

Engineering for Developing Communities at the University of Colorado Boulder: A Ten Year Retrospective

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Abstract – The University of Colorado Boulder started its Engineering for Developing Communities Program with a graduate track in environmental engineering in 2004. Over the past ten years, the program has expanded to include undergraduate- and graduate-level certificates and involves approximately twenty percent of the graduate students within the Department of Civil, Environmental, and Architectural Engineering. This article describes the history and current status of our program including challenges and successes that have led us to where we are today. We briefly describe our undergraduate and graduate certificate curricula, share course descriptions and evaluation methods and results, highlight student employment outcomes, and reveal lessons learned. This discussion should prove useful to faculty and administrators, from department chairs to chief academic officers, who might be considering adding this type of program at a research-intensive university such as ours.

Index Terms - Engineering curriculum, global engineers, sustainable community development

INTRODUCTION

The Mortenson Center in Engineering for Developing Communities (“Mortenson Center”) at the University of Colorado Boulder (CU-Boulder) combines classroom learning, research and development, and real world, on-the-ground experience to train engineers to work in partnership with organizations in developing communities worldwide. Our goal is to train engineers to create sustainable and appropriate solutions to meet people's basic needs. Students who participate in Mortenson Center activities learn the importance of building relationships and conducting a thorough assessment alongside community members before attempting to tackle any particular “problem” or implementing a “solution.” Students are reminded that long-term commitments to a community can encourage incremental growth towards improvement. The Mortenson Center’s methodology focuses on transferring knowledge in both directions: from the community and on-

site organizations to the engineers, and from the engineers to the community and on-site organizations so that together, they can develop long-term solutions based on local conditions. This empowers the community to move forward with completing and maintaining the project, using a collegial participatory approach rather than the project being driven from the outside¹.

The core of the Mortenson Center approach to educating global engineers is the belief that the challenge of engineering in the future will be to meet the needs of a rapidly growing human population while preserving Earth's biodiversity, its delicate ecosystems, and its rich cultural heritages. Educating this next generation of engineers requires a new perspective on education, one that is broader and deeper, richer and fuller. In recent years, this type of education has been described as "T-shaped," where breadth, relevance, and context (the cap of the "T") are added to the traditional depth (the stem of the "T") provided in most engineering curricula². Solving critical issues of the 21st century will require interdisciplinary and transdisciplinary approaches, connecting teams of technically competent and broadly educated individuals. Mortenson Center programs address this need by expanding education beyond traditional numbers and formulae into the realm of human relationships and experience, into history, sociology, economics, and political theory. The intent of this approach is to train well-rounded, broadly educated engineers who have a global perspective and understand that actions have potential ripples around the world, intended or not. This type of engineer understands that a successful solution must be a collaboration that takes into account local geography, technology, materials, and personnel. Finally, this type of engineer is committed to helping people in developing areas help themselves.

This paper provides a reflection on the Engineering for Developing Communities (EDC) Program's evolution during its ten year existence at CU-Boulder. It includes a description of the initial goals and curriculum, and how those have changed over time. After a brief discussion of the program's history, we highlight our current courses, program outcomes, our ongoing challenges, and lessons learned that are indicative of the program's progress since its inception. The discussion should prove useful to faculty and administrators, from department chairs to chief academic officers, who might be considering adding this type of program at a research-intensive university such as ours.

BACKGROUND / HISTORY OF PROGRAM

As documented previously^{3,4}, the EDC Program, which was renamed the Mortenson Center in Engineering for Developing Communities in 2009, grew out of the realization that while hands-on engineering projects may engage and energize students to use their skills in a humanitarian development context, those activities are insufficient if the intended outcome is sustainable development. Without a clear understanding of global economic, social, and political systems, stand-alone engineering projects are likely to fail to meet sustainable development goals. The stated mission of the EDC Program at CU-Boulder was to educate globally responsible students who could offer sustainable and appropriate technology solutions to the endemic environmental problems faced by developing communities at the local, national and global levels.

After a year of program development, the environmental engineering faculty group within the Department of Civil, Environmental, and Architectural Engineering (CEAE) approved an EDC track within their graduate degree in February 2004. The track consisted of the four required core courses that all environmental engineering graduate students took, a new course in public health, a new course in appropriate treatment technology, a course loosely defined as a

sustainability course, and a service project that included a semester of planning followed by an in-field activity. Students with significant past field experience were allowed to forgo the project requirement. The two new courses were expected to be team-taught endeavors. The first three EDC Program students enrolled before the track in environmental engineering was officially approved. As word of the program spread, interest increased. In academic year 2005-06, the first full recruiting cycle after the EDC track approval, six prospective environmental engineering students enrolled. Four students per year entered during each of the next three academic years (fall 2006 to fall 2008).

