AC 2007-1638: INTERDISCIPLINARY INTERNATIONAL SENIOR DESIGN: HOW SERVICE LEARNING PROJECTS IN DEVELOPING COUNTRIES SUPPORT ABET ACCREDITATION

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Interdisciplinary International Senior Design:
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Introduction

Responding to shifts in society and industry toward a globalized economy, engineering schools are beginning to address the realities of engineering and design in developing communities. A globalized economy is defined here as one of international marketplaces and hybridized companies that draw on a range of cultural and disciplinary perspectives. To prepare students for this emerging workplace, engineering education must incorporate global, environmental, economic and societal issues as well as prepare students to work across cultures and disciplines.

This paper reports the work of International Senior Design (ISD), developed at Michigan Technological University. ISD introduces environmental and civil engineering students to both cross-cultural and interdisciplinary work within a capstone design project. Partnering with classes in the Humanities (HU), ISD classes emulate the work of design/build firms in industry to provide students a service-learning design experience situated in the developing world so they can explore the technical, economical and social implications of engineering design and construction.

More specifically, this paper reports the basic elements of ISD. We offer them as a model for working across disciplinary, cultural, and international boundaries in a business setting to attain Criterion 3 of the U.S. Accreditation Board for Engineering and Technology (ABET 2006 Engineering Criteria). A survey of student work shows how each ABET Criterion 3 requirement is met for various majors throughout the design experience.

Key Concepts

We begin with definitions of four concepts that are central to the ISD mission: ABET criteria, service learning, cross-cultural learning, and interdisciplinarity.

ABET Criteria:

ABET, Inc. is the independent accrediting body for U.S. University engineering programs. Each accredited program must demonstrate conformance to certain criteria. In the case of this paper, ABET 2006 Engineering Criterion 3 will be used.

Service Learning:

We define service learning as experiential education in which students participate in projects designed to serve the needs and interests of local communities.

Cross-cultural Learning:

We understand cross-cultural learning to be an experiential process of deepening respect for people of different cultures and increasing sensitivity to their local practices.

Interdisciplinary Learning:
We understand interdisciplinary learning to be a process of exchange among students from a range of disciplines that results in new knowledge or “literacies” (for further discussion of literacies see 1).

Background

Following is background on the history, goals, design, and structure of the two courses that constitute ISD.

History
Since January 2001, Michigan Tech’s Civil and Environmental Engineering Department has administered ISD capstone design project classes for seniors, which allow students to obtain university credit for working on engineering projects in the developing world [2]. ISD was created as a response to consistent student requests in a third-year professional practice course required by civil and environmental engineering majors. At that time, the professional practice course included a contract document preparation project for the developing world. Students completing the project frequently requested an opportunity to travel to the international project site and actually implement their ideas.

Since the ISD program began in 2001, ten senior design classes (118 students) have successfully completed projects improving water supply, water resources/management; site master planning; site reclamation; solid waste management, and wastewater treatment to benefit communities in Bolivia and the Dominican Republic. Currently, 20-25% of undergraduate civil and environmental engineering majors take this course. Ownership of the student design projects is so great that 15% of ISD alumni have returned for additional ISD in-country experiences as mentors and class assistants.

ISD began as a single semester, 3-credit, major design experience that could also fulfill a technical elective requirement. In 2004, the course underwent revision to a 6-credit, two-course sequence. The credit change was precipitated after a review of the student hours required for completion of the experience and the ABET criterion students satisfied in each segment.

ISD recognized the value of multidisciplinary and mentor involvement early in course development with incorporation after the first class delivery. In 2005, and continuing through the present, ISD “contracts” with other Michigan Tech Humanities courses by hiring classes and their student “employees” to produce brochures, grants, publications, and translations.

Goals
ISD course goals integrate and advance the U.S. Accreditation Board for Engineering and Technology (ABET) accreditation criterion throughout the design experience.

One goal is to provide students a service-learning design experience situated in the developing world so they can explore the technical, economical, environmental and social implications of engineering design and construction.

A second goal is to afford students a cross-cultural learning experience, that is, to prepare engineering students for ethical, reflective, quality service to diverse communities and demonstrate that social responsibilities of engineers are fundamentally important and address real facets of sustainable engineering with global and community awareness.

A third goal is to give students experiences in interdisciplinary work, that is, to provide students concrete opportunities to learn new skills, such as international construction techniques, to think critically, and to test new roles in an environment that encourages risk-taking and rewards competence.

Design

To accomplish the goals of service learning, cross-cultural learning, and interdisciplinary learning, ISD is designed as a two-course sequence.

Students spend two weeks in-country, during the first course, working on a construction site to learn local tools, materials, and techniques in addition to performing the design project needs assessment, client meetings and design data gathering (see Table 1 for examples of ISD engineering projects).

Table 1. Examples of Engineering Projects Performed by ISD Students.

