization, vegetation and land cover mapping, light detection and ranging (LIDAR) imaging, green infrastructure and outfall monitoring and assessment, and best-management practices. One of the most fruitful outcomes from the GCS has been the contribution of background research on RBC to the National Science Foundation (NSF) Experimental Program to Stimulate Competitive Research (EPSCoR) Innovative Urban Transitions and Aridregion Hydrology (iUTAH) program. The iUTAH program is a statewide collaborative program focused on improving water sustainability in Utah. This relationship has facilitated the sharing of data and institutional knowledge from the GCS course, including the following: (1) locations for installation of a climate and aquatic sensor network along RBC; (2) a summer institute for Kindergarten through Grade 12 teachers and students, and the Research Experiences for Undergraduates (REU) program focused on field-based activities along RBC; and (3) refinement of design ideas for the Green Infrastructure Research Facility (GIRF) along the RBC. Each of these projects builds upon suggestions made in the RBC project, with follow-up ensured by GCS liaisons and collaborating stakeholders. This highlighted the broader impact of place-based projects, such as those undertaken by the GCS, on national-funded and state-funded opportunities for research targeting improved stakeholder education, outreach, and collaboration.

Broader Community

The GCS class also facilitated connectivity amongst on-campus and off-campus groups, first through a broad range of guest speakers (e.g., academic institutions, municipal, county and state government, and nonprofit organizations; Table 2). While each speaker discussed topics related to their professional activities, the common denominator was RBC, and speakers were supportive of the interdisciplinary plan to engage RBC stakeholders on sustainability issues. Providing students with a variety of perspectives, this initial support from a diverse and notable set of professionals was essential in guiding the RBC project and FORBC development. Speakers also provided valuable perspectives on how working across disciplines can be successful in improving outcomes. As a result, partnerships between university academic activities and agencies (e.g., municipal, county, and state) have improved through GCS involvement. This is evident in the increased involvement with annual meetings (i.e., the Salt Lake County Watershed Symposium and the iUTAH Symposium) coordinating data collection and analysis efforts with RBC.

In particular, GCS arranged the approach for dialog among students and the university administration, facilities, maintenance and operation, and external collaborators [e.g., universities, state/local government, and nongovernmental organizations (NGOs)]. Class participants broadly surveyed students, faculty, and staff, about their awareness and perceptions of RBC and sustainability. These surveys indicated a lack of awareness with the transient student body relative to sustainability and RBC issues. Along with multiple presentations to the public as well as university faculty and administration, the GCS reasoned the need to improve RBC stewardship and suggested methods for doing so. One important outcome has been the formation of FORBC. The mission and activities of FORBC honor the legacy of RBC by educating students, residents, and visitors through stream and riparian ecology education, conducting and facilitating interdisciplinary research,

Table 2. Speakers Network List from the GCS, Representing a Subset of the Numerous Disciplines Required to Approach Sustainability Topics and Issues Related to the RBC Project Area

Speaker background	Field	Discussion topics
Terrestrial ecologist	Academia	Sustainability concepts and background, and common language
Water resources engineer	Academia	Sustainable engineering concepts and watersheds
Biometry, conservation biology, biodiversity, and watershed sciences	Academia	Stream and biodiversity restoration, and anthropogenic impacts
Manager of development review team	Local government	Red Butte Creek management, and community engagement and feedback
Watershed coordinator	State government	Red Butte Creek stream monitoring
Watershed planner and scientist	Local government	Jordan River total maximum daily load and RBC Chevron oil spill
Facilities planning	Architecture	Campus master plan and campus growth
Nonprofit environmental advocates	Advocacy	Engagement of a broader community and nonprofit/university institution ties
City and metropolitan planning	Architecture and academia	Environmental planning, and improving human health and well-being with sustainable development
Natural resource recreation planning and management	Academia	Place-based environmental education and stakeholder engagement
Geochemistry	Academia	Sediments, contaminants, human health, and environmental impacts

providing an informational web portal, implementing conservation projects, and establishing sustainability initiatives. These efforts highlight the significance of RBC, both as an entity and a resource to campus and community. The FORBC is not simply a student group focused on advocacy with a predefined agenda. Rather, this student-led initiative endeavors to promote a well-informed stewardship base with support from and collaboration with multiple partners (University of Utah, GCSC, and Salt Lake County). As such, reliance upon sustainability-based measures and principles for a decision-driven management, recreation, conservation, and utilization are anticipated.

