Creating an Engineering for Developing Communities (EDC) Emphasis in Environmental Engineering

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Abstract
A comprehensive program in Engineering for Developing Communities (EDC) is being created at the University of Colorado at Boulder (CU). As part of the program, an EDC option in the Environmental Engineering (EVEN) B.S. degree is being proposed. Given the success of the Engineers Without Borders (EWB) outreach and service program, it is expected that student interest in the EDC option will be significant. At a workshop on "Integrating Appropriate-Sustainable Technology and Service-Learning in Engineering Education" held at CU on September 27-29, 2004, participants were surveyed on existing courses and programs at their universities that are relevant to EDC. A description of the proposed curriculum, option courses and technical electives for the proposed EDC emphasis in EVEN are provided. Relevant social science and humanistic electives are recommended. The information will provide a foundation for other universities interested in an EDC program, although it will take a number of years before outcomes assessments are available.

Background

In the next two decades, almost 2 billion additional people are expected to populate the Earth, with 95% of that growth taking place in developing or under-developed countries. This will create unprecedented demands for energy, food, water, materials, waste disposal, health care, environmental cleanup, and infrastructure. Since such global problems are not usually addressed in engineering curricula in the US, we do not have engineering schools that educate engineers to address the needs of the most impoverished people on our planet, many of them living in industrialized countries. This is unfortunate as it is estimated that 40% of the world's population lack adequate sanitation, 20% lack clean water, and 20% lack adequate housing.[1]

Furthermore, engineers have a critical role to play in addressing the complex problems associated with refugees, displaced populations, and large-scale population movement worldwide resulting from political conflicts, famine, land shortage, or natural hazards. According to the World Health Organization (WHO), currently 1.8 billion people (30% of the world's population) live in conflict zones, in transition, or in situations of permanent instability.

It is clear that the pedagogy of engineering education needs to change (or even be reinvented) in order to address the challenges associated with the global problems mentioned above. Today, there is still a strong disconnect between what is expected of young engineers in engineering firms, the magnitude of the problems that we are facing in our global economy, ABET's

engineering criteria (criteria 3 and 4 for instance)[2], and the limited skills and tools traditionally taught in engineering programs.

Engineers of the future will have to be educated to make intelligent decisions that enhance the quality of life on Earth rather than endanger it. They will also be called to make decisions in a professional environment where they will interact with others from many technical and non-technical disciplines.

Workshop and Review of Other Programs

A workshop on "Integrating Appropriate-Sustainable Technology and Service-Learning in Engineering Education" was held at the University of Colorado at Boulder (CU) on September 27-29, 2004. More than 70 participants from around the world discussed how to best educate engineers to meet these challenges. The workshop was sponsored by a department level reform grant from the National Science Foundation (NSF) and the National Collegiate Inventors & Innovators Alliance (NCIIA). One focal point of the workshop was a review and development of an educational program termed Engineering for Developing Communities (EDC).

EDC related undergraduate (Table 1) and graduate (Table 2) courses and programs are currently active at other Universities, including initiatives across the fields of engineering, science, and humanities. A brief summary of selected programs is provided below.

Table 1. Review of Existing Bachelor's Degree Programs Relevant to EDC

University, Program, website URL	Brief Description
Colorado School of Mines. Dept. Civil Engineering, Liberal Arts and International Studies. *www.mines.edu/academic/epics/*	The CVEN EPICs course is a multidisciplinary and vertically integrated course program with opportunities for service learning. Courses incorporate sustainability; values, society & decisions; environment, resources, science & technology; international studies.
University of Dayton, OH. Engineering in Technical, Humanitarian Opportunities of Service (ETHOS) *quickplace.udayton.edu/ETHOS*	ETHOS provides international service internships as well as through collaborative research and hands-on classroom projects that support the development of appropriate technologies for the developing world.
Georgia Tech. School of Civil & Environmental Engineering. *www.ce.gatech.edu/*	Courses include: Lab for Sustainable Design & Construction; Sustainable Issues for Design; Environ Conscious Design & Manufacturing; Environmentalism & Ecocriticism; Technol & Policy; World Food, Population & Env.
Univ. Illinois Urbana-Champaign International Programs in Engineering *www.engr.uiuc.edu/international/*	Provides information about study abroad, work abroad and other international opportunities
Kalamazoo College, MI. International Sustainable Development Studies Inst. *http://www.isdsi.org*	SDSI's People, the Environment and Development study abroad program in Thailand allows college and university students to examine critical issues in globalization, sustainability, and cross-cultural learning.
Marquette Univ. Dept. Civil & Environ Engrg; Health, Environment, and Infrastructure in Latin America (HEILA) Program. www.eng.mu.edu/	Students perform 2-week service learning projects in El Salvador, Guatemala, or Honduras while learning about the region's history, culture, and politics. Students explore their profession and its relationship to society in the US and abroad.

