

Integrating Sustainable Community Development in Engineering Education

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Abstract

In 2004, we received a grant from NCIIA to develop a new course in the area of community service and engineering for humanitarian development. Over the past four years, the course has been offered through the Engineering for Developing Communities program at the University of Colorado at Boulder. The course went through four iterations, with the final configuration offered in academic year 2008-09 as a six-credit hour course titled Sustainable Community Development I (SCD I, fall) and II (SCD II, spring). SCD I emphasizes a public health perspective and participatory models, with an overview of development and global health concepts and issues. SCD II covers the principles, practices, and strategies of appropriate technology as part of an integrated and systemic approach to community-based development. The paper describes the context in which the course was developed and how it fits into the global framework of engineering education for humanitarian development.

Introduction

Over the past ten years, engineering students and professionals in the US have shown a strong interest in directly addressing the needs of developing communities worldwide—a field that has traditionally been in the hands of international development organizations. That interest has taken the form of short- and medium-term international trips through Engineers Without Borders-USA (EWB-USA) and similar organizations. EWB-USA started as a small project in Belize in 2001 involving the first author and a handful of undergraduate engineering students. It has quickly grown to an organization with over 12,000 professional and student members spread over 295 chapters in the US and working on close to 400 projects in 45 countries (<http://www.ewb-usa.org>).

The work of EWB-USA falls into what Bugliarello (2008) refers to as “engineering for development” as a new interdisciplinary thrust in engineering which “...responds to the global need for engineers who understand the problems of development and sustainability, can bring to bear on them their engineering knowledge, are motivated by a sense of the future, and are able to interact with other disciplines,

with communities and with political leaders to design and implement solutions.” More specific to the developing world, “engineering for humanitarian development” contributes in part to the implementation of the eight Millennium Development Goals (United Nations 2003) and represents an alternative to top-down development. It is a grassroots movement consisting of individuals who are willing to donate time and expertise to solve poverty issues. The projects are smaller in size and funding than traditional engineering projects and do not compete with those conducted by large engineering firms.

Since 2004, engineering for humanitarian development has been the main emphasis of the Engineering for Developing Communities (EDC) program at the University of Colorado at Boulder (<http://ceae.colorado.edu/mc-edc>). The program was recently renamed the Mortenson Center in Engineering for Developing Communities (MC-EDC) following a recent endowed gift from the Mortenson family and Mortenson Construction Company. The center promotes integrated and participatory solutions to humanitarian development by educating globally responsible engineering students and professionals to address the problems faced by developing communities worldwide. MC-EDC recognizes that community development requires an integrated approach bridging across various seemingly independent disciplines such as engineering/technology, public health, social entrepreneurship, public policy, and security.

The EDC program was born out of the realization that students scheduled to participate in EWB-USA projects needed technical and non-technical preparation and skills. A program of study was therefore developed to educate students in sustainable community development and appropriate technology. MC-EDC addresses a wide range of issues such as water provisioning and purification, sanitation, public health, power production, shelter, site planning, infrastructure, food production and distribution, communication, and jobs and capital for developing communities including villages, refugee settlements, Native American reservations, etc. Whereas EWB-USA focuses on extracurricular outreach projects and project delivery, MC-EDC places equal emphasis on education, research/development, and service/outreach and, more importantly, the relationship between those three components. In compliment to EWB-USA, MC-EDC focuses on knowledge delivery and dissemination pertinent to community development.

We present below the educational component of MC-EDC and more specifically the development of a new core graduate course on sustainable community development. Further information about the center, its projects, research and development, and service activities can be found in a recent paper by the authors (Amadei and Sandekian 2009).

Engineering Education for Humanitarian Development

Background

Today’s engineers need to show a high level of adaptation and flexibility in order to address more global problems in a dynamic, changing environment where multidisciplinary approaches are the norm. They must also be able to address the formidable challenges associated with the interaction of adaptive technical systems with societal systems (National Academy of Engineering 1991).

Engineering education is still subject to conflicting demands. On one hand, there is a need for more specialization in narrower fields of study to respond to ever-increasing knowledge and complexity. On the other hand, there is a need for more general education, with a wider breadth, so that engineers can work in global areas in interdisciplinary teams. Both depth and breadth have to be integrated into a four year curriculum, and the balance between the two continues to be a topic of major discussion in the

engineering profession today, especially in accreditation organizations. Both depth and breadth have to be supplemented with the acquisition of life-long skills to train students to address problems that are ten to twenty years into the future. In their working lifetimes, engineering students now attending college can expect to see a 50% increase in world population, the consequences of rapid climate change, and major losses in biological and cultural diversity.

