Engineering in Developing Communities: Curriculum Development around Graduate Certificate and Professional MS Programs

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Abstract

The University of Colorado Boulder, USA has an almost 10-year history supporting a graduate education program in Engineering for Developing Communities (EDC). This program interfaces a dynamic engineering graduate curriculum with classes and skills development specifically to bridge this engineering training to applications in lesser developed communities and non-western cultures. The program consists of a four course sequence that focuses on how engineers can work effectively in sustainable community development. Our approach promotes the integration of social, technical, economic, institutional, and environmental activities as the foundation for sustainable development. The classes include training in field work methods, global development theory and the development industry, community assessment methods, and includes an extensive field-based experience. Students are required to synthesize and integrate knowledge acquired in their coursework and other learning experiences, and to apply theory and principles in a situation of professional practice in engineering and international development. This presentation provides an overview of the ongoing EDC graduate certificate and new professional Masters of Science Degree programs at the University of Colorado Boulder. It also presents the results of a survey conducted on past and current students involved in different aspects of the graduate certificate program. The results of the survey were used to evaluate how the EDC educational experience has shaped their graduate experience and careers.

1 Introduction

The Mortenson Center in Engineering for Developing Communities (MCEDC) at the University of Colorado at Boulder (CU Boulder), USA is housed in the Department of Civil, Environmental, and Architectural Engineering in the College of Engineering and Applied Science. The mission of the MCEDC is to *promote integrated and participatory solutions to international development by educating globally responsible engineering students and professionals to address the problems faced by developing communities worldwide*. The Engineering for Developing Communities program (EDC) was founded in 2003. Thanks to a generous gift from the Mortenson Family and M. A. Mortenson Company in 2009, the program's offerings expanded significantly and EDC grew into an education, research, and

outreach center called the Mortenson Center in Engineering for Developing Communities (MCEDC). An overview of the EDC program is presented in Figure 1.

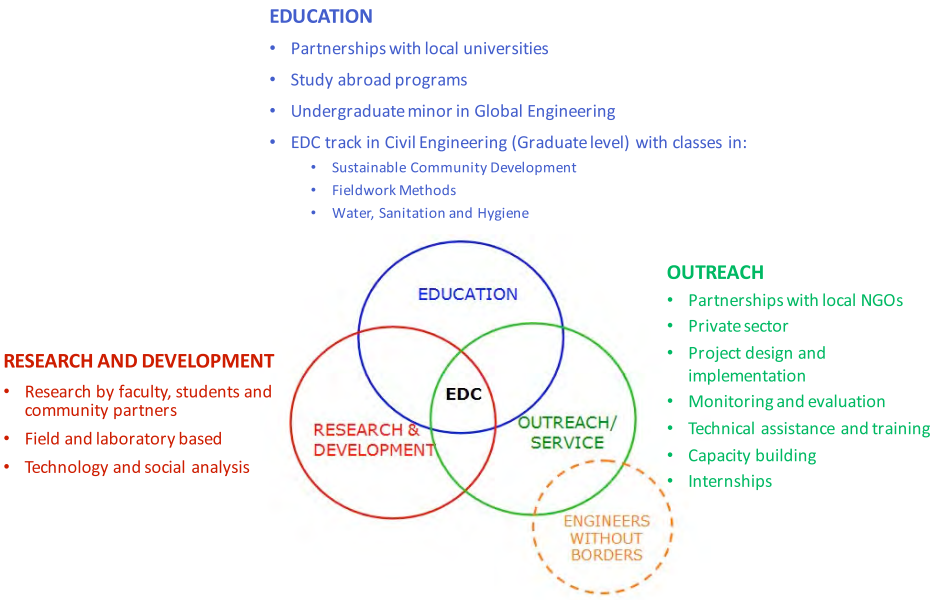

Figure 1: Overview of the Engineering in Developing Communities (EDC) program at the University of Colorado.