As the graduate student body within the EDC program reached the critical mass needed for the new courses, the EDC leadership team sought assistance from non-engineers who could teach students about key development-related topics including public health, participatory community research, and other social science areas that would help to round out an engineers' strictly technical education and help students apply their skills to this new context. To do this, the environmental engineering faculty members reached out to their professional networks to identify individuals who were willing to join in this fledgling program. In spring 2005, a new course called Environmental Health for Developing Communities⁴ was team-taught by adjunct instructors with specializations in medicine, public health, participatory community development, and GIS. Nine environmental engineering students enrolled in the course and one audited (no credit). The next semester, eight environmental engineering students enrolled in the first offering of the Appropriate Treatment Technologies course. That project-based course allowed students to develop an understanding of the design and implementation of processes used in the treatment of water, wastewater, hazardous waste and solid waste in developing communities. Students, in consultation with the instructor, selected a treatment process or an environmental scenario and developed a project around the topic. The final report represented a current, in-depth review of the chosen specific treatment technology or environmental scenario and addressed the non-technical aspects of the implementation of treatment technologies in developing communities, e.g. the role of the local culture and gender issues¹⁹. Since then, some of the content of the Environmental Health for Developing Communities course has been folded into a course called Sustainable Community Development 1 whereas some of the Appropriate Treatment Technologies course content has been folded into a course called Water Sanitation and Hygiene (WASH). The Mortenson Center manages the Sustainable Community Development course sequence and the environmental engineering group manages the WASH course.

Separating University-Controlled Efforts from Extramurally-Controlled Efforts

As the founder of both the EDC program and the non-profit organization, Engineers Without Borders-USA (EWB-USA), Dr. Bernard Amadei initially directed both the fledgling curricular program in CEAE and advised the CU-Boulder student chapter of EWB-USA (known as EWB-CU). The EDC program was described as the intersections of a Venn diagram that included education, research and development, and service with the extra-curricular projects conducted by EWB-CU reported as the service activities of the EDC Program. However, as EWB-USA grew and built an infrastructure to oversee their chapters' activities nationwide, faculty and staff who worked with the EDC Program recognized that we had no control over those projects. Therefore, the decision was made that the EDC Program (the precursor to the Mortenson Center) would focus on the university-based activities including faculty-led research projects and developing

curriculum-based field experiences that embedded graduate students into existing organizations. Concurrently, EWB-CU would run as a student organization with faculty advisors who would be responsible for managing their projects separately, in accordance with EWB-USA guidelines.

DESCRIPTION OF THE CURRENT PROGRAM

In 2009, a gift from Mortenson Construction and the M. A. Mortenson family led to the creation and endowment of the Mortenson Center and provided the opportunity for program expansion. The Mortenson Center is housed within the CEAE Department for three reasons: the program founder is a faculty member there; the benefactor, Mauritz “Mort” Mortenson, was a 1958 graduate of that department who wanted to support the work of the program founder; and CU-Boulder’s guidelines for establishment of centers require that they be hosted by an academic department⁵. In the early years, with the exception of the program founder, all faculty and student participants came from the environmental engineering sub-discipline group within the CEAE Department. In more recent times, individual faculty from additional CEAE groups and from departments outside of CEAE have joined in specific activities, but no other engineering department has created an explicit path for their students interested in EDC. That lack of a clear path for students outside of CEAE’s environmental engineering group led to the idea of creating a graduate certificate that would be open to any student in the College of Engineering and Applied Science.

In response, the first major academic initiative of the Mortenson Center was to offer a certificate program consisting of the engineering-based courses that had already been integrated into the graduate degrees in the CEAE department’s environmental engineering sub-discipline. The main difference was that the certificate would be available to any graduate student in an engineering discipline and it would be listed on a student’s transcript. The certificate includes four courses (twelve semester credit hours), including two that focus on sustainable community development (SCD 1 and SCD 2) from a systems perspective that emphasizes the importance of community participation throughout all design stages.

The third course in the graduate certificate is Life Cycle Engineering of Civil Infrastructures. The purpose of including this course is so that students can learn about sustainability from an infrastructure perspective. The final component of the certificate is the practicum, which requires field experience working with an existing, on-the-ground development organization. Students spend several weeks to several months embedded with an organization that is seeking specific assistance and whose needs match each student’s skills and capabilities. The field-practicum provides a supervised experience in which the student applies theories and concepts learned in SCD 1 and SCD 2. Students can typically complete their Graduate Certificate in EDC in three semesters plus one summer of fieldwork.