pages/Home/Departments/Civil_Environmental /International_Service_Learning	
University of Massachusetts, Lowell. Solar Energy Engineering; Center for Sustainable Energy *energy.caeds.eng.uml.edu/*	Seeks to improve energy efficiency in end-use sectors and increase the diversity of energy resources consistent with an economically and environmentally sustainable future. Combines undergraduate and graduate education, research, public service, service-learning, and public education.
Massachusetts Institute of Technology. Dept. Civil & Environmental Engineering; Earth Systems Initiative; International Development Initiative. *web.mit.edu/esi/*	D-Lab is a full year course including a January field trip to a developing area. The course frames international development and appropriate technology featuring technical lectures, hands on work and language elements. Project teams are led by international students in partnerships with various organizations. Projects are implemented in the summer field component of the course.
Messiah College, Grantham, Pennsylvania. Dept. Mechanical Engineering. *www.messiah.edu/acdept/depthome/engineer/*	A course in global sustainability identifies scientific, environmental, economic, social/ethical and technological aspects. Topics include sustainable agriculture, health care, construction, institutions, communities; renewable energy systems, energy and resource conservation**.** Students and faculty cooperate with Society for International Ministries (SIM) on Service Learning Projects in West Africa.
Michigan Tech, Houghton, MI. *www.cee.mtu.edu/projects/projects.htm*	Undergraduates can participate in international design projects in a course designed to emulate the work of a design firm in industry while providing a class experience that combines field construction with an engineering design project to benefit people of the developing world.
University of Pittsburgh, PA. Mascaro Sustainability Initiative; Department of Civil and Environmental Engineering. *www.engr.pitt.edu/msi/*	Offers undergraduate research and courses in sustainability and development. The Green Construction and Sustainable Development Program offers a grassroots approach to project planning and design; political economy of development; and skills in development.
Purdue University. Engineering Projects in Community Service (EPICS) Program. *epics.ecn.purdue.edu/*	Vertical, multidisciplinary teams define, design, build, test, deploy, and support real systems, and bring affordable engineering expertise to community service organizations. Students participate for up to 7 semesters and long-term projects span several semesters. Lecture Series covers project management, team dynamics, entrepreneurship, ethics, diversity, communication, and the community.
Rowan University. RU Community Partnership; Engineering Clinic. *www.rowan.edu/colleges/engineering/departments/civilenvironmental/cee_cl.htm#cp*	A required course sequence spanning 4 years that emphasizes engineering practice and professionalism in a multidisciplinary setting; combines hands-on learning, composition and rhetoric, and culminates in 4 semesters applying engineering principles to emerging technologies.
Temple University Ambler. The Center for Sustainable Communities. *www.temple.edu/ambler/csc/*	Educational programs, interdisciplinary research, and a community resource to address issues of the environment and sustainability. Faculty from landscape architecture, geology, geography, urban & suburban studies, land use policy, environ economics, environ justice, chemistry...
Tufts University. Dept. Civil and Environmental Engineering. Education	College of Citizenship and Public Service is a university-wide initiative to promote active citizenship. Aims are

for Active Service. *uccps.tufts.edu/*	identifying, generating, and supporting students, faculty, staff, alumni and community partners who develop creative, effective approaches to active citizenship at the university and in communities around the world.
Worcester Polytechnic Institute, MA. Interdisciplinary and Global Studies. *www.wpi.edu/Academics/Depts/IGSD/*	Students have required projects relating science and technology to real needs. Over 35 years of outcomes based education.
Kingston University London, UK. School of Earth Sciences and Geography. *www.kingston.ac.uk/esg/*	The BS in Earth Systems Science takes a holistic approach by drawing on Geology, Geography and Environmental Science.