Area	**Example Projects**
Wastewater treatment	· Designed & constructed new on-site septic systems for schools · Designed retrofits for malfunctioning existing school systems
Water supply	· Designed gravity fed water transmission lines from springs to village · Designed and constructed solar powered water distribution system (i.e., spring box, pump box, & tank) to collect & distribute spring water
Water resources/management	· Designed & constructed neighborhood storm water drainage plans · Developed master drainage plan for 20-acre school and university site · Developed master drainage plan for city area · Designed a suspended bridge river crossing
Site master planning	· Designed, developed and constructed school site master plan and site fill plan · Designed and developed community center site master plan

Site reclamation & solid waste management	· Developed area reclamation and solid waste management plan

While in-country, each student is required to write a daily learning log including notes and reactions on gathering data, working on the construction site, observations and engineering opinions on tools or techniques, as well as observing and commenting on teambuilding, interpersonal relationships, and communications. Students document the appropriate ABET criteria for the noted project task, observation, experience or lesson.

For teams, each day in-country involves actual construction labor and daily administration and management of the jobsite or gathering design data. Meetings are held with the "client," mentors or other design professionals to gather additional data or information required to complete their respective design. During the "siesta" and in the evening, teams discuss observations and challenges or analyze progress and develop team plans for the following day. Team members may address issues in productivity assessment, materials management, construction progress forecasting, and investigate or discuss design feasibility or strategies in data gathering. Time is often spent making comparisons to traditional US industry practices.

During the second course, on-campus at MTU, students take the gathered data and produce design option feasibility studies, culminating in an engineering report recommending a final design. It is assumed that the international "client" accepts the recommendation and students complete construction documents.

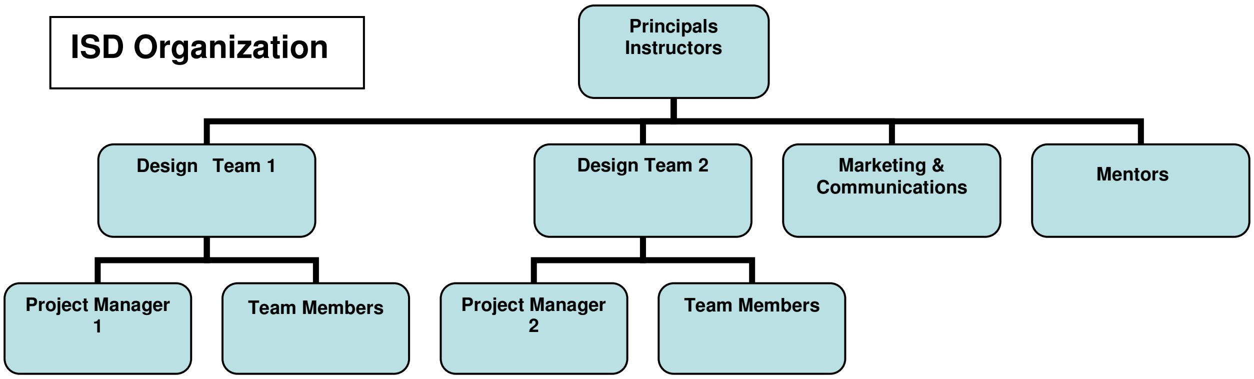
The engineering report includes the following: feasibility evaluation & assumptions; development and analysis of alternate design solutions; code analysis and review; discussion and analysis of potential design solutions including associated impact analysis, costs, economic and health factors, social impact, safety, constructability, sustainability, reliability, aesthetics, ethics; proposed construction schedule; engineering estimate, cost/benefit analysis; design calculations; and references (literature and personal). Students also complete construction contract documents as would be prepared by a design firm in industry**:** final construction drawings and a project manual including bid documents and specifications. As a final summary report for the international experience and in lieu of a daily learning log for the on-campus course, each student prepares a report to reflect how each of the ABET criteria was met.

One of the most important aspects of the courses is that students experience the evolution of a project in an industry situation from conception through completion of final design drawings and specifications. In addition, students work with developing world communities where modern technology is not always available, requiring ingenious thinking and adaptation to local practices to complete an effective project solution.

The ISD "Business" Structure

Both ISD courses are structured to emulate the business of a design/build firm in industry, an environment the student will find themselves in within 6-12 months after the class experience (See Figure 1).

Figure 1: ISD Class Organizational Chart



Design Teams
Students form self-administered "design teams," directed by team-elected project managers. Teams of 3-4 students are expected to complete the final project design, each team working on a different design project, just as in industry. Specific tasks are assigned within the team by the students themselves, sharing the work equally. Student teams complete feasibility studies, preliminary and final designs on their own time, which is monitored by individual timesheets to track project progress. Project teams update the Principal/CEO (instructors) via required weekly meetings. Timesheets serve two principal functions of timesheets. First, they help students manage their time by reflecting how time is actually spent. The Principal/CEO also reviews timesheet information to judge productivity. Timesheets are finally used by students to invoice clients for the project hours. Students learn the difference between direct and indirect (billable and non-billable) time and also realize the value in completing work correctly the first time or combining jobsite visits. The in-country experience historically requires approximately 120+ hours of class work per student while the on-campus portion requires 100-200 hours per team member which is at least 20 hours each week.