Around the same time as the inception of the graduate certificate, additional EDC tracks were approved by the faculty in the Civil Systems (2009), Construction Engineering and Management (2009), and Building Systems (2010) sub-disciplines of CEAE. Whereas the environmental engineering group developed new coursework and instituted additional requirements for their EDC track beyond the four course certificate, the three other tracks in CEAE mirrored the graduate certificate requirements exactly. By approving a track, the civil engineering faculty members in each sub-disciplinary group were agreeing to help arrange and supervise student practicums for their students because, in its initial configuration, the practicum was strongly dependent on technical oversight from faculty members. The distinction between hosting a track

within a civil engineering sub-discipline and simply allowing students to complete the certificate was that by agreeing to host a track, faculty indicated their willingness to allow the student to use the twelve credit hour certificate as part of the thirty-credit hour non-thesis option master's degree without having to take additional coursework.

Graduate Certificate Course Descriptions

Sustainable Community Development (SCD) 1 and 2

In fall 2008, SCD 1 subsumed the Environmental Health for Developing Communities course and expanded the focus beyond environmental health to provide a background and framework for sustainable community development based on a participatory design model⁶. A strong public health perspective remained but additional topics included discussions of vulnerable groups, participatory community development, project design, and behavior change communication⁷.

The follow-on course, SCD 2, covers the principles, practices, and strategies of appropriate technology as part of an integrated and systems approach to community-based development. Course content includes technical issues and global cooperation in development, environmental health and communicable disease, and hands-on workshops in appropriate and sustainable technologies. Self-selected groups of students apply course topics to a case study of an actual appropriate technology project in local or international developing community settings⁷.

Guest lecturers have been used extensively throughout these courses to allow topic specialists to discuss their individual roles within sustainable development efforts, and a co-instructor who specialized in participatory research methods and public health was responsible for portions of the SCD 1 course for fall 2008, fall 2009, and fall 2010.

In fall 2012, to accommodate the sabbatical of the lead faculty member who designed and taught the SCD 1 and SCD 2 course sequence for the first five years, the SCD 1 course was replaced with a global development theory course offered through the Alliance for Technology, Learning and Society (ATLAS) Masters of Science in Information and Communication Technologies for Development program. This change brought interdisciplinarity back into the course enrollment and provided students with the opportunity to study a wider breadth of development theories using a survey approach to understanding the major historical outcomes, theories, institutions, policies, alternatives/critiques, and themes in international/community development. Through case studies, multilateral declarations, academic papers, news clippings, films, and domain experts, students gain an understanding of how their work in development affects, and is affected by, other development sectors and agendas⁸.

SCD Field Practicum

The SCD Field Practicum provides an opportunity for students to gain insight into the field of international development, experience the reality of working in a developing community, and apply theoretical foundations of SCD classes to real world experiences. Field-based experiences are an important component of engineering for developing communities. We believe that a true understanding of humanitarian engineering requires students to actively engage in a significant field-based experience in a developing community. The practicum encompasses engineering fieldwork and analytical reporting⁹. Students earn graduate-level credit for the analytical reporting component, not the hands-on skills development. In part, this separates the credit-

bearing practicum (a service-learning course) from the non-credit service activities of engineering student groups.

Practicums are typically located outside the United States, although Mortenson Center students have also worked with development organizations in Denver and Washington, DC and on the Crow Reservation in Montana. In summer 2014, fifteen EDC graduate students completed fieldwork in eight countries across North and South America, Asia, and Africa. Students completed scopes of work ranging from water testing in communities along the Amazon River, to supporting program development for the Millennium Challenge Corporation, and support of reconstruction activities by evaluating sustainable, local construction materials in the province of Eastern Samar (Philippines) six months after Super Typhoon Haiyan destroyed tens of thousands of structures and killed nearly 7,000 people.

To date, the Mortenson Center has paid the majority of the costs for students' international airfare and visa expenses for practicums. Host organizations are expected to provide in-kind or financial matching, on a sliding scale based on their financial ability to do so. Students must cover the difference in costs, typically including personal expenses such as meals and lodging. The students earn credit for completing an analytical report of their experience, not for conducting the actual fieldwork.

Life Cycle Engineering of Civil Infrastructure Systems

This course presents philosophical and analytical issues for lifetime design and operation of civil systems including optimization tradeoffs of construction, management, and sustainability. Students discuss facility operation and service, including present-value economic analysis and study decision-making alternatives of safety and performance including hazards consideration⁵. Course information is relevant for infrastructure systems in both developed and developing contexts.