Table 2. Review of Existing Graduate Degree Programs Relevant to EDC

University, Program, website	Brief Description
University of Colorado - Boulder. Dept. Civil, Environ & Arch. Engrg. bechtel.colorado.edu/web/grad/environ/ms-guide.htm	MS degree has an area of emphasis in Environmental Engineering for Developing Communities (see further discussion in this paper)
University of Massachusetts, Lowell. Energy Engineering. *energy.caeds.eng.uml.edu*	MS in Energy Engineering; students may specialize in any area in the college related to the energy field. All students must take the following core courses: energy engineering workshop; system dynamics; advanced transport phenomena; fundamentals of solar utilization; solar systems engineering.
Michigan Tech, Houghton, MI. Master's International Program. *www.cee.mtu.edu/peacecorps/*	3 programs combine graduate work with service in the U.S. Peace Corps: Civil & Environmental Engineering, Geology/Geological Engineering, Forestry. A graduate certificate in sustainability recognizes the following areas: i) policy, societal, and economic systems, ii) environmental systems and iii) industrial systems.
Rice University, TX. Dept Civil & Environmental Engineering; Environmental and Energy Systems Institute (EESI). *eesi.rice.edu/education*	Provides a professional science Masters program; includes the sustainable development Pinedale initiative and Shell Center sustainability internships.
University of Cambridge, UK. Engineering Department, Centre for Sustainable Development. www-g.eng.cam.ac.uk/sustdev/mphil.html	MPhil in Engineering for Sustainable Development program addresses fundamentals of environmental science, economics and social issues and examines suitable evaluation frameworks and methodologies for assessing the sustainability of engineering activities at every stage of planning, design, implementation and disposal.
Cranfield University, UK. Institute of Water and Environment. *www.silsoe.cranfield.ac.uk/iwe/*	While addressing generic issues, the course allows specialization that enables students to pursue focus in five specific sectors of water management: environmental water management, community water supply, advanced irrigation, water and society, and water for sustainable agricultural development.
Kingston University London, UK. School of Earth Sciences and Geography. *www.kingston.ac.uk/esg*	MSc in Environmental and Earth Resource Management is intended to provide students with a holistic and multidisciplinary education and training in the understanding, management and sustainable development of

	our natural resources.
The Open University. UK. *www3.open.ac.uk/courses/bin/p12.dll?Q01D21_6_48*	MSc in Environmental Sustainability including extensive sustainable development coursework and modules spanning: principles of environmental sustainability; climate change; ecology; water resources; environmental impact assessment; management of sustainable development; land use environmental interactions; participation in policy and planning; rural development; waste reduction and recycling.
School for International Training (SIT). Master of Arts in Sustainable Development. *www.global-partnership.net/*	Education in development, program planning, proposals, policy advocacy and training. The role of non-profits, NGOs, and other civil society institutions (CSI) as catalysts and providers of development programs and influencing public and corporate policies. The Global Partnership educates the leaders and staff of NGOs and CSIs around the world. The accredited school offers a postgraduate diploma in NGO Leadership and Management; and a Joint Diploma-Master's Degree. Programs build on participants' prior development work experience. New learning is grounded in practice through which participants directly contribute to strengthening the capacity of their own organizations
University of Southampton, UK. MSc in Engineering for Development. *www.soton.ac.uk/PostgraduateTaught/EngineeringSciencesandMaths/EngineeringforDevelopment/*	Provides the skills to plan and develop integrated infrastructural facilities in partnership with poor communities in developing countries; includes water supplies, sanitation, transport, buildings, energy and agricultural development. The program provides an understanding of basic economics and relevant social issues in community development, and offers both theoretical and practical training in the design, construction, operation and maintenance of facilities.
University of Surrey, UK. Center for Environmental Strategy; Environ Technology. *www.surrey.ac.uk/eng/ces/research/lcsa.htm*	The MSc in Sustainable Development provides interdisciplinary training that will enable students to be fully conversant with the various constituents of sustainable development.
Institute of International Education and Global Engineering Education Exchange Institute for Village Studies, Harbor, WA. *www.iie.org/*	IIE is a global higher education and professional exchange agency. IIE designs and implements programs of study and training for students, educators, professionals and trainees from all sectors with funding from government agencies, foundations, and corporations. These programs include the Fulbright and Humphrey Fellowships, administered for the U.S. Department of State, and the People, Energy, and Development program administered for USAID.
Solar Energy International in Carbondale, CO. International Volunteers in Environment-ally Sustainable Technologies (INVEST). *www.solarenergy.org/programs/INVEST/*	SEI provides education and training to decision makers, technicians and users of renewable energy sources. SEI also provides the expertise to plan, engineer and implement sustainable development projects.