Over the past ten years, we have observed several independent efforts at domestic universities to integrate service learning, civic engagement, and outreach into their curricula. Initiatives explicitly focusing on creating global citizen engineers through domestic and international humanitarian engineering projects are already changing the landscape of engineering education and practice. Flagship examples in the US include the Engineering World Health Summer Institute Program at Duke University (<http://www.ewh.org>), the Humanitarian Engineering Program at the Colorado School of Mines (<http://humanitarian.mines.edu>), the Engineering Projects in Community Service at Purdue University (<http://epics.ecn.purdue.edu>), the Peace Corps Master's International Program at Michigan Tech (<http://www.geohazards.mtu.edu>), and the Mortenson Center in Engineering for Developing Communities at the University of Colorado at Boulder (CU-Boulder). A review of some initiatives in the areas of accreditation, service learning and hands-on experience, awareness building, and curriculum development can be found in a recent paper by the authors (Amadei and Sandekian 2009).

The EDC model of education

Education of engineering students within the EDC framework emphasizes both knowledge and skills in sustainable community development. The model is partially didactic (classroom environment) and partially hands-on (field projects). MC-EDC brings together a wide range of courses in engineering, sustainability, appropriate technology, renewable energy, public health, international education and development, business, and various fields of humanities. It also provides an opportunity for undergraduate students in engineering to enroll in a traditional degree program in the College of Engineering and Applied Science at CU-Boulder and, at the same time, take some of their humanities and social sciences electives, technical electives, and independent study credits in courses emphasizing community service and sustainable community development.

Five tenured faculty members within the Department of Civil, Environmental, and Architectural Engineering (CEAE) currently provide the core of the MC-EDC and its programs. In addition to tenured faculty, five adjunct faculty members with experience in areas ranging from water resources, sanitation, and hygiene to public health and participatory action research also actively participate. Outside the department, the program receives project support from the director of the Center for Advanced Engineering and Technology Education (distance learning) and a senior faculty member in the Department of Electrical and Computer Engineering. In addition to the faculty leaders, a full-time Managing Director oversees program operations.

The MC-EDC program of study for undergraduate and graduate students was designed to match what is expected today of engineering education by the Accreditation Board for Engineering and Technology (2007) and the recommendations by the American Society of Civil Engineering (ASCE) Body of Knowledge for the 21st Century (2008).

Undergraduate education

In 2007, faculty of the CEAE Department at CU-Boulder approved an EDC track in the Civil Engineering undergraduate curriculum. Interested students complete the standard core and proficiency courses in their specialty and enroll in specific elective courses focusing on topics relevant to developing communities. In general, the students must complete the following academic requirements in addition to their respective

programs of study:

1) Technical Electives (six credits, upper division)

Technical electives are upper-division courses, generally in engineering or science. Two appropriately focused technical elective courses must be chosen in conjunction with the student's primary academic advisor and the EDC track coordinator. The list of EDC-appropriate and currently approved technical electives for Civil Engineering is a subset of the department-approved list.

2) Humanities & Social Science (nine credits, including six upper-division)

Students must take two upper-division and one lower-division humanities/social science courses from a list of approved courses that fulfill the College of Engineering and Applied Science graduation requirements.

Detailed lists of EDC-approved technical and socio-humanistic electives can be found on the MC-EDC education web page (<http://www.edc-cu.org>).

The EDC undergraduate track is the result of several iterations based on the input received from students and faculty over the course of four years. The guiding principle behind the track has been to integrate it into the existing Civil Engineering curriculum by leveraging existing courses offered in the department, the college, and in other academic units on the campus. To date, the undergraduate program has been based on existing coursework within the ABET-accredited program in Civil Engineering. MC-EDC faculty members who teach undergraduate courses have added relevant examples and international project opportunities, and have encouraged their colleagues to do the same. Specific assessment of these activities is underway and has been documented in a variety of conference papers including Bielefeldt et al. (2007).

The only new undergraduate module developed for the EDC track has been an added section of an existing course called GEEN 1400: First-Year Engineering Projects. As described on the course website (http://itll.colorado.edu/index.php/courses_workshops/geen_1400/), GEEN 1400 is a three-credit hour course offered to engineering students through the Integrated Teaching and Learning Laboratory (ITLL) in the College of Engineering and Applied Science at CU-Boulder. It is a first-year, interdisciplinary, hands-on engineering project course for entry-level engineering students. The purpose of the course is to introduce engineering through a series of small projects done in interdisciplinary teams. Students learn, in a hands-on way, valuable engineering skills including communication, how to function in teams, the basic steps in the engineering design process, and a variety of computer tools appropriate to their projects such as spreadsheets, dynamic modeling software, or computer-aided design. The course is usually divided into about ten thematic sections, each consisting of thirty students under the leadership of a faculty member, with the help of two teaching assistants.

