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Drawing Upon Non-Engineering Disciplines to Research Sustainability of Engineered Infrastructure in South America

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Abstract

The academy has evaluated and debated the merits of international service learning from the perspective of the student, but little research exists to assess the success and sustainability of an engineered infrastructure system over an extended period of time from a developing community's perspective. The University of Illinois at Urbana-Champaign (UIUC) has implemented a new course that will exist for ten years and will bring together the College of Engineering, along with departments of Kinesiology and Community Health, Anthropology, Global Studies and Regional and Urban Planning, to collaboratively teach an undergraduate research-focused course elective targeted at evaluating baseline conditions preceding implementation of a new irrigation system for the indigenous community of Lumbisi, Ecuador. The course is NOT a capstone design course – rather its intent is to rigorously evaluate the effectiveness of engineering design practices serving the developing world. This paper will document the development of the course, the proposed instructional objectives and community outcomes, and the process of effectively engaging students in this work. The course was offered for the first time in Spring 2016, co-taught by faculty from all five departments, plus an additional collaborator in the College of Engineering at the Universidad San Francisco de Quito (USFQ) in Ecuador. All six educational units share knowledge and resources, both in the classroom and via a virtual meeting space, which also is accessible by the community itself. While the research course will track the process of design, implementation, maintenance and modification of the irrigation system over the next ten years, students of Engineers Without Borders (EWB) UIUC Chapter and EWB USFQ will team with the community to devise an actual infrastructure design that meets both the needs and cultural constraints of the indigenous community. This innovative approach to cross-disciplinary, cross-cultural, and cross-organizational international service learning is expected to generate significant data regarding the factors that most strongly affect sustainability of an engineered infrastructure.

Introduction

Building upon the success of an engineering course that invited non-engineers to participate in investigation and design of a potable water system for a community-in-need in the developing world, the authors proposed a broader interdisciplinary effort that would integrate engineers with social scientists, community developers, and applied health academicians to conduct long-range research into the sustainability of a student-designed service project in South America. In keeping with the previous course's commitment to inquiry-driven learning, in which the students self-identify outcomes and methodology with guidance from the faculty, the intent of this course was not to impose a value for each of the disciplines represented in the classroom so much as to

expose students from each of these disciplines to each others' thought processes and knowledge bases. As a result, it is hoped that the students will determine an effective collaborative learning approach that informs each others' areas of interest regarding international development sustainability, while building a knowledge base for better understanding the interrelationships among these disciplines to evaluate long-term interactions between an engineered infrastructure and a recipient community.

We emphasize that this course is not design-based, such as an Engineering Capstone project, nor does it teach technical design. Instead, it focuses engineering minds on the non-engineering influences that must be considered to produce a successful, sustainable engineering design for a recipient outside the designers' own sociocultural experience.

Course outcome each year is to investigate the evolving relationship between the community and the designed infrastructure and document that changing relationship. Interdisciplinary research teams focusing on technology, power, land use, governance, and health the first year developed a research plan, visited the site, and documented and archived their data for analysis in upcoming courses. Subsequent years of the course will begin by analyzing past data, then continue to acquire data on community/technology interrelationships. It is the intent of the instructors to offer the course for a minimum of 10 years, not only to provide students with an opportunity to obtain the learning benefits as described in Riley, 2006, using the inquiry-driven model, but also to build a body of evidence that connects the relevance of each discipline to the other with respect to the sustainability of engineering design[1].

This paper discusses the development of this unique course, how it was implemented, a description of the student experience, and conclusions drawn from the process in its entirety.

Course Development

The genesis of this course was rooted in a combination of desire to increase engineers' cultural competence and a pure coincidence that brought together a team of like-minded faculty, collaborating agencies, and community leaders.