CU Program in Engineering for Developing Communities

There are three academic elements to the CU EDC program. We have recently instituted an EDC track in the M.S. graduate environmental engineering program. We are proposing to implement

an EDC option in the undergraduate environmental engineering B.S. degree (EVEN), which is the focus of this paper. We are also proposing to integrate Earth Systems Engineering (ESE) concepts which include EDC materials into the undergraduate Civil Engineering courses, which is the focus of another paper.[3] Our goal is to offer an EDC curriculum option to undergraduate EVEN students starting in fall 2005.

The overall mission of CU's EDC program is to educate globally responsible students and professionals who can offer sustainable and appropriate technology solutions to the endemic problems faced by developing communities at local, national and global levels. The challenge is the education of engineers:

- Who have the skills and tools appropriate to address the issues that our planet is facing today and is likely to face within the next 20 years;
- Who are aware of the needs of the developing world; and
- Who can contribute to the relief of the endemic problems of poverty afflicting developing communities worldwide.

The EDC program at CU Boulder assists in educating a new generation of engineers through meaningful course work, research and outreach/service that respond to the global needs of our planet. The program will serve as a blueprint for the education of engineers of the 21st century who are called to play a critical role in contributing to peace and security in an increasingly challenged world.

The EDC program is interdisciplinary and involves engineering and non-engineering disciplines (business, sociology, history, etc.). It is being developed in partnership with a wide range of academic and non-academic groups including: (1) universities, technical, vocational schools, and individuals in the US and in developing communities; (2) engineering companies; (3) humanitarian organizations; (4) NGOs; and (5) interested individuals. The program is being designed to address a wide range of issues such as water provisioning and purification, sanitation, health, power production, shelter, site planning, infrastructure, food production and distribution, communication, and jobs and capital for various developing communities including villages, refugee settlements, etc. Finally, the components of the new program include *outreach and service*, *research and development*, and *education*.

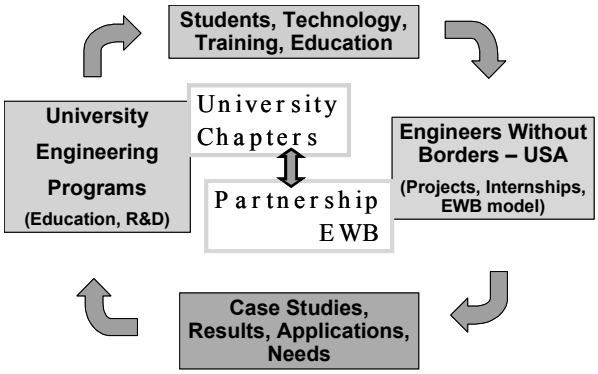
The graduate program in EDC as a special track in the MS/PhD program in environmental engineering in the Civil, Environmental and Architectural Engineering Department at CU Boulder started in spring 2004 (http://civil.colorado.edu/web/grad/environ/index.htm). The curriculum includes three new requirements in public health, appropriate technology, and sustainability, as well as basic environmental engineering courses. Graduate students make take a thesis or non-thesis approach. The non-thesis approach utilizes a two-semester service project with both planning and in-field service components.

Outreach and Practice - Student Learning and Work in Developing Communities

The outreach and practical component of the new program is well underway in the College of Engineering at the University of Colorado at Boulder with the launching in fall 2001 of a new activity called Engineers Without Borders. This new activity was created as a follow-up to fieldwork in May 2001 when Prof. Amadei took ten undergraduate students from the Department

of Civil, Environmental and Architectural Engineering to help with the construction of a water distribution system for a small Mayan village in southern Belize.