Ultimately, the GCS course has changed the interdisciplinary dialog among first-year graduate students. Students from diverse backgrounds across campus have adjourned to explore new ways to integrate interdisciplinary work regarding sustainability. The GCS has shaped students' experience with implementing institutional change and broadening research and outreach networks. This has created a nucleus for new projects, discussion, and hands-on experience. While the GCS currently only spans one semester, the lessons learned and changes made will likely be long-lasting.

Discussion

Interdisciplinary collaboration is hard to initiate and is rarely a smooth process. Acknowledging the necessity of academic faculty and administrative commitment to such endeavors, success in academia can be bolstered by proactively reaching out to departments through students, student groups, and research groups. The value for first-year graduate students can be profound. The breadth and depth of the previously mentioned outcomes suggests that the GCS course was successful on a variety of levels. This section discusses course features that lent themselves to its success. More importantly, many of these features and lessons can be adapted by other institutions.

Course Design

Although not explicitly stated as a goal of the GCS class, its evolution was in accordance with that of a community-based participatory research model. A CBPR relies on individuals with professional, personal, cultural, and social relevance to a given issue. Incorporation of these stakeholders aims to improve research, action, and education with participation and recognition of power relations (Israel et al. 2001). Questions driven by community

interest and undertaken by academia provide research satisfying beyond purely scientific aims. In this case, the problem to be solved stemmed from community-garnered requests, through the Red Butte Creek Management Plan (BIO-WEST 2010). This document was the result of efforts by the Salt Lake County Watershed Planning and Restoration Program, to improve community outreach and education regarding the sustainability and conservation of RBC (BIO-WEST 2010). It also provided a benchmark upon which to structure future conservation and rehabilitation measures. Similarly to the CBPR, this insight was used to tailor the questions and methodologies for scientific research and experience by GCS students.

Communication and trust being the key, stakeholder partnerships were encouraged to realize a successful interdisciplinary approach (Bracken and Oughton 2006). For the GCS, these relationships included invited speakers, the student body, faculty and staff, university administrators, and local and state organizations (Tables 1 and 2). Separate but equally important to interdisciplinary coordination is an attachment to place, especially with respect to human response to global environmental and climatic changes (Devine-Wright 2013). The GCS partnership base can be attributed to being in accordance with this model. For example, using the resources of the Red Butte Creek Management Plan in tandem with site visits, external collaboration, and student body and administrative input, the GCS outcomes were able to expand and provide tailored results for stakeholders. These results included data collection and analysis, external course projects and lecture materials, and graduate research.

Since sustainability and interdisciplinary collaboration concepts lend themselves to theoretical approaches in academia, the GCS established practical outcomes for students, including skillset development and expanded/informed methodologies and networks. This directly impacts students' abilities to approach and solve problems. From the development of a place-based project to the implementation of a research plan, the action-oriented nature of the course required collaboration to achieve actual outcomes. These efforts addressed the practical needs that translated beyond abstract conceptual application. For instance, since the identified problems were multidisciplinary in nature, individuals' solutions required reliance upon the greater group. As a result, similarities between disciplines' approaches and backgrounds were illuminated. Furthermore, individuals exercising discipline-specific professional judgment were required to present, defend, and discuss this approach with the group. Incorporating this process early in graduate

training is useful to disentrenching students from the particularities of home departments, advisors, and research groups.