Industry Mentorship
Due to the number and variety of design projects, in addition to corporate and alumni interest, industry mentorship has been included beginning with the second course offering. Practitioner involvement and international partner affiliation has been a key enhancement to the success of ISD classes. Mentors may travel abroad with the group and advise on a daily basis, or may choose to "mentor from afar" coaching the students on project delivery and procedures as well as the technical concepts. Mentors serve as functional experts to augment class activities, volunteering their time and talents. During the on-campus course, design teams are required to hold weekly meetings or conference calls with mentors to solicit design feasibility advice, review design ideas and construction details. The mentors are either seasoned professional engineers or recent ISD alumni working towards professional registration. Both provide helpful and at times different advice, wisdom and experiences as well as intergenerational exchange. Since traditional approaches may not be an option, students and mentors need to "think outside the box" to develop alternate methods of obtaining data or approaching the design problem.

Industry Performance Evaluation Standards

A sizeable portion of grades, as in industry performance evaluations, is based on student participation, attitude and effort throughout the courses. Participation, effort and attitude are vital to team work, and are assessed in two ways: Principal/Mentor assessment and Team Member assessment. In industry this is called a 360° degree review since peers, managers and subordinates (if appropriate) have input into the performance evaluation.

Results

How ISD Meets Course Goals
One method to evaluate the ISD courses is to review how they meet their goals of service learning, cross-cultural learning, and interdisciplinary learning, all three of which integrate and advance ABET criterion.

Service Learning
Service learning is experiential education in which students participate in projects designed to serve the needs and interests of local communities. Because students are taken outside their comfort zones [3] and because they are asked to reflect on their involvement as it relates to course content, they come to a robust understanding of their discipline and its relationship to social needs and civic responsibility. In addition, Mihelcic, et al. [4,5] have made a strong call to action for engineers and engineering educators to answer the developing world needs as espoused by the World Health Organization (WHO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO).

ISD students
In the case of ISD students, engineering and humanities students together serve communities with pressing public health and welfare needs that students might not experience in the comfort zones of the U.S. As well, students work with clients who represent a range of economic, social, and political positions that are often invisible or unrepresented on privileged university campuses. Opportunities for developing creative problem solving strategies and increasing lifelong learning are thus increased. One student reflected on the service learning aspect of ISD in this way: “Water sanitation solutions involve both a technical solution along with a social education aspect. The two aspects work together to provide a sustainable solution that neither could achieve independently. It is part of the professional and ethical responsibilities of engineers to recognize and implement this. Through design of this project and by becoming familiar with previous projects done in the same discipline through these classes, I feel I have greatly increased my understanding of global responsibility.”

Women in ISD
Historical ISD enrollment demonstrates the significant interest of women engineering students. Busch-Vishniac as referred to by Hokanson [4], suggests that ISD coursework encourages a diverse engineering student population because it links fundamentals and application, require team experiences, and create an atmosphere of inclusion, rather than exclusion.

Bielefeldt [5] as well as Widnall and Farrell as referred to by Mihelcic. [6] and Hokanson [4], respectively, reason that women do not go into engineering due to imperceptions of social welfare and relevance, when in fact, this is the primary reason given by ISD students for taking ISD courses: "chance to make a difference". (See Appendix 1) To date, 53% of ISD students have been female. Table 2 compares percentage female enrollment in the ISD program for environmental and civil engineering to national undergraduate student enrollment and departmental enrollment. Female ISD enrollment is more than double the national average for female civil and environmental graduates. Popularity of the courses with women alone is not the only positive. At the completion of the 2006 courses, every female student stated that she "now knew that she had chosen the right career and could see how she could use her engineering skills to make a difference." One went on to say:

> "I participate and do very well in my engineering classes. But I am never satisfied with these classes because through performing the work required for them I do not feel I am contributing to the world in any positive way…. I understand that I may have needed many of my previous classes in order to effectively participate and that the mental discipline I acquire through various classes was important. But the truth is I value this experience gained in ISD more than I value every engineering class I have ever taken combined. Because it involved something that is real and brought face-to-face at every level with all of the humans involved."

Service learning experiences, with a societal impact focus, has a broad appeal to today's youth as evidenced by the 2006 Cone, AMP Insights survey that show education, poverty, environment and health and disease as the top 4 issues on the minds of the Millennial Generation.[7] Solving engineering related social problems resonates with today's student, especially young women as demonstrated by ISD participation.

Table 2. Comparison of gender balance among undergraduate civil engineering and environmental students and participants in the International Senior Design (ISD) Program (data from annual surveys of the Engineering Workforce Commission of the American Association of Engineering Societies).

	2001-2005 Degrees Awarded % Female		**ISD 2001-2006 % Female**
	National	**Michigan Tech**	
B.S. Env. Engrg.	42	51	70
B.S. Civil Engrg.	22	22	46
% of Total C&E degrees that are awarded to females	23	28	51
B.S. Other Eng	N/A	N/A	100
B.S. Other Majors	N/A	N/A	80
Total ISD Participants			53

Cross-cultural Learning

Cross-cultural learning is an experiential process of deepening respect for people of different cultures and increasing sensitivity to their local practices. The American Society of Civil Engineers (ASCE) is currently drafting outcomes as prerequisites for professional practice. The draft Project Management section, suggests undergraduate students should be able to apply project management principles including "the ability to work alongside and report to people from other cultures." [8] Cultural empathy such as this can certainly be introduced in the classroom. But in a global economy, where engineering and humanities students can expect to work with clients and colleagues from a range of cultures, hands-on experience in international contexts can be a way of securing cross-cultural skills as they intersect with complex problem solving.