The indigenous community of Lumbisi, Ecuador, has been working with UIUC Global Studies department for several years on a summer program to support indigenous youth with education through a community day camp taught by university students. Faculty associated with that summer program, after becoming familiar with the College of Engineering's multi-disciplinary, water-system design course, learned while talking with Lumbisi community leaders that the community was struggling with drought conditions in recent years, which was suppressing crop yields for indigenous farmers. This need was brought to the authors' attention, and discussions began about whether UIUC could initiate a new type of program to assist the community with

irrigation design. A partner in the Global Studies program, non-government organization Fundacion Para la Educacion y el Voluntariado Internacional (FEVI), offered to act as facilitator between USFQ and the community because of its close ties to both institutions.

As discussions among colleagues on campus continued, interested faculty began applying for and receiving grant support to investigate and secure course participation by the community and partners in Ecuador, to recruit and develop partners across the university campus, and to establish course learning objectives and faculty roles—all clearly defined through a shared syllabus—so that the course could be offered in Spring 2016. In addition, conversations began with the EWB-UIUC chapter, which was looking to initiate new projects and expressed an interest in designing an irrigation system following the contextual approach espoused in the precursor water-system design course.

One faculty member traveled to Lumbisi in June 2015 to meet with FEVI and the community, and while there she established an additional critical relationship with the college administration at nearby USFQ in Cumbaya, Ecuador. Coincidentally, a USFQ student who had studied abroad at UIUC the academic year before had participated in the precursor course, and the student volunteered to act as liaison between the EWB-UIUC and USFQ students, who at the time were seeking to establish an EWB of their own.

Confident of the commitment by Lumbisi, USFQ, and FEVI, UIUC Engineering faculty began to recruit colleagues from UIUC departments complementary to the contextual approach in service design. This contextual approach emphasizes the importance of developing an understanding not only of infrastructure needs and objectives, but also cultural, economic, technological, and health-related conditions that could affect the way a community interacts with infrastructure[2]. Senior faculty from the Colleges of Liberal Arts and Sciences, Applied Health Sciences, and Fine & Applied Arts all expressed an interest in taking part in the course, and a committee of faculty convened in August 2015 to begin developing a curriculum. Using additional grant monies, the committee hired a course coordinator, a visiting professor of Community Health from Nigeria who had worked with the EWB-UIUC chapter on a previous project, to provide continuity and oversight to the multi-college effort. Additionally, staff from the UIUC Center for Innovative Teaching and Learning and from the College of Engineering's IT Department joined the committee to provide input regarding learning objectives and outcomes, and to enhance communications-technology capabilities to the course effort.

The committee met throughout the fall semester, frequently including USFQ faculty and FEVI staff via Skype, to refine course objectives, balance departmental interests, and define roles both in teaching and in project implementation. It should be noted that the engineering department's faculty member associated with this effort also acts as faculty advisor to EWB-UIUC, which allows for close collaboration between course objectives and student-design procedures. As a

result, EWB project applications and planning proceeded concurrently with the course development, leading to complete integration of intent and collaboration processes among the partners.

Early in the curriculum-development effort, faculty committed to following an inquiry-led model for the classroom, focusing on student-led collaboration rather than faculty-initiated learning procedures. To facilitate this approach, the curriculum was developed around key concepts and questions, rather than around lectures and information dissemination. By creating general areas of inquiry that span across disciplines, multiple faculty could provide the perspectives of their own disciplines to inform a broader understanding of the topic relevance. For example, on the topic of environment and society, the engineering faculty led the discussion and introduced activities associated with building an understanding of environmental need, while anthropology faculty contributed a cultural understanding of community attitudes toward the land, urban planning faculty brought a perspective of societal reliance on environmental resources, and community health faculty focused on the relationship between environmental conditions and wellness. In this way, relevant topics were fully explored from all perspectives, with one discipline leading the discussion and others adding their insights. This approach prevents over-simplification of any topic while integrating all perspectives.