Next Steps

Approximately twenty percent of all CEAE graduate students are now enrolled in the graduate certificate in EDC, plus a few degree-seeking students in other engineering departments and two non-degree students who are looking for additional education that will allow them to expand beyond their existing engineering training and work experience. Given the stability of the graduate program, and the strong focus on undergraduate education demonstrated by the Mortenson endowment funding categories, we felt that it was time to expand our efforts in the undergraduate realm. From the earliest years of the Engineering for Developing Communities Program there has been an appropriate technology project section in the College's first year engineering design courses. The primary course objective was for students to learn the iterative design method through the completion of a group project. As detailed in a paper by Montoya, Sandekian, and Knight¹⁰, appropriate technology sections have been offered on a regular basis since fall semester 2002, and some of those sections have included projects for authentic clients in developing communities. Research findings based on one of these authentic client experiences is highlighted in the *Outcomes* section of this paper. In addition to the first year engineering design course, supportive faculty have worked to include EDC-focused modules or examples in other classes including environmental engineering senior design and air quality. Until recently, however, dedicated EDC courses have not existed in our College.

Undergraduate Efforts – An Undergraduate Certificate in Global Engineering

Since engineering for developing communities is a small niche, our college's Administrative Council (comprising all department chairs within the college) suggested that we design a program that could engage a broader swath of students and therefore have far-reaching impact across the college. We took that challenge and developed a certificate that has relevance to all engineers while maintaining a focus on coursework that would better prepare students to enter our graduate program in developing communities. The Undergraduate Certificate in Global Engineering is relevant to all engineering students because the engineering profession has become one in which its practitioners need to be competent in developing systemic solutions with global impact.

Whether a student's career aspirations involve small projects in developing communities, or mega-projects, it is likely that they will be working in a multi-disciplinary and international context. Completing the new undergraduate certificate will help students expand their understanding of how to operate in an international context from an engineering perspective, acquire the capacity to work as part of an international team within an office located domestically or internationally, and, gain an appreciation of the economic, social, and cultural considerations and other non-technical issues that should be considered when working on engineering projects. The curriculum includes requirements for conversational (second) language skills; communications, development, economics, or world history; and international cultures, governance or sociology. As is the case with the graduate certificate, completion of the program is noted on a student's transcript.

Undergraduate Certificate Course Descriptions – EDC Courses

Our undergraduate certificate relies heavily on existing courses offered through the College of Arts and Sciences. Those courses are taught on a regular basis and are already approved to count towards the undergraduate engineering degree programs. This significantly lessened the burden of engaging undergraduates, and supports faculty and departments campus-wide that devote resources to teaching concepts relevant to development. Starting in spring 2015, the EDC Program will change the historic lack of EDC courses by offering a sophomore-level course in engineering for developing communities and a senior-level course in global engineering design and development. Both of the courses will count towards the new undergraduate certificate.

Engineering for Developing Communities

This course introduces lower-division students to the role of engineering in poverty reduction and human development. It examines concepts of systems engineering for understanding how actions lead to intended and unintended consequences, especially in the case of communities where the social, political, and economic systems differ from those most commonly experienced by engineers in the developed world. The students will also be introduced to a framework and guidelines for conducting small-scale development projects in communities in medium- to high-risk and low resilience environments. The framework combines concepts and tools that have been traditionally used by development agencies and other tools more specifically used in

engineering project management. Finally, students will be introduced to the various leadership skills necessary to make decisions in complex and uncertain environments (Amadei 2014).

Global Engineering

In the engineering and construction industry, discussions of globalization have centered on three topics; (1) *market issues* [U.S. firms expanding into other countries and international firms increasingly competing with U.S. firms domestically], (2) *offshoring* [U.S. firms securing services from offshore service providers such as low cost engineering centers], and (3) *project scope* [the increasing size and complexity of projects requiring participation of engineers, contractors, and suppliers from multiple countries]. However, *globalization* is only the most visual component of global engineering. In fact, two additional areas must be considered when focusing on global engineering. First, *international project teams* must be understood as the next requirement for a successful engineering career. Second, *appropriate engineering solutions* must be considered in terms of what are appropriate designs and solutions for developing countries. In this course, students will have the opportunity to explore the issues associated with global engineering ventures. Students will explore the political, cultural, economic, and geographic issues associated with established and emerging markets.

What makes our program different?