Since 2002, students have been able to sign up for a section (when offered) focusing on appropriate technology for developing communities. It gives students a thorough understanding of some of the most common and important technologies being introduced in small-scale community development projects. Students are asked to create, design, and construct appropriate technological systems, processes, and devices for a variety of settings associated with the developing world. Examples of final projects include: production of biodiesel; production of biomass from bananas; generation of electricity using water turbines; heating of water for refugee camps; water filtration systems; solar-powered refrigeration; and solar- or gravity-powered water pumping.

Graduate education

Since graduate programs have not previously been ABET-accredited, the MC-EDC faculty have had more leeway to incorporate humanitarian development concepts and courses into the graduate curriculum. EDC tracks are currently offered within three of the six focus area programs leading to MS and PhD degrees in Civil Engineering (CE): Environmental Engineering (since 2004), Civil Systems (since 2008), and Construction Engineering and Management (starting in 2009). EDC tracks in the other CE programs (Building Systems, Water Resources, and Geotechnical Engineering) are under consideration by their respective faculty groups. Students enrolled in the EDC graduate track are required to take courses designed to provide both short-term (three weeks) and long-term (three-to-six months) practicum experiences in domestic or international developing communities. Advising guides showing the sequence of courses and the list of courses for the EDC graduate tracks can be found on the web at <http://ceae.colorado.edu/mc-edc/?ii=Education>.

The EDC track in environmental engineering focuses primarily on integrating interdisciplinary studies of public health and international development into the standard curriculum. Several courses have been co-developed over the past four years, although some of them have now been combined to lessen the extra teaching burden and/or additional expense of hiring adjuncts or instructors from outside the CEAE department. Examples include:

- Hygiene and Sanitation in Developing Countries, one credit hour (fall 2008)
- Sustainable Community Development, six credit hours (2008-09; 2009-10) which encompasses formerly separate courses:
 - Engineering for the Developing World, three credit hours (fall 2007)
 - Appropriate Treatment Technology, three credit hours (fall 2006)
 - Public Health for Developing Communities, three credit hours (fall 2006)
- Sustainability in the Built Environment (spring 2007, 2008; currently only available via distance education through the Center for Advanced Engineering and Technology Education)

Courses developed and funded by other departments, schools, and colleges on the CU-Boulder campus have included:

- Energy Technology and Policy, three credit hours (fall 2007)
- Sustainability Ethics and Practice, three credit hours (spring 2006, 2007)
- Social Entrepreneurship in Emerging Economies, three credit hours (fall 2009)
- Information and Communications Technology for Development, three credit hours (fall 2009)
- Global Development (Political Sciences), three credit hours (fall 2009)

A high percentage of women are enrolled in the MS-level environmental engineering/EDC graduate track. Since its inception, women have represented more than 53% of all enrollments in EDC-sponsored courses. Three of the six 2007-08 academic year EDC MS graduates were women, and EDC track students accounted for one-quarter of all civil/environmental engineering graduates during that same time frame. This percentage is expected to grow to one-half or more within the next two years, based on the interests of incoming MS-level students. The EDC program is still relatively young but graduates have gone on to work in careers including small community water treatment solutions for the State of Colorado's Department of Public Health and Environment, positions with environmental engineering consulting firms, the Peace Corps, and graduate degree programs in Civil Engineering.

The EDC track in the MS/PhD in Civil Systems is still in its early stages of development and implementation. It emphasizes a systems approach to the development, management, and monitoring of civil infrastructure systems under natural and society-induced hazards, the integration of model-based analysis and field and laboratory experiments, and the creation of tools for effective and informed life-cycle decisions for the built environment. Students apply to the Civil Systems graduate program within the CEAE department and have the opportunity to develop a customized program that fits individual academic and professional goals. In addition to core courses and electives, students must take twelve credit hours in an area of emphasis: either traditional CEAE disciplines or interdisciplinary areas such as EDC, Engineering for Society, Sustainable Development, mega-city planning, or renewable energy.

A multi-year graduate course development

In 2004, we received a grant from the National Collegiate Inventors and Innovators Alliance (NCIIA) to develop a new course in the area of community service and engineering for humanitarian development. Since then, the course has gone through four iterations based on feedback received from the students and input from the EDC faculty.