Finally, because of the diversity of voices and interests associated with this project, it was determined that a virtual meeting space on line would improve exchange of ideas and efforts, so technical advisors worked with our coordinator to develop a web space that would bring together students in the classroom, partners in Ecuador, student organizations and the community itself. The virtual meeting space links to class-management software for assignments and grades, a social media platform for exchange of ideas, a document-translation area to support the bilingual nature of communication with the community, a faculty-only space for sharing of lesson plans and resources, a link to the EWB websites for designers both in the United States and USFQ, and a public-facing area for potential donors or professional advisors to the project.

Because the focus of the course is on research rather than design, an optional component of the learning includes travel to Lumbisi to collect field data. Supported by a grant from the Office of Undergraduate Research, the course must provide training and practice of approved research methodology. But because the nature of the researched process will change year-by-year—from research into decision-making during the design process, to research into implementation during the construction phase, to research into interaction and adaptation during the operation phase of the irrigation system—instructors opted to make determination of the appropriate research methodology a part of the learning objectives of the course. Those students who elect to travel at the end of the semester will perform research using the methodology devised during the semester. To give those students who don't take part in travel an opportunity to practice research, however, the methodology will be "tested" and honed with a community-based program near

campus, and results of the research will be compared with expected outcomes to illustrate to students how techniques and context may or may not be universally applicable.

Students who elected to travel to Lumbisi were scheduled to arrive in Ecuador along with several faculty during the last week of May. Members of the EWB-UIUC design team were scheduled to travel at the same time to begin project assessment for the irrigation system design, and the course's students prepared their research protocol to observe the EWB-UIUC designers as well as the community itself. Before traveling, the course research teams applied for and obtained approval from the Institutional Review Board, however for many, this was the first time they had performed actual qualitative research. To give them an opportunity to practice research techniques in a beneficial yet non-critical setting, the class was introduced to a local community gardens, the community-based program referenced above which was created by a social service agency to address nutritional needs in a low-income part of the college community. After meeting the founder of the community gardens, students visited the site weekly to observe and/or work with the gardeners and develop an understanding of how to build an understanding of a society outside their own experience through immersion and examination. Teams documented their observations using blogs that focused on the same general area of inquiry they would pursue in Lumbisi. The blogs were available to the garden community and organizers, as well as other teams, allowing them to dialogue about their understanding of the subject. Research teams also were required to review other teams' blogs and comment on observations.

During the course development, coordination across educational units, universities, organizations and countries flowed surprising smoothly and without issue. Perhaps the greatest challenge of the entire effort came when devising a course name that would reflect the interests of engineers, social scientists, planners and community health faculty. Words such as "subsistence," "sustainable" and "development" all carry interpretations specific to disciplines, and those interpretations don't always align in meaning or intent. Ultimately, the course was entitled "Investigating Sustainable International Development," and was listed as an upper-level undergraduate/graduate course in all departments.

Another challenge to faculty developing the course was assessing student performance and evaluating course learning outcomes. Working with the UIUC Center for Innovative Teaching and Learning, assessment tools were implemented that included weekly reflection essays, team blogs, peer-to-peer milestone presentations, and final reports. The combination of in-class assignments, personal reflections and team presentations allowed faculty to assess individual as well as group performance and learning. Frequent informal feedback surveys allowed faculty to assess how well students were following the material and make adjustments to classroom presentation.

Implementation

Interest in the course was rapid and extensive, reaching beyond the target departments to attract students from across campus and beyond. Five sections of the course were created, composed of Engineering, Regional and Urban Planning, Kinesiology and Community Health, Anthropology, and Global Studies. While the course number attracted upper level undergraduate and graduate students, no restrictions or prerequisites were placed on enrollment. Of 40 students who registered for the course in its first semester, 13 came from Engineering, eight came from Urban Planning, six came from Community Health, seven from Anthropology, and five from Global Studies, with one additional student a faculty member teaching science at the University of Illinois Laboratory High School. One registrant was professional staff of the University who audited the course because of a personal interest in the topic. Within these five sections, students represented additional programs ranging from Translation & Interpretation Studies to African-American Studies. All five sections met together, with faculty from each of the departments co-instructing all class sessions. One faculty member acted as lead facilitator for each class, with all others participating as supporting instructors.