The Mortenson Center at CU-Boulder provides students with the opportunity to earn a certificate in EDC or global engineering alongside their traditional degree in engineering. Students who complete the required courses have the certificate noted on their transcripts. Our program is different in that the Mortenson Center does not initiate or manage projects. Rather, the Mortenson Center collaborates with established organizations with existing projects and management structures. We believe that this arrangement increases the likelihood of long-term success for both our program and our partners. Our students bring skills and a depth of global development knowledge that are not taught within typical engineering degree programs. Our partners provide the ongoing project development and management infrastructure that is beyond our capacity and mission. Together we complement, rather than attempt to duplicate, each other's strengths.

At the graduate level, our students learn to apply global development theory to engineering practice and then integrate into organizations with larger infrastructures that are capable of and dedicated to managing projects. In the fledgling undergraduate certificate program, students are encouraged to concentrate their humanities and social science elective and free elective credits in areas that will provide the knowledge needed for them to make the most of their extra-curricular activities in engineering service student groups such as Engineers without Borders-USA and Bridges to Prosperity. Students can choose to be added to an email list that is used to announce courses and extra-curricular opportunities of interest. In addition, the certificate coordinator arranges events where working professionals or members of development-based student groups discuss the benefits of gaining a global perspective of engineering. Approximately 20 students have noted their interest in pursuing the undergraduate certificate during its first semester of operation.

On-going challenges

Staffing

Tenure-track faculty still participate on a volunteer basis due to traditional course staffing requirements. For that reason, and because the Mortenson Center still does not have a large enough pool of students or financial resource base to support the hiring of a full-time instructor, the program relies heavily on adjunct faculty. Reliance on adjunct faculty has benefits and drawbacks. The primary benefit is that we are able to engage individuals who have significant experience working in the field of engineering for development; the drawback is that our program is constantly seeking individuals with appropriate experience and credentials to teach at the graduate level. Teaching single courses at a university is not economically beneficial for many of these professionals who can command high consulting salaries and who need flexibility within their schedules to conduct those consulting assignments across the world. Legitimacy questions also arise when a program relies heavily on adjunct faculty, even if those individuals possess specialized and relevant experiences that the typical tenure-track faculty member lacks.

Funding

In the environment of ever-shrinking state appropriations for higher education, funding a small graduate program can be difficult. The Mortenson Center was fortunate to receive an endowed gift that covers most of its administrative expenses, provides limited financial support to graduate students through scholarships and one funded research assistantship, and provides an administrative stipend to the center's faculty director. However, in order to grow the education and research programs, we had to seek additional revenue. In 2014, our program signed an MOU with the Deans of the Graduate School and the College of Engineering and Applied Science. This agreement provides additional revenue to the Center that is directly proportional to the tuition generated by our EDC students. This offers an incentive for the program to grow and, more importantly, provides the potential financial support needed for that growth to happen sustainably. Revenue generated from this agreement will be used to make the program self-funded for the first time in its history by using a portion of the revenue to pay the remaining 25% of the managing director's salary that had been funded, to date, by either the CEAE department or the college. Remaining funds will be used to provide salary support for adjuncts to teach elective courses hosted by the Mortenson Center, for additional scholarships, and to help pay for student practicum activities.

Besides the additional funding, this agreement allows for a group of CEAE faculty involved with the Mortenson Center to admit students directly into a graduate program where the primary focus is EDC. This new direct-enrollment courses-only track in EDC was envisioned as the first step of broadening the admission possibilities for students whose backgrounds do not fit the typical preparation for a specific sub-discipline offered within CEAE. Although all students still have to meet the admissions standards for the CEAE Department, prior to this arrangement, students had to apply directly to one of the disciplinary groups within the department and could only note a secondary interest in EDC. However, they now have the option to apply directly to EDC which allows them to add breadth into their graduate program and select more coursework that has a stronger development or interdisciplinary focus. For designated students in the EDC graduate certificate or the new direct-enrollment courses-only track in EDC, the campus returns

fifty-five percent of the tuition collected back to the CEAE Department for disbursement proportional to course enrollment. The Mortenson Center receives the portion of revenue generated by enrollment in Mortenson Center-hosted and funded classes including SCD 1, SCD 2, and the SCD Field Practicum while the remainder is shared by CEAE and the other campus departments that enroll our EDC students.

OUTCOMES

The graduate certificate was approved by the Graduate School in December 2010 and the first certificates were awarded to students graduating in May 2011. Since that time, fifty-six students have earned a Graduate Certificate in Engineering for Developing Communities and another fifty students are in process of completing the requirements (because the certificate is not awarded until the student graduates). As shown in table 1, most of the fifty-six certificate holders are currently employed in jobs within engineering industry.