ISD students

ISD advances this kind of experiential learning. More specifically, the class is intended to build bridges of understanding between people of varying ethnic, cultural, economic, and social backgrounds. All twelve engineering students participating in the 2006 summer project discussed this kind of cross-cultural experience. One said: "Overcoming the language/cultural barrier of working with the Bolivians, either at the construction work site or at our school project site. Alternative communication techniques were commonly utilized as well, including body language and pictures/drawings. This provided for a unique demonstration of our ability to function on a multi-disciplinary team, a multi-cultural team. This also provided for a cultural experience that is not typically found in any engineering class."

By placing student design teams at international sites where improvements in wastewater treatment, water resources management, and solid waste management are necessary for the health of local communities, ISD enables students to complete tasks that meet basic human needs and solve pressing problems in the world. Because students are interacting with local communities directly, using local materials that are sustainable in local contexts, students become more aware of the interdependence of all people and more receptive to creative problem-solving strategies. One student reported that to solve "our engineering problem, it was necessary to determine the social and political stance in our neighborhood. By doing this, we were able to think about fixes to their problem in a politically and socially accepted way."

Study abroad experience

Furthermore, because ISD has become a way for MTU engineering students to study abroad, it leads the way in engineering education. Of the nearly 175,000 American students that studied abroad in 2003, only 3% were engineering students, which is only 1% of the Americans students enrolled in engineering programs. [9]

Interdisciplinary Learning

Interdisciplinary learning is a process of exchange among disciplines that results in new knowledge for both. ISD thus trains engineering and humanities students not only in technical skills, but also in understanding the value and use of other disciplines to manage projects that cross international and disciplinary borders.

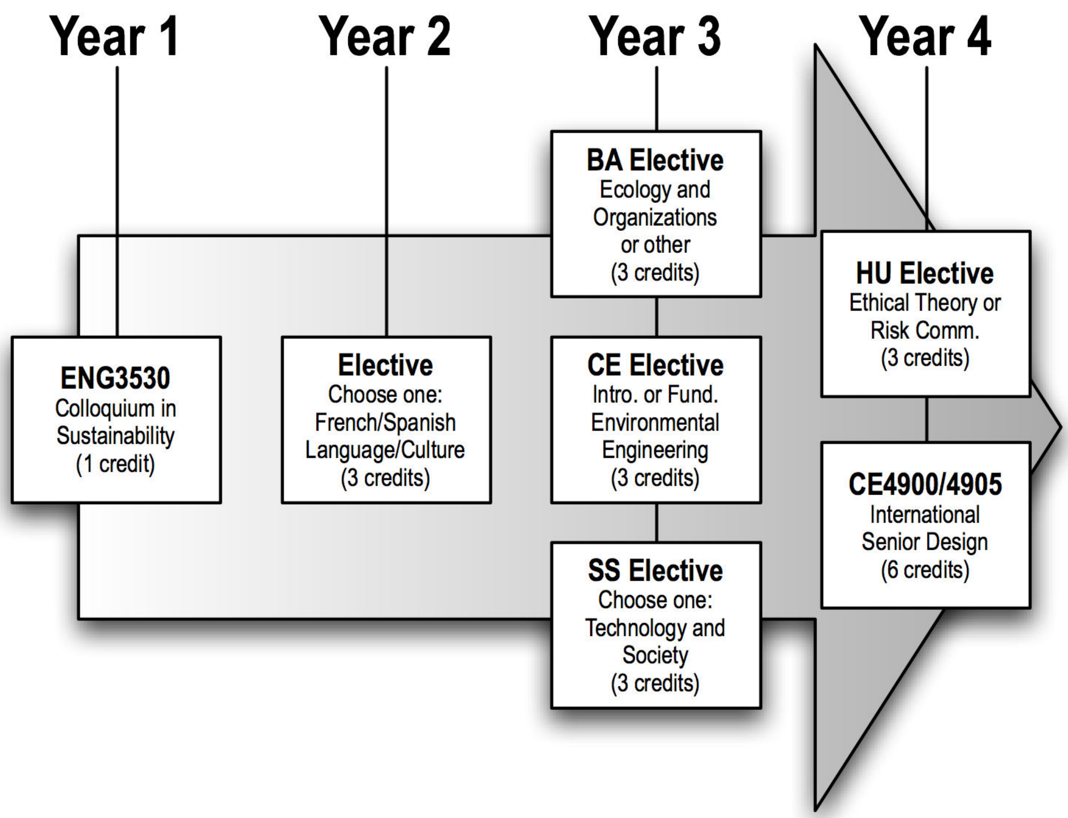
The process begins by identifying a problem and the different disciplinary perspectives that could be used to solve it. Having assessed the concepts and skills that relevant perspectives offer, disciplines familiarize themselves with the knowledge and discourse of each other with the intent of appreciating what is available to them there. Reciprocal understanding is the third stage of the process. At this point, disciplines stretch themselves to understand the conventions and knowledge of their hosts. The fourth, and last, stage is an integrative synthesis [10]. Paying particular attention to how their new understanding can be combined with their own disciplinary knowledge and applied to the problem at hand, participating disciplines engage in research and data collection based on their melded knowledge, which offers them a new way of thinking about the original problem.

