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Sustainability capstones: Data-driven, policy-relevant projects to enhance learning

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Abstract: Sustainability capstones at UNC-Chapel Hill use the environmental capstone model—senior team projects for clients—to tackle problems with clear social and economic dimensions in addition to environmental. As one of a set of applied-learning course options in sustainability education, capstones draw students into data-driven and policy-relevant research and development, and generate useful products for campus and community clients.

Keywords: capstone, experiential education, applied learning

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Sustainability capstones: Data-driven, policy-relevant projects to enhance learning

Applied sustainability training in higher education helps define the still-evolving fields of sustainability sciences and studies through practical, small-scale problem-solving, and in the process responds to questions about sustainability as a legitimate framework for education and research. Several years of experience with applied sustainability education at our institution suggest substantive benefits for all parties: undergraduate students, who gain a leg up and a view into the working world; graduate students, who build a portfolio of teaching, mentoring and applied study; faculty, who relish bringing training and knowledge to bear on client-generated problems with new partners; and clients, who propose projects for which they lack expertise or staff and benefit from the energy and intellectual efforts of soon-to-be college graduates. Community-engaged research and development projects may provide a reality check on relevance for students and faculty interacting with community experts and stakeholders, and increase the community's confidence in the research and educational mission of higher education.

Sustainability—the potential and the challenge

Sustainability pedagogy and research face a daunting challenge— seeking to stake out defensible intellectual and professional territory and communicate that to public and political audiences; questioned by some scholars in other disciplines for lacking a clear body of theory and methodology; and sometimes attacked by social and political entities as a threat to American society. There is ample support for sustainability as a legitimate field of inquiry and training, including a growing body of research and recognition from prominent institutions such as the Environmental Protection Agency, National Academy of Sciences, and National Science Foundation.[1, 2, 3] Clark describes sustainability science as neither basic nor applied, but rather problem-inspired inquiry that "serves the quest for advancing both useful knowledge and informed action."[4] Kates points to parallels with agricultural and health sciences as other "use-inspired fields with significant fundamental and applied knowledge components, and commitment to moving such knowledge into societal action."[5]

Still, work remains to clarify and communicate more persuasively what sustainability is and is not, and how it may be useful as a framework for identifying and analyzing problems that cross traditional disciplinary boundaries, and for generating practical and effective solutions.

Sustainability-relevant fields may benefit from thoughtful consideration of the level at which curriculum is delivered and how it ties in to undergraduate and graduate education. Upper-level undergraduates offer a promising target population for explicit sustainability coursework, given their earlier exposure to the broad realms of academic thinking and their eagerness to synthesize disciplinary knowledge and personal passions into the problem-solving power of sustainability sciences. By contrast, master's programs may be an ideal level to start with sustainability framing and apply it to areas of specialization, while maintaining a general integrated canvas against which to tackle specific problems in research and practice.

Some disciplines and professions already have a deep tradition of applied learning; urban planning and design, government, journalism, business, public health and social work are examples of academic departments or schools that traditionally bring practitioners or citizens into the classroom and send students into the community. Established models for applied

learning, such as workshops, practica or studios, may be deployed in sustainability education with careful attention to appropriate and productive subject content, useful output and products, and effective pathways for interaction between students and community partners.

Rowland[6] references the importance of the educational context for effective sustainability education, including a receptive institutional culture, and good timing with regard to emerging and evolving curriculum. At our university, student demand was the driving force behind recent new offerings in sustainability curriculum—both traditional and applied. Given this journal's goal of understanding how people learn about sustainability,[7] our undergraduate capstones may be of interest as an example of sustainability training in tertiary education. These senior team projects are among a set of courses taught at the University of North Carolina at Chapel Hill ("Carolina") that collectively represent—but do not exhaustively catalog—experiential education in sustainability at one large public university.

Beyond "green"

The environmental curriculum at Carolina, housed primarily in the Curriculum for the Environment and Ecology (CEE) in the College of Arts and Sciences, is taught by scholars from disciplines across campus, including anthropology, geography, geology, marine sciences, city and regional planning, and more. While traditional classroom environmental curriculum is taught through the CEE, Carolina's Institute for the Environment delivers experiential or applied courses such as capstones, internships and independent study. Some courses—both traditional and applied—are explicitly and comprehensively focused on sustainability. An example is "Principles of Sustainability"—the core course for the sustainability minor. In addition, there are hundreds of courses across campus with a sustainability theme or component; indeed, an AASHE STARS (https://stars.aashe.org/) inventory conducted in 2009 (itself delivered as an undergraduate capstone) identified 72 courses with an explicit sustainability focus, and 235 with relevant content. A follow-up capstone team inventoried sustainability-related research.