The Mortenson Center has taken a developmental evaluation approach¹¹, which involves “track[ing] and attempt[ing] to make sense of what emerges under conditions of complexity, documenting and interpreting the dynamics, interactions, and interdependencies that occur as innovations unfold” (p. 7). One of the key tenets of this approach is that it is impossible to know how an intervention will function, so the process involves evaluation and rapid feedback that can lead to programmatic changes on an ongoing basis. To date, global engineering concepts have been integrated into coursework offered during students’ freshman and senior years of undergraduate study and at the masters/PhD level. Assessments of EDC Program outcomes have included triangulated data gathering from professional sponsors, university faculty advisors, and students themselves. Both quantitative and qualitative assessment methods target program goals. Collected data are analyzed and debriefed with stakeholders. Results have revealed the development of a breadth of competencies including skill in engineering design, teamwork, and project management. Long-term follow-up interviews have revealed the development of a humanistic orientation in our engineering students centered on developing communities and an interest in incorporating additional EDC work into their engineering career. Some of our recent assessment efforts and outcomes are highlighted here.

Table I

CURRENT STATUS OF EDC CERTIFICATE GRADUATES, 2011-2014

Field of Employment / Other Activity	Number of Students	Percentage of Graduates
Engineering industry	22	39.3
Faculty or staff in higher education	9	16.1
Graduate student	7	12.5
Unknown	7	12.5
Non-governmental organization	5	8.9
Other industry (non-technical)	3	5.4
Peace Corps	1	1.8
AAAS Fellow (current)	1	1.8
Unemployed	1	1.8
Total	56	100.0

Course evaluations

CU-Boulder requires all courses to be evaluated by enrolled students using Faculty Course Questionnaires (FCQs). “FCQs include nine questions and a 1 to 6 response scale...Information from FCQs is used by students for selecting courses and instructors, instructors for improving their teaching, and deans and department chairs for promotion, tenure, salary, and course-assignment decisions”¹². FCQs are administered for all courses during the second-to-last week of each semester, and without the instructor present. For paper-based administrations, students are asked to complete the surveys and turn them in prior to leaving the room. Alternatively, faculty can request that FCQ surveys be completed online. The instructor for SCD 1 and SCD 2 varied which method of FCQ was administered (paper/in class vs. online).

SCD 1 and SCD 2

Between 2008-2009 and 2012-2013, the SCD course sequence received higher average ratings than other courses offered by the CEAE department, the College of Engineering and Applied Science, and the university for the student’s self-reported prior interest in the topic with a 5.36 (sd=0.09) and 5.38 (sd=0.21) out of 6.00, respectively for SCD 1 and SCD 2. However, the instructor ratings for SCD 1 were slightly below departmental peers for four of the five years and intellectual challenge ratings were statistically below departmental peers for three of the five years. For SCD 2, instructor ratings were statistically similar to the department, college, and university averages but the intellectual challenge rating was still below those comparatives. Average FCQ survey return rates were eighty-seven percent for SCD 1 and seventy-eight percent for SCD 2, indicating that the results were reliable, although given the known biases in student

surveys that could be debatable^{13,14,15}. Not surprisingly, return rates were always one hundred percent when conducted via paper forms but response rates varied from fifty-eight percent to eighty-three percent when FCQs were conducted online. Results from these standardized evaluations are publically available at <http://www.colorado.edu/pba/fcq>.

SCD Field Practicum

The practicum course ratings are not comparable across semesters because students enrolled in various sections based on their faculty advisor and occasionally they registered the semester before completing their field work and then received a grade of incomplete until they submitted their final report. This enrollment pattern also meant that no individual faculty member received teaching credit for the practicum course. Therefore, in 2013-2014, the program switched to a process where all practicum students enroll in a single section of the course during the semester following their practicum field work (typically fall semester). In addition to FCQs for this course, the Mortenson Center surveyed students and host organizations. Survey host and student results from the 2013 summer practicum cohort are shown in figures 1 and 2, respectively.