The work in Belize led to the creation of a non-profit 501 (c)(3) tax-exempt corporation called Engineers Without Borders™ – USA (www.ewb-usa.org). The first chapter of EWB-USA was formed at the University of Colorado at Boulder in late fall 2001. Three years later, EWB-USA has 80 student and professional chapters across the US and involves 1700 engineering students, faculty and professional engineers.



In general, EWB-USA is dedicated to helping disadvantaged communities improve their quality of life through implementation of environmentally and economically sustainable engineering projects, while developing internationally responsible engineering students. Most EWB-USA projects involve the design and construction of water, sanitation, and energy systems. These projects are initiated by, and completed with, contributions from the host community, which is trained to operate the systems without external assistance. All EWB-USA projects are designed to be appropriate and self-sustaining. They are conducted by groups of engineering students under the supervision of professional engineers and faculty. The students select a project and go through all phases of conceptual design, analysis and construction during the school year with implementation during breaks and the summer months. By involving students in all steps of the projects, the students become more aware of the social, economic, environmental, political, ethical, and cultural impacts of engineering projects.

EWB-USA has had projects in 35 different countries. In 2004 alone, more than 100 students from various US schools have been involved in projects in Mali, Mauritania, Senegal, Thailand, Haiti, Belize, Nicaragua, Afghanistan, and Peru. Detailed description of these projects can be found on the web (www.ewb-usa.org).

This figure depicts the important symbiotic relationship that is being sought between EWB-USA and its university chapters. University engineering programs focus on academic student education, and research. These activities are complemented by field experience opportunities that result in case studies, practical applications responsive to local needs, contributions to local development, and multi-disciplinary practical experience that feeds back into meeting academic requirements.

All projects conducted by the CU Boulder chapter of EWB-USA have been financed by small grants from the University of Colorado at Boulder (Outreach Committee; Engineering Excellence Fund; Undergraduate Research Opportunity Program) and private donations. During academic year 2002-2003, a total of 25 engineering students participated in the projects.

Research and Development – Appropriate and Sustainable Technology
The outreach component of the EDC program has revealed that there is an urgent need to

develop appropriate technologies that are more specific to the developing world. Appropriate technology is usually characterized as being small scale, energy efficient, environmentally sound, labor-intensive, and controlled by the local community. It must be simple enough to be maintained by the people using it. Furthermore, it must match the user and the need in complexity and scale and must be designed to foster self-reliance, cooperation and responsibility[4].

The field of appropriate technology is not usually addressed in engineering education, as it is often perceived as "low tech" and unimportant. Studies by the World Bank and the United Nations have shown, however, that appropriate technology is critical to bringing more than 3 billion people out of poverty.

Research at CU targets the *testing and improvement of existing technology*. A wide range of appropriate technology systems already exist on the international market. Many of these systems have not been tested under different external conditions (temperature, humidity, etc.) and are poorly documented. Research with undergraduates through college programs such as the Discovery Learning Apprenticeship explores existing technologies, identify their range of applications and propose necessary modifications. New technologies must be developed to meet the challenging needs of the developing world. Examples of on-going studies being conducted by students and faculty in the Department of Civil, Environmental and Architectural Engineering at the University of Colorado at Boulder include:

- Pathogen removal by the Filtron, a colloidal silver lined permeable ceramic point-of-use drinking water filter;
- Prototype rope and solar pumps for water wells and ram pumps;
- Pesticide removal and drinking water treatment methods;
- Arsenic removal technologies;
- Attenuation of pathogens from latrines to nearby water sources;
- Solar water pasteurization;
- Improvement of existing earthenware cooling techniques to provide storage of food and maintain the viability of vaccines at low cost;
- Production of biofuel and biomass;
- Solar, wind and hybrid systems for energy production;
- Solar heating, cooling, and cooking systems;
- PV computer systems;
- Seismic design and performance of traditional buildings (adobe, earth, stone, etc.)

These are limited examples of a wide range of technologies that could be further developed in a university environment and be of great benefit to the developing world.

Education – Teaching Sustainability and Appropriate Technology

The education component of the EDC program is designed to include new courses as well as existing courses at the University of Colorado that emphasize issues critical to the understanding of the developing world. The objective is to provide an opportunity for engineering undergraduate students to enroll in a regular program of study in the College of Engineering and to take at the same time a limited number of their required socio-humanistic electives, technical

electives and independent study from a pool of courses emphasizing engineering for developing communities.