Classes were taught in a collaborative space on campus, allowing students from all disciplines to move about the room and interact freely so that they may complete lessons collectively. While specific topics were introduced and discussed, lectures were discouraged among participating faculty and students were encouraged to partner with faculty in discussing concepts and formulating understandings of the relevance of introduced materials. This became problematic for some of our faculty, who were accustomed to lecturing in larger halls rather than in smaller, collaborative workspaces. With gentle encouragement to consider themselves partners in learning, rather than "the experts," our faculty began adapting to the kinetic, interactive style of exploring concepts. Student feedback on early course surveys, which requested more interactive discussion, helped to encourage more activity as well, and by mid-semester faculty developed more comfort with being active partners in learning rather than informants.

A variety of learning tools were implemented in the classroom to encourage collaboration. A softcore tossable microphone was employed to randomly draw students into discussion, and letter tiles were used for word games that forced teams to collaborate on concepts while competing against other teams.

A faculty-only area was created on the course website, where instructors could trade ideas and resources, as well as reading materials and activity plans, so that in-person meetings among the teaching staff were infrequently needed and were scheduled primarily to debrief. A teaching assistant provided by the Community Health department acted as grader for all five sections.

The Student Experience

Many students in the course had never before been in a course in which the main objective is to work with a real-world partner, in-class learning is done through discussions, and the project is completed in teams. However, students quickly embraced this education model as demonstrated through their willingness to contribute their thoughts during discussions and the generally positive and friendly atmosphere of the classroom. In fact, students became comfortable with this learning style before some faculty and pushed the course toward a more interactive execution through feedback and post-class discussions with facilitators.

Beginning the first day of class, the students were instructed to sit with people whom they did not know. As there were various groups of students who knew each other previously or signed up for the class together, some were hesitant to move seats. However, after a few weeks this became the classroom norm and students waited to hear the prompt by which the day's seating would be determined before finding a seat.

Although this activity had the benefit of having the students become familiar with each other, it also exposed students to themes and lessons relevant to the research project itself. For instance, one class period students were to sit with individuals from their own majors to determine what they knew about the project and what they knew that they didn't know. They then rearranged themselves so that students could only sit with individuals in majors different than their own, and they all compared notes to see if they could unearth information about the project that they *didn't* know that they did not know. An engineering student, for example, stated that she knew about simple irrigation design and was familiar with the EWB-UIUC group working on the engineering design component of the project. However, it was not until a student from Urban Planning shared that she realized that she also does not know the economic atmosphere of the community or until a student from Global Studies spoke that she does not know how the residents of Lumbisi make decisions about the construction of infrastructure that the Engineering student acknowledged she hadn't considered these unknowns before. These breakout discussions at various tables were then brought together into a class discussion. Occurring on the first day of class, this conversation laid a critical foundation about how the students have the opportunity to work together in an interdisciplinary setting, which will be crucial for the success of the research project.

Not only do the students get to work with others from various departments, they also get to interact with and learn from faculty and staff from across campus. The faculty members led various discussions in the classroom and shared their experience and background with the students. The faculty and staff were also an integral part of discussions when they would sit at a table of students and help encourage the conversations, provide insight, and challenge thoughts.

This unique structure gave students the opportunity to interact with faculty in a way not ordinarily seen in a traditional classroom.

The students spent a great deal of time in the classroom discussing and learning from their peers and instructors, but they also spent time outside of class learning and reflecting. Each week students had to read various articles about international service learning and its impact, both negative and positive. The students then wrote a 250-500-word reflection. These reflections then served as a basis for discussion in the next class.

Guest speakers were also invited to the classroom to share their experiences with service and to help the students gain deeper insight into the irrigation project. For instance, the coordinator of the community garden spoke with the class early in the semester. Not only did she reveal an area of need in our own community – the fact that a "food desert" has arisen in one part of town that makes nutritional food difficult to obtain for low-income families there – she helped point to the need for human-centered design in the course project and that successful and appropriate solutions are only discovered when the true needs of a population are heard. The students had time to ask further questions while the course instructors were also able to add their own insight.