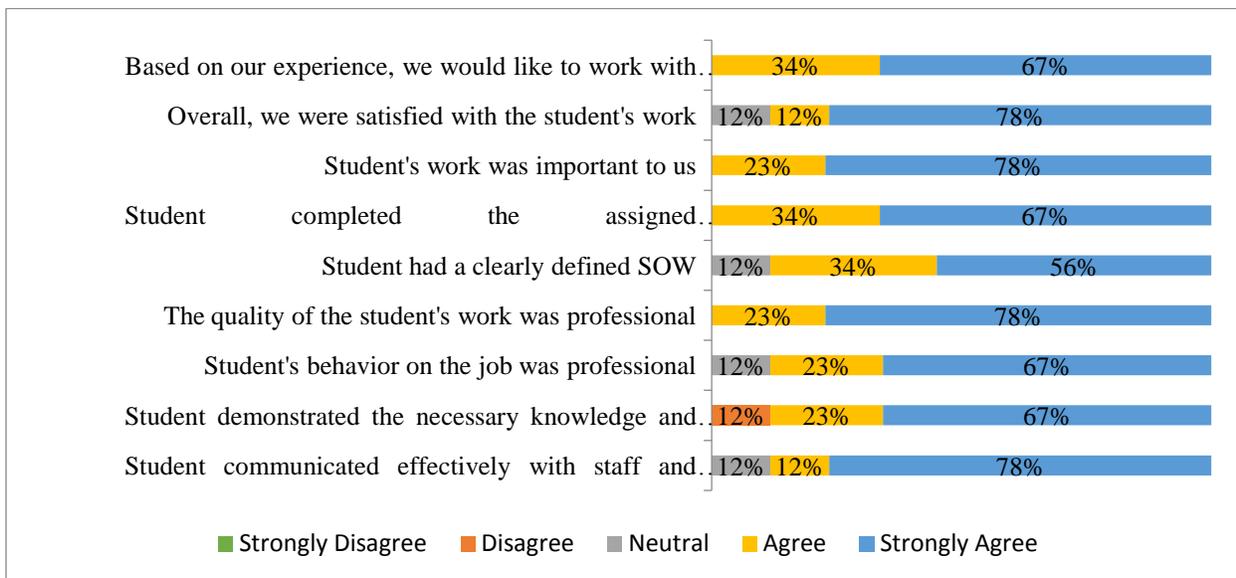


FIGURE 1
 PRACTICUM HOST SURVEY RESULTS FOR SUMMER 2013 ACTIVITIES (N = 11)

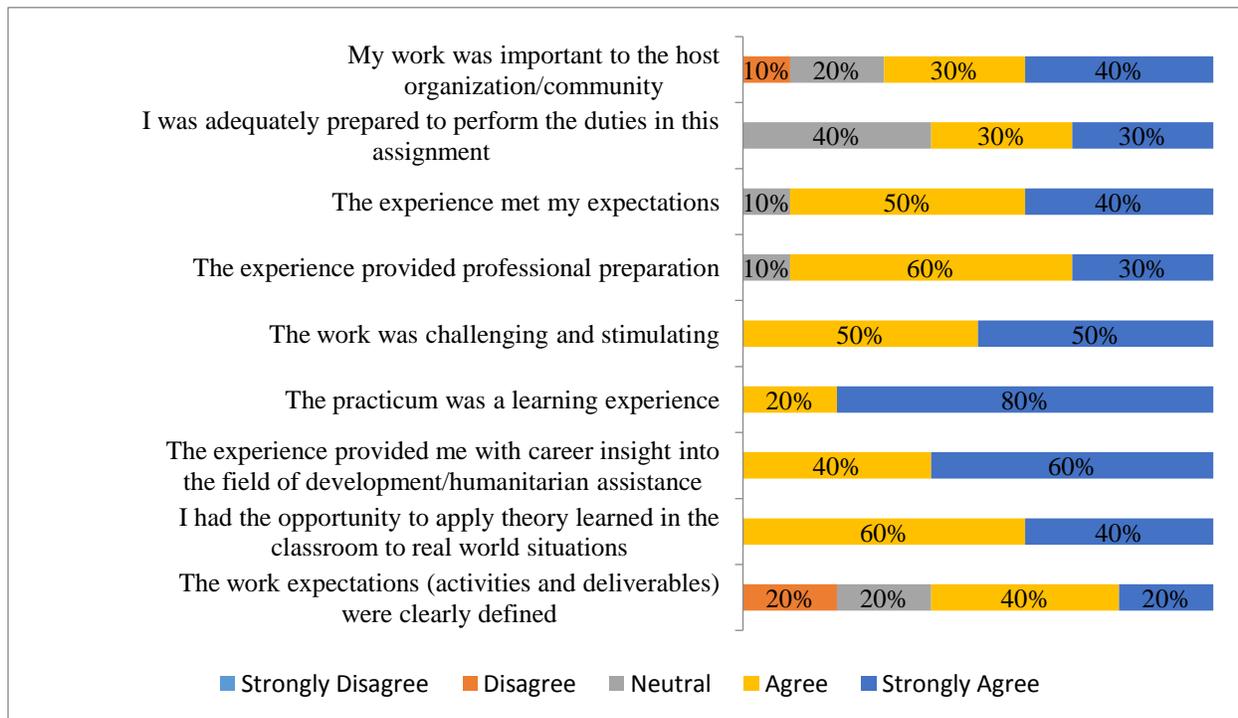


FIGURE 2
 PRACTICUM STUDENT SURVEY RESULTS FOR SUMMER 2013 ACTIVITIES (N = 10)