ISDE Certificate

Initiated in 2006 to encourage interdisciplinary exchange within the international experience at Michigan Tech, an undergraduate certificate in "International Sustainable Development Engineering" integrates cross disciplinary coursework components with ISD. The certificate provides students preparatory interdisciplinary background to ISD, and furthers the traditionally ignored or absent societal ties in engineering education.

The certificate (See Figure 2) "provides students breadth in the areas of ethics, communications, resource equity, community participation, interactions between technology and society, and engineering connections with the environment. Upon graduation students will have gained skills for working in diverse interdisciplinary teams, consensus building, appreciation for how engineering can assist the global community, critical thinking, oral and written communication as well as community service. The National Academy of Engineering called for such engineering education in their recent report, "The Engineer of 2020.""[11]

Figure 2: International Sustainable Development Engineering Certificate.



Disciplines in ISD

To date, although listed as civil and environmental engineering courses, ISD courses have appealed to various disciplines. In addition to the traditional civil and environmental engineering majors, geological and mechanical engineering students have participated as well. In 2006 the class was composed of thirteen students: seven civil engineering majors, four environmental engineers, one mechanical engineer, and one scientific and technical communications major. Although these students were divided into four separate groups, all of the 13 students worked together at some time while in Bolivia or doing design work back on campus.

Math and science high school teachers pursuing their Masters in Education have substituted these courses for their required engineering industry internship. The high school teachers were assigned to design teams so they could participate and experience the entire design/construct process. In addition, some were involved in developing and delivering education lessons relating to the specific engineering project to local residents.

Scientific and Technical Communication in ISD

To give a more specific example of how students from disciplines outside of engineering worked in ISD, we offer a work description of one Humanities student in Scientific and Technical Communication who joined ISD in summer 2006. Karina Jousma participated in ISD courses and joined ISD teams in Santa Cruz, Bolivia, as a communication, writing and marketing consultant. With the addition of STC, activities were added which further replicate work of firms in industry.

Jousma majors in Scientific and Technical Communication at Michigan Tech with a concentration in engineering, as well as a background in pre-medical biological sciences. Prior to Jousma's involvement in ISD, she had earned 13 credits toward her major requirements, including courses in technical writing, journalism, and risk communication. Since she had previously concentrated in biological sciences, her engineering knowledge was limited. She utilized credits acquired through completion of ISD toward the engineering concentration within her degree. Following is a description of each of the roles she played, preceded by relevant assignments.

1. Construction
When practical, Jousma participated in ISD construction projects in order to learn techniques used in Santa Cruz. In an assignment proposal she stated the reasoning behind this role, "Realizing how and why something occurs is important: if I do not understand what occurs on the jobsite, then I cannot help anyone." As a result, she, like her engineering student peers, was able to realize the relationship between construction and engineering-design projects.

2. Learning Log
Similar to ISD engineering students, Jousma logged her experiences, thoughts, and observations; however, the log conformed to her needs and responsibilities. For example, it included observations for news articles, instead of data for calculations.

3. Communication Consultant
Jousma facilitated communication by asking questions and observing the communication practices among ISD engineering students, stakeholders, and professional engineers and designers.

She became an advocate for not only project stakeholders by ensuring that residents of communities in Santa Cruz understood ISD participants' messages, but also for ISD engineering students by supporting usability and needs assessment. The consultation served to assess what technology users need or will utilize, and anticipate how users will interact with that technology: what complications may arise and how can ISD engineering students adapt the technology for users?

4. Writing Mentor
Jousma taught three writing lessons, composed of material in three report-writing areas: general rhetorical principles, report design and content, and grammar. Since all ISD student-engineering sub-groups utilized the same general background information, she facilitated its development during brainstorming sessions.

5. Marketing Consultant
While enrolled in Bolivia, Jousma took photos and selected them for marketing assignments. The assignments included the following: writing a summary of 2006 ISD engineering-design projects and construction work; writing and submitting news releases to ISD engineering students' hometown news publications; preparing recruitment posters and informational materials for potential students; emceeing the annual ISD symposium, as well as advertising the event with

posters, public radio messages, and letters addressed to ISD students' parents, ISD mentors, donors, and Michigan Tech faculty; and preparing a speech about her experiences as an STC major in ISD.

Scientific and Technical Communication Lessons Learned

Cross-cultural

The STC student met with a Bolivian university student studying communication, and conversed with him through a translator.

They partnered to address several questions and issues regarding locals' risk communication/education, such as the following found in an excerpt of the STC student's learning log: "…Who are the stakeholders? Who's affected by the flooding: homeowners, as well as people who walk through the floodwater? This is everyone's problem, because the wastewater from homes mixes with storm water. How do we communicate this risk? Via plays, fiestas, public service announcements, goods, meetings, etc. We need to increase sense of community in order to promote maintenance and educate. We need to educate members about maintenance: how often will it need to be maintained?..." Innovative communication ideas and methods emerged from the meeting. They were able to cross both cultural and, ironically, a communication barrier to assess the needs of Bolivian communities.