At CU, EVEN is an ABET-accredited cross-departmental B.S. degree offered by combining courses from chemical, civil, and mechanical engineering. Over the past 3 years, about 9 to 16 students have graduated with this degree each year. Students are currently given an opportunity to select 1 of 4 emphasis areas – water/wastewater treatment, air pollution, ecology, or chemical processing --- for their degree, each requiring four option courses comprising the emphasis, and four technical electives. The curriculum is shown in Table 3 below. Underlined courses in gray boxes already include or will be modified to include EDC material. Some of these courses already include content related to EDC (*) and modifications to include EDC content are proposed in others (+). Courses in *italics* are proposed changes in the EVEN core.

Table 3. Block Diagram of the EVEN Curriculum at CU.

Sem	Cr	**Environmental Engineering B.S. Degree – EDC Option**					
1	16	Calculus I	Chemistry for Engrs & Lab	Intro to Environ Engrg + (1 cr)	Intro to Engrg Computing		SS&H elective
2	17	Calculus II	Physics I	* Freshman Engrg Projects		Tech Elective	SS&H elective
3	15	Calculus III	Physics II	Experimental Physics	Material & Energy Bal		SS&H elective
4	16	Diff Eqn & Lin Algebra	Physical Chemistry	Solid Mechanics	Env Engrg Fund. *		SS&H elective
5	17	Probability & Statistics	*Aquatic Organic Contaminants +*	Thermodynamics *AREN 2100*	** Intro to Public Health*	*Fluid Mech & Heat Trans*	Communica-tions
6	17	Numerical Methods	*Tech Elective*	Water Chem & Laboratory*+	*Water & WW Tmt*+*		*Sustainabilty & the Built Environ **
7	15	Environ Engrg Processes *	Environ Engrg Microbiology *	Environ Engrg Design *	*Engineering Economics+*	Tech Elective/ Sr Thesis	
8	15	Option course	Air Pollution Control	**** EDC Projects***	Option course	Tech Elective/ Sr Thesis	

SS&H = social science and humanities

Examples of EDC content in existing required courses:

- GEEN 1400 Freshman Projects.
  In fall 2002, Prof. Amadei introduced a 3-credit hour design course for undergraduate students (engineering freshmen) with emphasis on appropriate technology and on the use of such technology in solving water, sanitation, energy, and health problems in developing communities. This course is required for freshman in EVEN, although they are free to take any of a number of different sections of the course that are offered. To date, the course has been offered twice through the Integrated Teaching and Learning Laboratory (http://itll.colorado.edu). The course gives students a thorough understanding of some of the most common and important technologies being introduced in small-scale

community developments. 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 include: production of biodiesel; production of biomass from bananas; generation of electricity using water turbines; water heating for refugee camps; water filtration systems; solar refrigeration; and solar water pumping.

- CVEN 4434 Environmental Engineering Design
  Prof. Bielefeldt; has included 1 or more EDC projects in the course for the past 3 years. Since these projects are real needs in various communities, this is a service learning (SL) component to the curriculum. Examples of recent projects are: (1) Upgrade existing over-loaded evaporative wastewater treatment lagoons for Jemez Pueblo, New Mexico (Fall 2003); (2) Replace existing individual cesspools and septic systems in the community of Guadalupe, CO (Fall 2002); (3) Provide reliable water and sanitation for a primary school in Jalapa, Nicaragua (Fall 2002); (4) Provide treatment to achieve safely potable water for San Pablo, Belize (Fall 2001); (5) Provide treatment of animal manure to safely use as a soil amendment for growing human food crops in Mayapan, Belize (Fall 2001).

  Prof. Bielefeldt received a grant from the CU Service Learning Program to expand SL in this course. Of particular importance is having the students reflect on their experiences[5,6]. Future plans include expanding the multi-disciplinary nature of the course, such as including Environmental Studies and Business majors in the course. Currently, the multi-disciplinary nature of the course is limited to undergraduate EVEN students, undergraduate CVEN students, and recently added (first time in Fall 2003) CVEN graduate students.