After reviewing some of the principal topics of the course, students self-formed teams using a "speed-dating" process to identify others with whom they shared interest and felt comfortable. During one class, students were given two minutes to move from classmate to classmate, discussing their own interests and recording the names of those with whom they felt they connected. Lists were compiled to create eight cross-disciplinary teams with students of varying backgrounds but who shared a common interest or shared comfort.

These self-selected teams then were tasked with developing a clear research question to answer throughout the course of the semester. Examples of questions that were researched include:

1) How do farmers in the community utilize technology (i.e. tools and techniques) in response to irrigation needs?
2) What power structures exist amongst community members and how do these structures influence community decision-making?
3) In what ways does the involvement of a non-governmental organization influence decision-making and project sustainability?
4) In what ways does the Engineers Without Borders group obtain information regarding community needs and how does this information influence the engineering design?
5) What is the historical context of the community?
6) What environmental factors are present in the community and in what ways has climate change affected the community and farming practices?

The second half of the semester was spent determining a clear methodology to answer these questions, including interviews, statistical analysis, surveys, and observational checklists that were then used on the trip.

For many of the students in the class, this was their first experience on a curricular team in which they work with students in majors different than their own and learn from each other's backgrounds and past experiences. Although not all the students have worked on international service projects or traveled internationally before, the combined insight of the students and their knowledge from various departments has been and will be instrumental in the course. Ultimately, the perspectives offered by the students and instructors help to build a collective understanding as to how to approach this project and complete it successfully.

Discussion

At the midterm of the inaugural offering of the course, students who hadn't taken other course offerings with the lead instructor expressed some concern over the ambiguity of the research project. Some students rightly perceived, though, that the ambiguity was part of the pedagogical process, since one of the learning objectives is to expose students to the challenges of working with the developing world – particularly, the unavailability of reliable information, the slowness of correspondence, and the ever-changing landscape of attitudes and messages that can occur when a service provider interacts with an unfamiliar recipient culture. Regular reassurance by faculty, as well as by those students who have undergone the learning process in other courses, was accurately expected to ease the anxieties expressed. Additionally, some of the faculty continues to struggle with breaking out of the lecture mode to create a more interactive classroom, and this phenomenon required continued vigilance, supported by regular student feedback.

While it is still too early to pronounce the course a success in building a cross-disciplinary, contextual understanding of international-development infrastructure design, the enthusiasm of the students coupled with the collaborative facilitation provided by faculty suggest transformational learning will occur in the classroom. The openness of students to learn from each other, as well as the faculty, is apparent as they compare their understanding of the multi-faceted relationship between infrastructure design and the recipient community's interaction with the system. By allowing the students to explore the importance of each discipline—technology, health, culture, planning—to the irrigation system's long-term viability, the opportunity exists to develop a clearer understanding of the interrelationship between these critical areas of influence. It also provides students in each discipline with a window into others' thought processes and relevance.

Conclusions

The utilization of research methods from a variety of disciplines leads to holistic research that encompasses the needs and expectations of all stakeholders.

Modification of the traditional lecture-style course to incorporate presentations from cross-disciplinary faculty and student-led discussions enhances overall learning and challenges students to reflect on their predisposed notions of international service design.

The challenges of coordinating faculty and staff from a variety of departments, colleges, and universities are offset by the benefit of bringing these various perspectives and backgrounds together.

The combination of faculty and staff from varying disciplines and academic backgrounds can strengthen each educator's own teaching and management capabilities by exposing them to other methods.

The availability of technology to provide new avenues for communication and interaction can allow for a richer student research experience by uniting diverse disciplines, partnerships and project roles.

Through interactions with peers who represent different academic backgrounds, students recognize the benefit of gaining other perspectives when approaching both the course project and in future endeavors. Gaining a broader view helps students realize the complexity of the problem and how the solution must consider more than technical design.

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