This enfolding of sustainability education and research into the environmental curriculum, while a natural expression of the interests and goals of many environmental scholars, highlights one of the challenges we face: the danger of conflating "green" goals of environmental research and education with the sustainability label. Sustainability studies and sciences, as practiced to date, generally seek to analyze problems and craft solutions with an eye toward multiple dimensions (beyond environmental, to economic and social) and various scales, both geospatial (local and regional to national and global) and temporal (past, present and future). Still, environment arguably remains dominant, with other dimensions of sustainability under-developed.

The recent emergence of sustainability curricula and degrees offers great potential in trans-disciplinary education and applied research. However, more discussion is in order to clarify where fields from the natural and social sciences, humanities, and the professions offer common ground in theory and methods that support sustainability research and pedagogy, and where those fields have incompatible frameworks, cultures and tools. The realm of sustainability education would benefit from more discussion of tools that could form a core skill set in which to train sustainability majors; these might include GIS and remote sensing, bio- and earth informatics, survey design and qualitative analysis, carbon accounting and emissions reduction, theories of political and cultural change, communications, and water and air quality analysis, among others.

Academic foundations of sustainability—collaborative inquiry and applied education

Collaborative teaching and research are natural fits for sustainability, and benefit from faculty who offer expertise and opportunities to students of diverse majors, and from ties to the community through roundtables, seminars, symposia and other public events, and community-based research.

The sustainability curriculum at UNC-Chapel Hill is targeted particularly at motivated juniors and seniors, from a broad range of majors, seeking to integrate diverse interests and academic experiences in their last semesters, in preparation for a career or graduate studies. At Carolina, applied sustainability education takes on various formats. Environmental and sustainability internships (a distinction based on focus and content) place upper-level undergraduates with mentors for work-like experience, supplemented with targeted readings and written reflections on the experience. Other students find directed readings or independent study to be the best vehicle for their applied education.

Carolina's environmental capstones—senior team projects for clients, designed as a bridge between the classroom and the work world—are data-driven and policy-relevant immersive projects. Students are subject to high expectations for independent effort and productive interaction with instructors, peers and clients, and gain experience with project planning, creative problem-solving and institutional processes. Each project, with a team of 5-10 students, involves data collection and analysis, and generates products including—at a minimum—a report with findings and recommendations, as well as a presentation. Capstone projects often yield additional items such as databases and electronic tools, physical structures, and educational or public awareness pamphlets or videos. Data may be quantitative (e.g., waste audits with baseline and post-intervention measurements of waste and diverted materials by category) or qualitative (such as key informant interviews or citizen surveys). Acquired skills range from interview instrument development and content analysis, to video editing, to GIS-assisted inventories (e.g., LED street lights or bicycle infrastructure), GPS-supported surveys using hand-held computers and logs, and sketch and design products (e.g., stormwater management best practices).

The nearly four dozen environmental capstone projects done on the main Chapel Hill campus since 2007 (excluding capstones at six remote field sites the Institute for the Environment operates in North Carolina and abroad) are split between on- and off-campus clients, including local and regional government, non-profits, and small and large businesses; projects range from primarily environmental sciences to planning and policy. Those designated as sustainability capstones have explicit social and economic dimensions in addition to environmental aspects. The capstones, required of all environmental majors and sustainability minors, also are open to qualified and motivated students from other majors who are able to contribute substantively to the team process. For some non-majors, it is a first exposure to incorporating environmental considerations into what is essentially a team problem-solving exercise. For some environmental majors working on sustainability projects that go beyond environmental data collection and analysis to include economic, social, and public health considerations, it may serve as a first opportunity to collaborate with peers from fields outside the sciences.

Figure 1. Capstone team members sort waste for measuring and weighing, as part of a project to reduce energy and solid waste in public housing complexes.