Interdisciplinarity

Likewise, the STC and engineering students crossed disciplinary boundaries in order to share ideas for educational/risk communication methods and media. The STC student logged:

> "Tonight I talked to [engineering students]. I'm concerned about waste management in Santa Cruz, because it's the root of many problems. It plugs the storm drains, and [one engineering student] compared the refuse in drainage ditches to grease (in a kitchen sink?). How can we best address this issue? I feel as though my marketing work is for naught if we cannot communicate risk to Bolivians…We need to address Bolivians' attitudes, needs, and knowledge. [Another engineering student] suggested handing out surveys to people on the street, which would ask where they dispose of refuse, why they dispose of it there, etc. [The first engineering student] says the people need to see a need before anything can be accomplished, with which I agree."

ISD in Scientific and Technical Communication

ISD has traversed traditional interdisciplinary and university departmental borders while mimicking industry relationships. The ISD "firm" also "contracts" with established Humanities departmental classes. For example, an advanced Spanish class was "hired" to translate ISD design reports.[1] And STC classes have provided contract deliverables of marketing materials, publications, grants and specific communications pieces all as structured HU course assignments. One STC student commented on the value of working with a real client. "When the ISD instructor came to our class to present her project and how we could contribute to it, we were motivated to do professional work for her, and particularly for the local communities in Bolivia." Another observed: "I learned so much about working with other disciplines for the success of a project. I could see how what we writers and designers had to offer engineering projects; and that was awesome."

How ISD Meets ABET Criterion 3

A second method to evaluate the ISD courses is to review how they meet ABET Criterion 3 requirements. Criterion 3 addresses the skills, knowledge, and behaviors students should have at graduation. Specifically, engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global economic, environmental and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 3 shows ISD student course requirements, associated ABET criteria intended to be met and how each activity overlays typical corporate work in industry. Reviewing the "Parallel Industry Activity" column quickly shows the strong correspondence between ISD student requirements and actual engineering practice.

Table 3. Student Requirements for ISD and U.S. ABET Accreditation Fulfillment
Key: X=Requirement O=Provide Assistance

Student Requirements	**Engineering Student Reqmt**	**STC Student Reqmt**	**Parallel Industry Activity**	**ABET 3 Criteria Met**
Maintain Learning Log	X	X		All
Maintain Daily Time Sheet	X	X	X	3f
Present Professional Safety Talk	X	X	X	3f,g,i,j
Gather Design Project Data	X	O	X	3a,b,c,d,e,f,g,h,j,k
Develop A Design Project Schedule And Cost Estimate With Cost/Benefits	X		X	3a,b,c,g
Compile Engineering Design, Calculations,	X		X	3a,b,c,d,e,f,g,h,j,k

Assumptions, Tables, Charts, Notes On Solutions, References				
Prepare And Present The Final Engineering Report In Written, Verbal, Web Page And Poster Form	X	O	X	3a,b,c,d,e,f,g,h,j,k
Work With Industry/Professional Mentors (& weekly meetings)	X	O	X	3d,f,g,i
Client Invoice	X	X	X	3a,f,g
Client Meetings And Needs Assessment	X	X	X	3b,e,f, g,h,j
Marketing & Publicity		X	X	3b,d,f g,h,j,k
Communications Consulting		X	X	3b,d,f g,h,j,k
Usability		X	X	3b,d,f g,h,j,k
Pre-Trip Project Plan	X	X		3b,c,e,fg,h,j,k
Design Team Schedule With Responsibilities	X	X	X	3b,c,e,fg,h,j,k
Project Document Distribution	X	X	X	3f,g
Weekly Meetings With Principal/CEO	X	X	X	3d,f,g
Risk Communication: Posters And Brochures	X	X	X	3b,d,d,e,f,g,h,i,j
Education	X	X		3b,d,d,e,f,g,h,i,j

There are several instruments that can be used to evaluate ABET Criterion 3 incorporation and understanding within the 2006 ISD courses: pre and post course student surveys, student learning logs and ABET summary reports, and pre and post trip interviews conducted by the STC student.

The pre/post course survey assesses student attitudes, self-confidence and project opinions. A review of the per cent change from the pre-course student survey responses show greater than 15 per cent increase in Criteria 3c (designing a system), 3d (multi-disciplinary teams), 3g (communications), 3h (understanding engineering impact), 3j (contemporary issues) and 3k (use modern skills, tools and techniques). See Table 4. The increase in Criteria 3h and 3j point toward the important incorporation of the traditionally lacking societal and cross-cultural issues. Reviewing spring 2006 graduating civil and environmental engineering student exit interviews, ISD student knowledge and recognition of these issues far out-paced those of their peers in conventional senior design courses. [12]

Although only survey questions showing 15 per cent change or greater are included in Table 4, it should be noted that changes of 14% were not uncommon and indicate the strength to which all criteria are met. See Appendix 1.