The new emphasis in EDC is proposed with the following additional required and optional courses:

- CVEN 3424 Water/Wastewater Treatment
  Basic water and sanitation issues are critical to all communities, and as such this introductory course is a requirement of the curriculum; new content on appropriate technologies for decentralized treatment and developing communities will be added (and are outside the scope of most similar courses)

- Introduction to Public Health/Environmental Health for Developing Communities
  Emphasizes sustainable approaches for improving public health and the importance of interdisciplinary collaboration between practitioners of public health, the environmental sciences, and engineering. Topic areas include: an international overview of public health and environmental health practice; common toxic agents and environmental diseases in developing communities; health effects of air and water pollution; environmental emergency and disaster response; practical methods of epidemiologic analysis; and sustainable engineering for healthy communities. Taught in association with the CU Health Sciences. Offered for the first time as a graduate course in Spring 2005.

- CVEN 4700 Sustainability and the Built Environment (first taught in 2002)
  The course provides undergraduate and graduate students with better tools and skills when conducting work in the developing world. The course presents the fundamental concepts of sustainability and sustainable development. Emphasis is placed on understanding natural systems, the interaction of the built environment with natural systems, and the role of technical and non-technical issues in shaping engineering decisions. Information about this course can be found on the web (http://ceae.colorado.edu/~amadei/CVEN4838). In Spring 2005, the course will for the first time include a significant hands-on component in a field laboratory.

- EDC Projects
  This would allow students who had spent the previous semester in Environmental Engineering Design working with a community to follow-through on their project, including helping the community find sources of funding, pilot test processes, and/or implement their designs. An EVEN student in Spring 2004 successfully worked with an Indian Pueblo to complete his fall design project as an independent study.

- Engineering Economics CVEN 4147

The EDC option courses may be expanded over time. Examples of other courses that are likely to be developed in the future include:

Appropriate Treatment Technologies – water, sanitation, and waste management suitable for developing communities and individual homes
Technical Aspects of Sustainability
Field Engineering for EDC
Small systems construction and structures
Civil Engineering in Natural Disasters and other Crises
Biomimicry

It is clear that new courses need to be developed soon to complement not only the courses mentioned above but also existing courses at the University of Colorado that emphasize issues critical to the understanding of the developing world. The objective is to implement these changes to our curriculum over a three year period.

Social Science and Humanities Electives

A selected sub-set of acceptable social science and humanities (SS&H) electives will be specified for students in the EDC track in EVEN. A preliminary list of these courses was identified from those already offered at CU and approved by the College of Engineering. The courses have been grouped into 9 theme areas. Examples of each theme and associated courses are shown in Table 4. Note that the list shown is not inclusive. These courses will be further refined after review in association with the Developing Areas Research and Teaching program (DART). DART is an active group in the College of Arts & Sciences that offers a graduate certificate and is in the process of developing a certificate for B.S. students. Most emphasis in DART is in the anthropology and geography departments (www.colorado.edu/geography/dart).

Table 4. Socio-humanistic Elective Courses Acceptable for the EDC option

Theme	Department	Example Courses
International Development & Affairs	Anthropology	Cross cultural aspects of socioeconomic development
	Economics	International economics & policy; Economic reform in developing countries
	Ethnic Studies	Immigrant women in the global economy
	Geography	Geography of international development
	International Affairs	Global issues and international affairs; Global perspectives and political philosophy
	Political Science	Intro to Intern'l relations; Global development; Intn'l law
	Womens studies	Women, development, & fertility; Global gender issues
Asia/Middle East/Pacific Region	Anthropology	Exploring non-Western culture Japan; Ethnography of SE Asia
	History	Intro to Middle East history; Intro to Chinese history
	Religious study	World religions: India, China & Japan; Islam
Africa Region	Anthropology	Exploring non-Western culture – Africa; Africa peoples & soc
	History	Rise and fall of African slavery; Africa in the 9th century
	Political science	Political systems in sub-saharan Africa
Latin America Region	Anthropology	Ethnography of Mexico and Central America
	Geography	Environ and Develop in S. America
North America/ Native American Region	Amer Indian Sty	American Indian religious traditions; Indian/Govmt conflicts;
Culture Related	Anthropology	Frontiers of cultural anthropology; Human ecology
	Geography	Place, power, & contemporary culture; population geography
Medicine/Biology	Anthropology	Nutrition and anthro; Human ecology: biolog aspects; Med anthro
Language and Communication	Languages	Chinese, French, German, Arabic, Spanish, Russian, etc.
	Communication	Communication and society; Human communication theory
Environment	Economics	Natural resources economics; Environmental economics
	Geography	Geographies and global change; Environment and culture
	Sociology	Sociology of natural and social environment; env & society