MCEDC offers a 4-course graduate certificate program and has recently developed curriculum for a Professional Masters of Science Degree Program (MS-PMP). A Masters of Engineering curriculum is under development. This paper presents the basic course sequence and learning objectives of the certificate program courses and the MS-PMP course structure and body of knowledge. It also presents the results of a survey conducted on past and current students involved in different aspects of the graduate certificate program. The results of the survey were used to evaluate how the EDC educational experience has shaped their graduate experience and careers.

2 EDC Graduate Certificate Program

The EDC Graduate Certificate consists of four classes (12 semester credits)

- Sustainable Community Development (SCD) 1 (Fall)
- Sustainable Community Development (SCD) 2 (Spring)
- Field Methods for Practitioners (Spring)
- Sustainable Community Development Field Practicum (Summer)

This course sequence is designed for graduate engineering students and others who plan to work on human development projects in developing communities. The MCEDC 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.

Sustainable Community Development 1 is designed to introduce students to the complex and inter-related nature of the development industry, providing 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 understand how their work in development affects, and is affected by, other development sectors and agendas. Different perspectives and opposing views on hot topics such as aid effectiveness, business at the bottom of the pyramid, subsidies, feeding the 9 billion, and microfinance are examined. As a survey class, this is an introduction intended to create comfort talking across development discourses and sectors, and to create familiarity with the thought leaders in the field(s) so that students can create more appropriate, comprehensive, and innovative development practices and research programs.

Sustainable Community Development 2 covers the principles, practices and strategies of appropriate technology as part of an integrated and systems approach to community-based development. The goal of this course is to examine the role of engineering in achieving transformative and sustainable development. Fundamental, cross-cutting issues facing the engineer/development practitioner are explored including: migration and displacement, gender, religion, climate change, conflict, food security, innovation, and urban resilience. These issues are introduced within the context of multidimensional strategies and solutions within selected engineering-related sectors, e.g. post-disaster reconstruction, energy, transport, housing, agriculture, environment, global health, drinking water supply, sanitation, and water resource management. Multi-sectoral solutions that successfully deliver development results are explored.

Sustainable Community Development Field Practicum is a learning experience carried out in partnership with various international development-oriented organizations that serve as host to the students. The practicum helps provide a true understanding of sustainable development engineering by engaging students in a significant field-based experience. The practicum requires students to synthesize and integrate knowledge acquired in EDC coursework and other learning experiences, and to apply theory and principles in a situation that approximates some aspect of professional practice in engineering and international development. The practicum is designed to help students:

- Explore the meaning and importance of global engineering practice
- Use field methods including community-based needs assessment, monitoring and evaluation, and household surveys
- Assist in the design of an engineering intervention addressing some aspect of development, e.g., water supply, housing, energy, etc.
- Experience major implementation issues, common barriers to implementation, and strategies for minimizing barriers to implementation
- Identify and observe strategies for scaling up and sustaining engineering solutions at the community level
- Apply planning, monitoring and evaluation skills to real-world problem solving; and
- Enhance practice skills of leadership, effective teamwork, and the mastery of competencies in global engineering

Over the past 5 years, MCEDC has placed almost 80 students in 60 organizations, including the ones highlighted in Figure 2 below.

Figure 2: Some of the organizations that have supported the SCD Field Practicum program.

Fieldwork Methods introduces methods and models that can be employed in program development and deployment. Examines the applications of participatory research, value-centric design, program scale, cross-disciplinary work, and appropriate monitoring and evaluation. The goal of this course is to build student confidence around existing evaluation toolkits and methods, while advancing multi-method approaches to designing and analyzing engineering initiatives.

3 Professional Masters of Science Degree Program (MS-PMP)

The MS-PMP is a new professional degree recently developed to provide a curriculum to emphasize the practical aspects of engineering for developing communities.