Table 4: Questions with greater than 15% CHANGE in Student Response between Pre-Trip and Post Presentation Survey

No.	Questions:	% Change	Applicable ABET 3 Criterion
9	I have confidence in my ability to interact with local constituents (villagers, mayor, etc.)	24%	g
10	I have confidence in leading a project team	15%	d
15	I have confidence in preparing and presenting a formal oral client presentation	17%	g
33	This senior design experience meets all the criteria that ABET expects	19%	all
35	I am confident in assessing the social aspects of my project on the local community	17%	c
39	I am confident in assessing the political aspects of project alternatives	17%	c
40	I understand cultural preferences and their impacts on project alternatives	18%	c
42	I understand constructability issues for project alternatives	25%	c
50	Life is much better in the U.S. as compared to my project site country	-28%	j
51	We have much to teach/show the people in my project site country	15%	j
54	I know how I could volunteer my time	15%	f
61	I understand the culture of my project's country	35%	c,h,j
63	I am working on this project mostly to benefit my "clients" at the project site	23%	f
64	I am working on this project mostly to fulfill degree requirements	-15%	f
74	The project contributed to my ability to use modern engineering tools and techniques	24%	k
80	The project had significant practitioner involvement	18%	d,k

The strong survey increases are supported by further examining the student responses to each criterion since integration of the ABET criterion is evaluated by each student throughout the experience, both for the in-country and on-campus design experience. While on-site, students maintain a learning log. For each entry or experience, the ABET requirement(s) that apply to the project task, experience or lesson are to be documented. A summary report of how each ABET criterion was met is also required of each student at the end of both the in-country and on-campus sections of the class as a method for the student to reflect on the importance of each criteria, the number of ways the criteria was met, and what the student actually learned with respect to each.

To further evaluate ISD ABET conformance, examples and evaluations from the 2006 student learning logs and ABET summary reports are examined below. The following documents what student responses to each of the ABET criterion. It should be noted that there were many cross links between ABET Criteria not expressed here. For example, in discussing the application of science, math and engineering knowledge to an on-site beam design problem, a student related the ethics of the situation as well as ethics of miscalculations in the project's engineering estimate.

Criterion 3a: Demonstrate the ability to apply knowledge of math, science, and engineering.

Before specifically discussing ISD students' proficiency in Criterion 3a, an engineering student's learning log entry follows, illustrating the need to employ knowledge from several fields: "This course served as an opportunity to apply years of classroom learning to a real world situation. Throughout the duration of this course, [my project group and I] used skills that we had gained from every single class that we've taken."

When addressing Criterion 3a specifically, the engineering students immediately include the traditional Stokes Law, Manning's equation, Rational method in addition to surveying, soil borings and analysis, estimating infiltration rates, measuring watershed sizes, and documenting existing facilities. Estimates and construction schedules as well as the final client invoices were also mentioned. On-site construction work involved measuring, calculating water/cement ratios, construction planning as well as designing a retrofit to a malformed and constructed beam.

The previous are logical and straightforward engineering responses; however, one-quarter of the engineering students also included communication activities to meet the "ability to apply knowledge" portion of Criterion 3a. Developing a logical data collection plan was mentioned as a first step. Once the plan was in place, the engineers said that they "needed to apply engineering knowledge to make a full engineering report and make recommendations for a solution." Once the report was complete, engineers stated that they needed to present the project to a mixed audience of technical and non-technical composition."

The STC student at first noted that Criterion 3a did not apply, but in the final report observed that "although I had no background in engineering, construction, and surveying, I learned applicable techniques and jargon." Interestingly, she commented that working with ISD students had helped her understand her STC major and the work she will do as a professional communicator: "Today, I realized how STC applies to engineering; one of our jobs is to ask questions, which is what people describe as an 'engineering' mind."

Criterion 3b: Demonstrate the ability to design and conduct experiments as well as analyze and interpret data.

Standard engineering student responses included topographic and land surveys, water quality testing, various soil testing methods, as well as designing usage surveys, unorthodox hydrometer tests, and data collection from experiments and field photographs. Half of the engineering students commented on meetings with local city officials, local residents, and professional mentors, noting the differences of opinions and need to investigate and determine fact or applicability.

The STC student highlighted the full applicability of Criterion 3b to her work when she reported that she conducted a usability experiment in order to prepare to teach ISD students a lesson in writing. To make certain that her lesson would be useful, she first surveyed engineers about their knowledge of, and attitude toward, writing, as well as how they would be using it in their ISD work. Having asked several students if they had taken writing classes previously at Michigan Tech and if the courses had helped them, she also asked them what they would like to see incorporated in her lesson. Completing her usability experiment, she analyzed the results and interpreted them by designing her lesson to meet the students' needs.

Criterion 3c: Demonstrate the ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.

Criterion 3c is the heart of the capstone design project and engineering students easily recognized the facets of their projects as they relate to each of the constraints listed above. A particularly important observation is that 75% of the engineering students directly stated the key role of "client" and city official meetings and communications within this criterion summary. Two more (for a total of 83%) inferred the meetings. This shows the extent of student recognition for communication factors and demonstrates sensitivity to the socio-cultural aspects as they relate to specific project constraints. ISD naturally elicits the client needs assessment and focused project planning due to the international aspect and time limitations of the in-country experience.