LESSONS LEARNED

Throughout our history, we have made programmatic changes in response to student, faculty, and practicum host feedback. Over the past ten years we have learned a series of valuable lessons outlined below.

1. As your pool of students change, so should your classes. We started out teaching Environmental Health for Developing Communities, which worked well when all of the students were environmental engineers. However, as the students' areas of studies expanded into building systems, civil infrastructure systems, construction engineering and management, and topics outside civil engineering, the depth in which we were delving into the environmental health became less relevant (from the students' perspectives). Therefore, we maintained a public health perspective but expanded lecture topics into other areas including a systems approach to development¹⁶, the appraisal/design/monitoring/evaluation framework for project implementation², and participatory research methods¹⁷.

2. It is vital to keep expectations realistic, for both faculty and students. In the early years, our leadership committee developed a body of knowledge that looked more like a wish list. Over the span of two development-focused courses and a three-week field practicum we expected our certificate students to reach mastery, competence, or exposure to thirteen different topics ranging from behavior change communication to public health to social entrepreneurship. It took us a while to realize that we could only offer so much information within the few courses and the field experience that we offered. After many hours of conversations with program advisors, we decided to identify our strengths and stick to those. In the end, we recognized that our intention and current capacity allows us to *introduce* engineers to sustainable development, not create

international development specialists. Students interested in additional studies in international development or public health go on to enroll in degree programs in those areas, but the majority of our students who choose to continue their schooling seek PhDs in engineering.

The practicum was another area of our program that required revision of expectations. For two years, the expectation was set that our students would be the resident engineering development *expert* working on behalf of the host organizations. In several instances they were placed in roles where they were expected to increase the capacity of the organization by training individuals without receiving any on-site supervision themselves. Some students rose to the occasion and were able to train host organizational personnel to conduct water testing and GIS mapping to a point where the person was self-sufficient after our student left. Conversely, anecdotal accounts from other students indicated that they were uncomfortable with this role because they did not feel competent enough for organizations to rely on them as *experts*. In subsequent years the program was redesigned to ensure that our students have organizational support for their activities. Students also needed to learn to be comfortable with changes that occurred in the field.

3. Faculty at research-intensive institutions have many competing priorities¹⁸. In order to garner as much support as possible across the CEAE department, we needed to recognize that the practicum experience had become something that was taking as much time as advising a student's thesis without the commensurate credit in the annual review or tenure and promotion process. Faculty advisors reported spending between four and thirty or more hours working with each practicum student to develop or review the technical content of the scope of work or final report. While this may not seem like much, some of the faculty were advising multiple students, making this a burdensome task. Based on faculty requests, in 2013 we modified the scopes of work of our students and removed the expectation that faculty would provide extensive technical advising. At the same time, we moved to a model where a single faculty member would coordinate the practicum program as the instructor of record so that person could report engagement at a level equivalent to teaching a graduate class rather than having six to ten faculty members with one or two independent study students. Currently, an adjunct faculty member with extensive professional experience in global development holds the practicum coordinator role so the question of whether or not this service will count towards promotion and tenure is irrelevant. If we change to having a tenure-track faculty member in this role, however, that individual will have to negotiate how it will count towards annual performance review, promotion, and tenure.

CONCLUSION

At the Mortenson Center at CU-Boulder, we believe that our program provides an essential global perspective to engineers who will work in varying economic contexts worldwide. Our students gain field readiness, a systems thinking perspective, and competence in global development theory, cultural sensitivity, and teamwork skills that extend well beyond what is typically required in traditional civil engineering graduate programs. The National Academy of Engineering, ABET, ASCE, and pillars of engineering industry have already recognized the value of engineering graduates with global perspectives and real world experience beyond the traditional internship or co-op. Yet many faculty, department heads, and deans still have to be convinced that programs such as EDC are worthwhile. We at the Mortenson Center recognize that change in educational philosophy and overall systemic change within higher education are not easy, but we are hopeful that the academy will recognize the value of these types of programs

and develop appropriate faculty reward systems to increase engagement and engender more widespread support.

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