The course sequence is focused in the areas of:

1) Core Courses in Sustainable Community Development Theory & Practice (9 credits)
2) Competencies in Data Analysis, Systems Thinking, and Project Management (9 credits)
3) Focus Area Options (9 credits) in
   - Environmental Health
   - Construction
   - Energy
   - Engineering Management
   - Policy
4) Field Practicum (3 credits)

EDC CORE COURSES (9 CREDITS)	COMPETENCY AREAS (9 CREDITS)
FOCUS AREA (9 CREDITS)	FIELD PRACTICUM (3 CREDITS)

Details of the program are provided here:

[http://www.colorado.edu/mcedc/node/312/attachment]

At the end of the MS-PMP program, graduating students will have acquired:

- The basic knowledge, attitude and skills to be able to develop integrated and participatory solutions for community development projects in different contexts and at different scales.
- The capacity to understand and operate in an international context as part of cross-disciplinary teams
- An appreciation of the technical and non-technical issues at stake in development projects.

4 Analysis of the EDC Program

In 2015, MCEDC decided to conduct an internal and external analysis of the EDC program to better understand strengths and areas requiring improvement within the program. A survey questionnaire was administered to past, current, and incoming students to the EDC program in the Fall of 2015. Incoming students were students beginning the EDC program in academic year 2015-16. Current students had begun the MCEDC program in earlier semesters but had not yet received their certificate. Past students had previously completed the EDC certificate. Sixty people responded to the survey, however, not all questions required forced responses, thus the sample size for questions varied. Table 1 shows the sample sizes for the different groups.

Table 1: Sample Sizes for Groups Responding

Group(s)	**Sample Size**
Past	31-32
Current	17-18
Incoming	9-10
Past & Current	48-50
Incoming & Current	26-28
All	57-60

The survey covered a range of topics, including how they heard about the program, other programs that they considered, why they chose to enroll in EDC and their ratings of satisfaction and importance of various elements of the program.

Students generally chose to enroll in the EDC graduate certificate program because of their interest in engineering for development and because they want careers in the development field. Most respondents had previous development experience, with the most common experience being from Engineers Without Borders-USA (EWB-USA). Of the survey respondents, Civil Engineering was the most common undergraduate major, followed by Environmental Engineering. Most students learned about MCEDC through the website and considered

programs at University of California-Berkeley, Stanford University, University of Washington, and Peace Corp programs.

Past and current students were asked to "Please indicate your *level of satisfaction* with the following aspects of your graduate experience in EDC" based on a five-point scale from 1-Very Dissatisfied to 5-Very Satisfied and "Please indicate your *level of importance* with the following aspects of your graduate experience in EDC" on a four-point scale (1: Not Important; 2: Important; 3: Very Important; 4: Extremely Important). For past students, this set of questions was forced-response. However, for current students this set of questions was not forced-response, in case any of the current students had not yet experienced any aspects of the program. Funding was included on the list of aspects of the program for current, but not past, students.

Based on Likert scale responses, Faculty, SCD 1, and Practicum Experiences were the most satisfactory aspects of the MCEDC program. Based on open-ended responses, Fellow students, Faculty, and Classes were the most satisfactory, or enjoyable parts of the program. Career Guidance, Job Search Support, Research Opportunities, and Funding were least satisfactory.

Practicum Opportunities, Practicum Experiences, and Faculty were rated as the most important aspects of the program. Facilities were rated least important. Due to its high importance, the practicum was subject to both praise and constructive criticism.

Charting the results of the importance and satisfaction questions against each other can provide even more insight into the state of the program. In Figure 3, Satisfaction and Importance are the x- and y-axis, respectively. In this manner, the aspects of the program can be divided into four quadrants: High Satisfaction, High Importance; High Satisfaction, Low Importance; Low Satisfaction, Low Importance; and Low Satisfaction, High Importance.

Practicum Experiences, Faculty, the SCD 1 course, and Interpersonal Support ranked highly in both satisfaction and importance, indicating that the MCEDC was doing a good job in these critical areas and should emphasize these aspects during recruitment. On the other hand, Funding, Practicum Guidance, Career Guidance and Job Search Support ranked high for importance but low for satisfaction. As a result, the MCEDC decided to focus on improving these areas. Areas where there was low satisfaction and low importance included SCD 2, Overall Curriculum, Research Support, and Facilities.

To respond to these needs, the MCEDC is trying to identify additional sources of funding for students. In addition, the MCEDC developed sessions where students could better prepare for their practicum and receive guidance from former students, and a session for reflection by returning practicum students. For career guidance and job search support, the MCEDC subscribed to Devex, held a session featuring university alumni working in development, and invited current development workers into SCD 2 to discuss their careers and career development.