The action-oriented projects undertaken by the GCS were locally based with global relevance, such that tangible impacts targeted the current and future community and stakeholder base. This approach kept students engaged, allowing them to both see the immediate fruits of their labors and to obtain insight into broader issues. This visualization factor can be best achieved with applied projects, rather than abstract or theoretical projects. The desired result is a physical testament to the goals, efforts, and successes of those involved. Also pivotal was the constraint of long-term ownership, requiring buy-in by all stakeholders involved, including the community and institution. This is a new concept for many first-year graduate students. Consensus decision-making processes, such as CBPR, improve the likelihood of long-term ownership by incorporating bottom-up issues into framing the research questions. An applied project has the potential to improve long-term ownership, or place attachment, through visualization and the act of creating something physical (Vandewelle et al. 1995). An abstract project increases students' reliance upon traditional disciplinary training, especially when real-time group feedback regarding the reception and progress would be absent.

Development of a common language early in the project development process was important to future success of the GCS course. Learning to listen to each other's message, even when individuals believe themselves to be speaking the same message, is pertinent. Interdisciplinary teams often report that establishing shared understanding for common terms used across disciplines is an essential task (Klein 2009). Such differences were highlighted when participants were prompted to define words in the context of a campus master plan or community outreach approach. Many of the terms defined in the GCS course commonly vary between disciplines (e.g., sustainability, system, model, and ecology), which required definition within the scale and context of the project and RBC. A helpful group exercise in communication was the real-time creation of tables on the board presenting the essential definitions of terms and defining commonalities. While not every single vocabulary word requires definition, the exercise illustrated different definitions by discipline and the need for sensitivity to this issue. Another initiative, undertaken by students, was to ensure subteams were not comprised of entirely one discipline. This forced students to adapt a common language in approaching tasks and solutions. As such, honoring the interests and disciplinary backgrounds of participants should be acknowledged in interdisciplinary courses, since each unique perspective contributes to project design. Without this approach, outcome quality may decrease because students do not expand beyond their scope of knowledge. This is recognized as one of the fundamental benefits of interdisciplinary collaboration; each participant sees the project through a different lens. However, this is often easier said than accomplished, as noted in several studies (Campbell 2005).

As challenges arise throughout the process of an interdisciplinary course, recommendations from the GCS experience include protocol development, clarification in defining problems, integrating assumed objectives, consideration of power relationships, and explicit knowledge structures (Boulton et al. 2005; Campbell 2005). For the GCS, presemester meetings were held by the course instructor to discuss such issues with enrolled students. When communication is underdeveloped or individual goals are engrained, such challenges are sure to disrupt the overall continuity and targeted efforts of any interdisciplinary course. Similarly, disconnection of concepts, problems, and methods from physical space can result in skewed interpretations and understanding by the range of participants.

As with any project-based course, visitation to the field site connected and familiarized the participants with the existing space. Trips also provided an inventory of variables and conditions. Despite being within 2 km of most students' offices, few had experienced RBC firsthand. Visiting the transition zone from a natural to urban zone, on the University of Utah campus, illuminated the importance of these goals. Students were asked to visit the site individually, to experience it personally, and as part of a group field trip, with the instructor and other stakeholders. The latter provided a shared experience for the group, connecting to RBC, and allowed identification of issues facing the creek. These included nuisance stormwater runoff from parking lots and encroachment from built infrastructure. More importantly, trips allowed students to explain and discuss each parameter and issue relative to their discipline, translating into a hands-on education for all. Trips were also used to document opportunities for improved stewardship, which was useful in motivating action and delineating key talking points, with the administration and stakeholders.

The role of the GCS professor as a project advisor was important in the development phase. For instance, despite a common interest in sustainable education, not all participants were as willing to commit to a project that had little so-called technical challenge, so-called scientific rigor, or clarity at the outset. Through the iterative process of envisioning, inspiring, researching, demonstrating, and advocating, students were allowed to discover their own place within the larger project. As such, group diversity allowed for expansive rather than narrowed thinking. Without the overall guidance and visioning of one individual (i.e., the course instructor), the potential for tangential research and process trajectories can derail any project. Retention of a representative from GCS1, who served as a liaison between academic years and with stakeholders, contributed to project longevity and continuity. For instance, the liaison shared project data and results with other research projects (e.g., iUTAH), thereby extending the GCS' efforts to other universities and organizations.