The capstones often have a hierarchical structure, with undergraduates led by graduate students (supervised by staff) and with frequent interaction with campus and community experts and partners. For example, a City and Regional Planning graduate student took a leadership role on two successive capstones devoted to greenhouse gas emissions inventories for a nearby town, later built on that work with an award-winning master's thesis, then secured a full-time post-graduate fellowship as the resident carbon accounting expert that ultimately became a permanent position. The undergraduates on this team presented their work to the Institute for the Environment's Board of Visitors, and in the process gained public speaking experience and useful professional contacts. The former graduate student leader, now working in local government, serves as a capstone client for a new round of applied research and development.

Whenever possible and appropriate, capstones are tied into sponsored research. In 2013, an undergraduate team assisted with research on "transportation deserts" (where there is a mismatch between residents' travel needs and their transportation options) funded by the North Carolina Department of Transportation. They helped develop, pilot and field-test instruments for key informant interviews and citizen focus group, participated in data collection in several different counties, then transcribed and coded qualitative data for the pilot counties, generating an insightful narrative analysis of major themes that emerged from many hours of interviews and informing the formal data analysis to follow in five different counties.

The capstone is particularly challenging and satisfying, because the students themselves must conceptualize the end-products, formulate a strategy, communicate effectively with clients and expert advisers, and manage the process of research and development. The student teams are given a problem to which the solution is not known at the outset. Capstone instructors provide background readings, data sources, introductions to expert advisers, and help with training or travel. Management of meetings, and the development of work plans and identification of necessary resources, are left to the students to the extent possible. Personal reflections from students often mention that the presence of the client—an outside interested party with a stake in the process and outcome—motivates them and lends a "real-world" urgency to the work.

Because of scheduling constraints, students may end up working on a topic new for them. This often forces teams to draw on their collective accumulated knowledge and general problem-solving abilities, and transfer analytical skills to a new target. Some of the most satisfying projects—for students and clients—may take shape when students are pushed into unfamiliar areas, and forced to collect and analyze new kinds of data and generate defensible findings.

As part of Carolina's public service mission, the capstones serve the state. Teaching staff seek out communities that would benefit from analytical services the teams can provide while offering students an opportunity to sharpen their skills on timely problems. This collaborative work is aided by contacts in foundations and agencies, who provide a critical bridge from the university to local partners, many in rural and resource-constrained sites. This process sensitizes our students to the challenges of working and communicating with diverse populations.

Shelter Accessibility and Livability Tool (SALT) - Draft Version

Question	Score (0,1,2)	Notes
A: General Habitability--Average Score _____		
A1. How susceptible is the location to flooding? (8)		
2- Minimal Flood Risk (Zone C, unshaded Zone X, Zone D)		
1- Moderate Flood Risk (Zone B, shaded Zone X)		
0- High Flood Risk (Zone A)		
A2. How close is the shelter located to a nuclear facility? (9)		
2- More than 10 miles		
1- 5 to 10 miles		
0 - Less than 5 miles		
A3. How close is the facility located to an evacuation zone? (9)		
2- More than 5 miles		
1- 1 to 5 miles		
0- Less than 1 mile		
A4. How close is the facility located to an evacuation route? (9)		
2- Less than 5 miles		
1- 5 to 20 miles		
0- More than 20 miles		
A5. Is this facility suitable to withstand the kind and scale of disaster that can reasonably be expected to affect this area?		
2- Building is expected to incur only minimal damage and should be comfortably habitable		
1- Building is expected to incur moderate damage and should be minimally habitable		
0- Building is expected to incur severe damage and will most likely be uninhabitable		
A6. Is the building ADA-compliant? Visit http://www.ada.gov/shleterck.htm for current		
2- Completely ADA-compliant		
1- Generally ADA-compliant; some exceptions may exist		

Table 1. Sample page from an emergency shelter assessment that addresses accommodations for vulnerable populations, piloted and field-tested at shelters in three counties by undergraduate capstone students.

In a more intensive and collegial program that forges strong relationships and offers enrichment through field trips and community networking, some students elect to earn the sustainability minor in a single semester through the Sustainable Triangle Field Site (STFS). This is an urban

counterpart to a network of remote sites operated by the Institute for the Environment in the North Carolina mountains and at the coast, as well as in Thailand, the Galapagos, and Cambridge UK. Each of these field sites has a specific focus: mountain ecology, marine science or coastal policy, energy policy, or renewable energy.