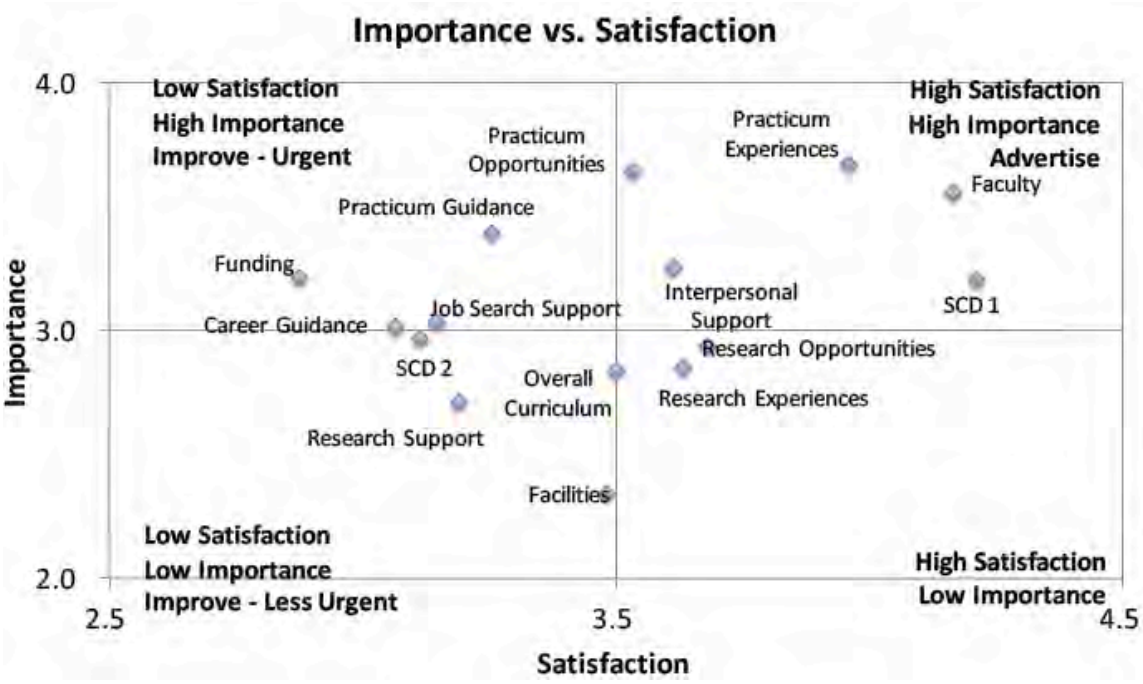

Figure 3: Competitive analysis of the EDC program indicating alumni and student satisfaction with aspects of the EDC program. SCD1, SCD2 and the Practicum are three of the core courses in the certificate program.

To analyze our coursework offerings and competitive advantage in relation to other programs, the MCEDC also undertook an external analysis of other programs in development and humanitarian engineering. That analysis, while not presented here, helped us to recognize our unique position and focus in engineering for development, allowed us to analyze our course content in comparison to other programs, and helped us focus on other areas of improvement which included identifying development-related journals, updating our website, identifying graduate fellowship opportunities for students, and identifying language learning sources.

5 Conclusion

The 10-year educational experience of CU Boulder's EDC program has validated both the pedagogical placement of such a program in an engineering curriculum and the strong and sustained desire of students to include this type of program in their engineering educational goals. Indeed, such a program likely draws non-traditional students into the engineering discipline. Past and current students involved in different aspects of the graduate certificate program reported that Faculty, Fellow Students, SCD 1, and Practicum Experiences were the most satisfactory aspects of the MCEDC program. Career Guidance, Job Search Support, Research Opportunities, and Funding were least satisfactory. Practicum Opportunities, Practicum Experiences, and Faculty were rated as the most important aspects of the program. Facilities were rated least important. These results were used to target areas for program investment and improvement.