To achieve expansive thinking and successful interdisciplinary outcomes, the two GCS courses approached project development differently. On one hand, GCS1 identified students' strengths and interests as a contribution to the whole of a sustainable RBC. Next was delineating a project with portions appealing to individuals while capitalizing on the group's strengths, interests, and areas for improvement. Alternatively, GCS2 identified the problem and how each participant's interests and strengths could contribute to the overall project scope. Consistently across both courses, self-organization of smaller groups allowed greater focus on the multiple aspects of each project. For example, subgroup objectives targeted organizational development, surveys and lesson plans, data compilation and analysis, web development, green infrastructure, visual communication, ecology, the hydrological system, and planning and management issues. While both classes ultimately engaged in interdisciplinary learning and collaboration, their different approaches highlight both challenges and possibilities.

Institutional Support from GCSC

Student motivation and campus culture often establish the underlying tone(s) and qualitative success of sustainability courses (O'Brien and Sarkis 2014). For many university members, engaging in sustainability issues may be worthwhile or contribute to class materials. For others, this represents an unnecessary investment of time, energy, money, and organizational capital. A course like the GCS can aid the evolution of university communities' culture, administration, economy, and education to be more sustainability-minded. Although an upfront cost may be expected, universities have unique roles in society to provide leadership and testing

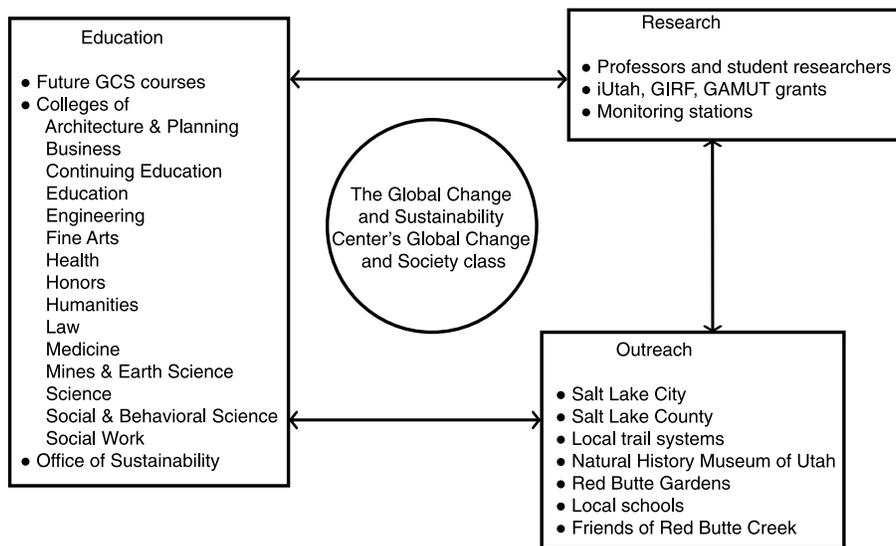


Fig. 2. Education, research, and outreach network into which the GCS course fits; this system's broad nature supports continuity, establishes a supportive fail-safe, and increases the possibilities for successful outcomes

grounds for innovative paradigms. With tides shifting in favor of interdisciplinary research and collaboration, universities have the opportunity to lead. At the University of Utah, the GCS and FORBC did not meet active resistance, although this may exist elsewhere from faculty, staff, and others.

Guidance from a home organization, the GCSC in this case, greatly benefited students and outcomes in the GCS course by providing a larger supportive community to develop ideas, foster broader reference and data networks, and an overarching identity providing credence to messages and efforts. Furthermore, the GCSC provided administrative and financial support, which was critical to implementing proposed outcomes. With this base of guidance, knowledge, and resources (e.g., datasets, methodologies, financial aid, and institutional knowledge), the GCS was able to sidestep time-intensive project basics. This increased the potential for realization of results within a semester's time frame. A larger organization can also benefit continuity and coordination, networking, and maintaining institutional knowledge.