Conducted on the main Carolina campus (without moving students to remote locations), the STFS allows students a non-travelling (and affordable) option for the intense cohort-based experience of the remote field sites, with a focus on sustainable urban planning and policy, and course work and experiential education tied to and reflecting the local region. A central strength of the sustainability minor and field site lies in strong ties with local, regional and state leaders, who serve as guest speakers, tour hosts, internship sponsors, capstone clients, and members of an active Community Advisory Board.

The STFS includes, in addition to three lecture courses (core principles, sustainable community design, and changing American landscapes), an individual internship and a capstone with a clear sustainability framework. The 2013 STFS capstone team developed a feasibility study for a regional "eco-industrial park" and a re-use district for businesses that salvage and recover discarded items, as part of a coordinated strategy to divert potentially valuable material from the waste stream at a waste-transfer station in a mid-sized city.

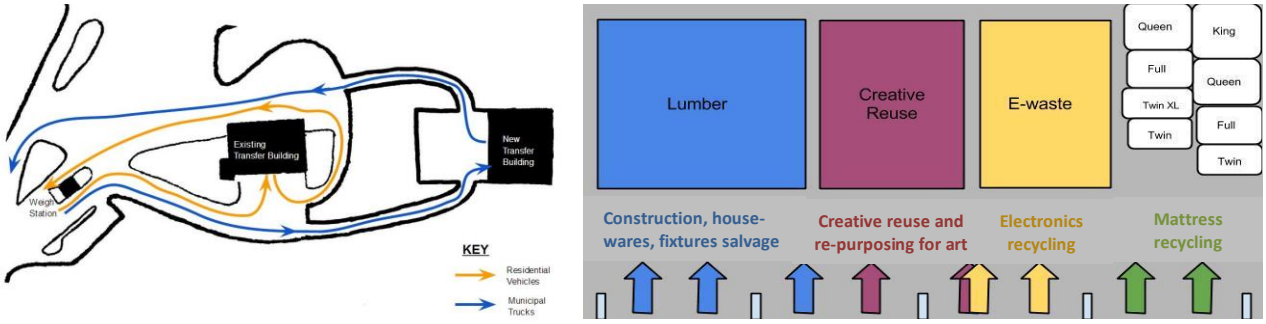

Figure 2. Proposed traffic flow of residential vehicles (left) to drop-off bays in a re-use collection depot (right), developed by capstone team as part of a feasibility study for a re-use district at a waste-transfer station

Sustainability sciences and studies for problem-solving

Capstones are one of a set of applied learning options for students pursing sustainability studies at UNC-Chapel Hill, and are designed to complement and support diverse majors beyond environmental sciences and studies. Kates identifies the test of success in sustainability science as "implementing […] knowledge to meet the Tabgreat environment and development challenges of this century."[5] There is clear evidence, from student reflections and client reports, that the Carolina capstones successfully connect students with community partners and expert advisers, to produce defensible analysis and actionable findings. Repeat clients, including campus units and local governments that returned repeatedly after an initial project proves to be valuable, are another sign that the model generates benefits for clients. To tie into this evidence, a current goal of the program is to apply more formal systematic evaluation to confirm the value to students and community partners and to identify areas for improvement. Meanwhile, the pipeline of projects continues to build a body of data-driven and policy-relevant products for

clients, while exposing undergraduate students to practical collaborative problem-solving, and providing graduate students with leadership and research development experience. The benefits to clients and teams alike include both concrete solutions to targeted problems, and a network of interested parties who bring new projects and new ideas to the table and take results out to other sites.

Select examples of sustainability capstone projects at UNC-Chapel Hill*—these and others posted publicly at http://ie.unc.edu/for_students/courses/capstone.cfm.*

Carbon accounting and emissions reduction
- Carbon sequestration on campus forest lands
- Greenhouse gas emissions inventories—municipalities and campus
- Transit system emissions inventory; transit rider survey
- Energy efficiency and waste management in public housing
- Energy management for water and sewer authority

Emergency planning, response and sheltering
- Assessing local vulnerabilities and strengths
- Assessing emergency shelters for vulnerable populations
- Door-knock surveys—citizen awareness of and planning for emergencies

Waste management
- Diverting plastic film from businesses' waste stream
- Measuring and reducing recycling contamination at student-oriented apartment complexes
- Campus waste audit and waste management planning
- Laboratory plastics recycling pilot

Transportation equity and transportation deserts—comparing data-driven maps of transportation disadvantage with qualitative data from expert informants and affected citizens

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