Program Outcomes Assessment

In developing the EDC programs at both the undergraduate and graduate levels, a variety of methods have been used. Two surveys have been distributed and feedback is being gathered. The first survey is an interest survey that was distributed to all graduate students currently in the Environmental program and all students in the undergraduate capstone Environmental Engineering Design course. After gathering information on their current degree status and major(s), responses to the questions in Table 5 were gathered. To date (Jan. 3, 2005), 25 surveys have been returned out of approximately 60 distributed. Note that not all respondents answered all of the questions, and thus the sum of the 3 response categories may not total 25.

Table 5. EDC Interest Survey

Question	Yes	Maybe	No
If a track in EDC were present as part of a BS degree in Environmental Engineering (EVEN), would you have enrolled in such a program?	5	15	1
If a track in EDC were present as part of a BS degree in Civil Engineering (CVEN), would you have enrolled in such a program?	7	13	2
If an emphasis in EDC were available as part of an MS degree in CVEN, would you/*would you have* enrolled in such a program?	12	8	4

An additional survey on important courses was also distributed. A list of 24 courses/course topics was provided and respondents were asked to rate their agreement on a scale of 0 (disagree)

to 3 (strongly agree) with 6 statements. This was sent to all environmental faculty members within the Civil Engineering group at CU, professionals with work experience in the developing world, and selected attendees from the Sept. 2004 workshop. Example questions from the survey are shown in Table 6 with the average score of the 11 responses received (as of January 3, 2005). Note that for all 5 example course topics shown, the response was significantly higher for "important for EDC-related work" in comparison to "important for all environmental engineers" (t-test at greater than 90% confidence). However, one leader in this area noted: "My prejudice is to keep the basic civil engineering curriculum (BS) intact rather than weeding out more material and putting in special 'stuff'. There are so many basics that need to be learned.... Keep the degree program at the MS level. Go ahead and put in 'flavors' of EDC in course work, and even electives, in traditional programs so as to turn on students, but don't cheat them of the basics." Once responses from the majority of the surveyed group are received, final recommendations of courses for the EDC undergraduate and graduate programs at CU will be made.

Table 6. EDC Course Survey with Average Response on Scale of 0 to 3 Shown

Course topic (example list of 24 topics)	Important for engineers wanting to do EDC-related work	Should be required in engineering BS degree with EDC emphasis	Should be encouraged as an elective course
Public health	3.0 ± 0	2.6 ± 0.5	2.3 ± 0.9
Construction methods	2.5 ± 0.8	2.3 ± 0.9	2.3 ± 0.9
Appropriate treatment technology for water & sanitation	3.0 ± 0	2.5 ± 0.5	2.4 ± 0.7
EDC projects course	2.8 ± 0.7	2.5 ± 1.0	2.1 ± 1.1
Exploring non-western culture	2.5 ± 0.8	2.1 ± 1.0	2.1 ± 1.0

A variety of tools will be used to assess the success of the program. First, a number of current and former CU graduate students have experience in the developing world, such as with Peace Corps. They will be asked for feedback on the proposed curriculum. An external advisory panel will initially review the proposed curriculum. This will meet for the first time in Spring 2005, using money to support travel from the NSF Department Level Reform grant. The normal EVEN external advisory board will review the proposed track. Optional questions pertaining specifically to EDC can be added to the FCQs of selected courses with EDC modules, such as CVEN 3414, CVEN 3424. A survey can be distributed yearly to students in the EDC track to begin collecting feedback on the SS&H and other courses. This information will be compiled to assist advising efforts. An overall view of the program will be acquired by adding questions to the existing EVEN graduating senior exit survey. In addition, alumni surveys will be distributed.

Conclusion

The proposed EDC program at CU was initially driven by the large student interest in this area. There is a critical need to train engineers capable of designing appropriate and sustainable technologies for water, sanitation, shelter, and energy for developing communities. The proposed curriculum in EVEN is a first step to meet this need at the undergraduate level.

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