Broader Community Developments

Membership in a broader interdisciplinary network of both on-campus and off-campus collaborations (Fig. 2) was essential in negotiating and expanding the basis for improved sustainability centered on RBC. With RBC as the nexus and the image of the university as a steward and partner, the network's pursuit of mutual goals continues to gain strength. This broader network of people and institutions related to the project's objective of sustainability is essential to the longevity of project outcomes. For RBC, community relationships provided quantifications of stormwater contributions; identification of ownership, management, and maintenance in the watershed; and prompting the need for expanded monitoring along the natural-urban transition zone. Stormwater contributions and hydrologic models of the area were provided through collaboration with university courses, while monitoring infrastructure was implemented with iUTAH. Delineation of the RBC ownership, management, and maintenance structure resulted from discussions with administration and planning staff.

Members of the GCS network represented a range of backgrounds, interests, and perspectives (Table 2), providing long-term

assistance with each project. Furthermore, a mutually beneficial relationship evolved with time. For example, hosting a speaker from the Salt Lake County Watershed Planning and Restoration Program established a working relationship, yielding data sharing and outreach opportunities. Similarly, the GCS has advocated improved stewardship of RBC, which is a goal of the Watershed Restoration Program. Other benefits include on-campus sustainable stormwater management projects, local symposiums, and a collaborative committee comprised of university administrators, facility managers, faculty, students, and other professionals (the Riparian Corridor Steering Committee) that endeavors to ensure sustainability in the RBC riparian corridor. Another important result of the GCS network is the distribution of minigrants through the partnership between FORBC and the Watershed Restoration Program. These grants target students and faculty pursuing action-oriented projects, related to the sustainability and stewardship of RBC. These efforts aim to embed GCS objectives into the local culture and increase sustainability for RBC, the University of Utah, and the broader community.

Conclusions

How society responds to increasing vulnerability and change will be a defining characteristic of the 21st century. Training students to address these multidisciplinary challenges is a critical component of the educational process. Combating the social, economic, and environmental consequences of degraded ecosystems, altered climates, and diminished resources has already proven to be a difficult global issue. Thus, learning to work within an interdisciplinary framework is an essential skill for future professionals (Barth et al. 2014). As such, courses and groups (e.g., GCS and GCSC) present ideal situations to test innovative educational methodologies the break free of historic discipline barriers, by recognizing and building individuals' skills prior to entering respective professions.

The necessity to change sustainability education to address global challenges is apparent through the process of interdisciplinary sustainability education and action at the University of Utah. Different solutions can emerge from such efforts, including

change beyond the classroom, when education is an iterative process that responds to feedback and implemented results, such as the RBC Project and FORBC. The resulting training is a necessity for tomorrow's leaders who will face sustainability issues. The University of Utah's GCSC and GCS courses are example responses to this call, highlighting the importance of applied projects, adaptation of CBPR methods, and an active, supportive network. The GCS has resulted in positive educational, institutional, and community outcomes, as well as movements towards improved stewardship of RBC, reinforcing the notion that sustainability can be addressed by enacting systematic and curricula changes in higher education. That being said, assessment of such outcomes is a necessity when successes and failures are to be determined and improved. Such assessments can also contribute to the accreditation [e.g., Accreditation Board for Engineering and Technology (ABET)] of higher-education institutions. Thus, it is recommended that future courses and adaptations incorporate more stringent assessments, beyond surveys and case study examples, that lend course outcomes to institution accreditation, elevated minimum requirements, and improved curricula facilitating sustainability in practice.

While RBC is specific to the University of Utah, its inclusion was the result of participants weighing the benefits and needs of various project ideas. The RBC provided the greatest potential for change, by reenvisioning a once-overlooked resource, targeting fundamental educational concepts, and broader community extension. This being stated, any number of issues could satisfy local-global requirements both at the University of Utah and elsewhere. This includes the development of on-campus sustainability plans engaging multiple institutional levels and resources (e.g., energy consumption, waste generation, water demand, stormwater management, and transportation) and on-campus partnerships with food services, to establish composting and recycling plans with local third parties (e.g., farmers' markets and community garden programs). Another example includes a lifecycle assessment (LCA) of on-campus services, working with the departments and staff to identify, assess, and present sustainable solutions to problematic areas. With increasing reliance and improvement of cloud computing, databases of historical, current, and future variables impacting campus-wide management and research could be created. Each of these project ideas contributes to the overall goal of enacting institutional change, educational reform, interdepartmental collaboration, and community outreach.

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