- 1) In year one (2005-06), the first author taught the course entitled Engineering for the Developing World (EDW). A single team of three undergraduate students (one majoring in civil, one in mechanical, and one in aerospace engineering) worked on two different projects for the Muramba and Mugonero communities in Rwanda over two semesters, earning six credits that could be applied as technical electives in their respective majors.
- 2) In year two (fall 2006), the course was taught by Dr. Bielefeldt from Environmental Engineering. Twelve students in three teams worked on a wastewater treatment/reuse design for a community in Sonora, Mexico. Students earned three or four credits for the course, which counted as the capstone design experience in their curricula. The students self-selected this international project from among three project options (the other two were service learning projects within the state of Colorado) in the capstone Environmental Engineering Design class. About 75% of the women and 75% of the minorities in the class chose to work on the international project. These students were undergraduates majoring in Civil Engineering (CVEN), Environmental Engineering (EVEN), and graduate students in Civil Engineering. A detailed comparison of student evaluations in fall 2006 with those in academic year 2005-2006 was reported by Bielefeldt et al. (2007).
- 3) In year three (fall 2007), the first author again taught the EDW course, but this time five seniors and sixteen graduate students were enrolled. The students were divided into five groups, each one addressing a project over the course of one semester. Two of the projects were local while the other three projects involved communities in Rwanda (EWB-USA project), Bolivia, and a Native American Community (EDC project).
- 4) The final iteration of the course as part of the NCIIA grant took place over the academic year 2008-2009. The six-credit hour course has been renamed Sustainable Community Development I (SCD I, fall 2008) and II (SCD II, spring 2009). It involved fifteen graduate and senior-level undergraduate students from engineering and typical pre-health majors. It was co-taught by the first author and Dr. Silver, who is an EDC program adjunct faculty member with degrees in medicine and public health. SCD I emphasizes a public health perspective and participatory models, covering an overview of development and global health concepts and issues as they apply to developing communities. SCD II, on the other hand, covers the principles, practices, and strategies of appropriate technology as part of an integrated and systems approach to community-based development. In this final grant-funded iteration of the course, the students were taught the broader picture of sustainable community development and the relationship between public health and development engineering and what represents healthy and safe

communities.

Course challenges and opportunities

The SCD course sequence is now an integral part of the MC-EDC program of study. All EDC graduate students have to take SCD I and II as core courses before embarking into master's or doctoral research in EDC-related fields. Both courses are also pre-requisites for non-thesis option MS students who must conduct a field practicum and write a project report.

A benefit of the SCD course sequence is that students must work in teams on real projects and show competency in applying principles learned in class to addressing community problems. A list of projects conducted in 2008 and 2009 can be found on the course web site: <http://ceae.colorado.edu/mc-edc/?ii=Education:Courses:CVEN 5834>. For each project, the team is responsible for data collection, assessment, problem identification, capacity analysis, design, implementation, monitoring, and evaluation. In SCD I and II, the students are exposed to a holistic approach that emphasizes participatory and integrated development. The students also benefit from outside speakers who are invited to give lectures on specific topics pertinent to community development.

The 2008-2009 version of the course is what will be offered for the foreseeable future. For academic year 2009-2010 it is once again being co-taught by the first author and Dr. Silver. As of September 1, 2009, twenty-six graduate and three upper-division undergraduate students were enrolled in SCD I, 44% of whom are female. Six community projects were identified: Ensenada (Mexico), Swayambu (Nepal), Mahbu (Nepal), Iquitos (Peru), Ayaviri (Peru), and a project along the Thai-Burma border.

Development of a new program of study such as MC-EDC does not come without challenges within an academic context. Until recently, the major challenges in continuing the offering of the SCD course sequence were to fund the salary of the adjunct faculty co-teaching the course with the first author and to cover course operations costs including equipment, materials, field trips, etc. Thanks to the NCIIA course and program grant, and a recent endowed gift to the EDC program by the Mortenson family and Mortenson Construction Company, the SCD course sequence can now be offered for the foreseeable future.

Conclusions

The Mortenson Center in Engineering for Developing Communities is developing a blueprint for the education of engineers interested in humanitarian development. Sustainable community development is the core issue in the center. Over the past five years, the EDC program has received growing interest from undergraduate and graduate students interested in environmental engineering and civil systems within the context of humanitarian development.

With funding from NCIIA, a new course sequence was developed to expose students to participatory and integrated community development. This new course has become the cornerstone of our graduate program, and is leading to changes in offerings available to undergraduates as well. In summer 2010, a modified version of the SCD I course will be taught by the first author in Haifa, Israel. Students from CU-Boulder will work and study side-by-side with students who are enrolled at the Technion, Israel's premier Institute of Technology. During this month-long seminar, students will study Israeli culture and the Hebrew language as well as working on projects for Bedouin and Druze communities.

The MC-EDC shows that engineering education for humanitarian development can be integrated into existing engineering curricula, service/outreach, and research and development. Such initiatives provide students a much needed field experience; create teamwork, leadership, and global competency; contribute to the making of civil societies; and above all give students a global outlook, a sense of belonging and

engagement, and a societal context for their work. Those skills match well with what is expected today in engineering education by accreditation organizations.

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