Following is one of the most eloquent testimonies to how the ISD experience meets this criterion:

> "No other ABET criteria deals directly with need assessment, so 3c could technically be divided into the ability to assess needs of a client and the ability to design a system, component, or process. For our project, needs of the client were assessed by examining the situation from several different angles. Time was spent before the trip researching Bolivia culturally and technologically, learning the current system of treating wastewater at local schools. Time was spent on-site in Bolivia learning construction techniques that local workers are familiar with. We examined the current system at our school to indeed confirm that it needed fixing (according to us as foreigners) then double-checked our decision with school & neighborhood members and finally the true clients, children at the school. The problem was also discussed with industry mentors and university faculty. We learned what each group wanted – essentially to be able to forget they even had a septic system."

The STC student also saw herself "designing a system or component" to meet her client's needs by helping the design teams formulate their data gathering plans and approach:

> "I helped them in defining their project by encouraging them to obtain original documentation of their neighborhoods complaints, from which a project originates. I also played the role of a communication consultant when ISD students met with their benefactors to gather information; thus, I helped them communicate through a translator, which sometimes entailed rephrasing a question or interpreting body language. For example, in English we use the phrase 'getting used to,' whereas Spanish speakers use 'accustomed'; the English phrase does not translate correctly into Spanish."

She further explains herself in her learning log:

> "I also helped them analyze the sub mayor and [a Bolivian] engineer as audiences-I raised the question of how stakeholders might maintain a project site. What's their role? What information do you need from them? How can they help you? How can you provide claims and evidence to persuade them? This is my method: asking questions. I had at least acclimated professionally."

Criterion 3d: Demonstrate the ability to function on multi-disciplinary teams
The engineering students recognized that their teams extended beyond their three engineering peers. Ten out of the twelve engineering students discussed the communications barriers as well as language barriers that challenged their teams, whether it was on the construction site, dealing with their clients, or in working with their professional mentors.

One team member noted how important it was to balance conflicting perspectives. Advice from professionals in industry and professors, in particular, sometimes seemed contradictory. "In one instance, a professional engineer who specialized in designing septic systems told us that a 24 hour retention time in the septic tank would be more than sufficient while a professor who specialized in wastewater treatment told us that a longer time would be needed to get good removal of solids." Given this, the team had to consider both perspectives as useful, take other elements, such as the size and cost of possible systems, into consideration, and decide what would be the best solution for the client.

Another engineering student noted the disciplinary differences in the project team. While two members of the team had been formally trained in environmental engineering, the third member was a mechanical engineer.

> "It was clear that each discipline brought specific skills to the table and that it was necessary to share information in a way that we could all understand." This student reported that when environmental engineering team members discussed septic systems or water testing, they would go beyond the knowledge of their mechanical engineering counterpart and realize the need to take the time "fill her in."

Noting the practical nature of this practice, the student reported that it helped the entire team discuss "septic systems with our school and neighborhood councils, since we were able to have a general idea of what they would understand initially and what we needed to explain with greater clarity." Reflecting on how these experiences might translate into preparation for the workplace, the students concluded by saying that "this is reflective of what we're likely to encounter both working as engineers alongside other engineers, and working as engineers with clients or the general public."

A third ISD student commented on how working with a scientific and technical communications student provided a different view of the work being done in Bolivia, one that was "informative and insightful in ways we could not have imagined previously. "

A fourth commented on giving a presentation about ISD projects to a client audience in Bolivia: "it was only possible with the help of a fellow Bolivian student. Although this student was studying civil engineering, work with him crossed international borders and was most certainly multi-disciplined."

Sounding a personal note, an engineer wrote "I also found out during this trip how important it is to create friendships with people I would normally not converse with. Living in tight quarters for weeks at a time with the same people could drive people mad. It was very cool to be able to use all of our differences to remain interested in each other throughout the trip. It is important to always respect your "co-workers" and value their input and work output."

The STC student reflected on her role within multi-disciplinary teams by reporting how much learning is exchanged among team members. She reported that she always welcomed feedback about her writing instruction from the engineering students she was teaching. Trained in rhetoric, thus valuing multiple perspectives on communication, she wrote "One engineering student observed that when the author of a composition does not specify a purpose for an audience, it is unintended. I had deduced that rule at one point in my college career, but unintentionally omitted it from my lesson; thus, my student shared an important insight with us, which my lesson had possibly fostered."

She also discusses establishing credibility as a technical communicator in the engineering "firm"—a useful professional process—during the first meeting with each ISD engineering project group:

> "…I met with each group for about twenty minutes, which elevated my confidence level as I returned to my comfort zone; my field of knowledge. The purpose of my meeting, originally, was to define my roles, which the article "Getting Dissed" [13] recommends; therefore, I started by doing that. I proceeded to ask the groups about their projects, and found that some struggled with defining their project scope. I asked myself, "How do I help them do that?"…. I delved into my rhetorical principles in order to help them write or revise questions for future meetings. Rhetoric applies to everything, including (and especially) engineering…."

Criterion 3e: Demonstrate the ability to identify, formulate, and solve engineering problems.

Based on the following extended illustration, representative of all the teams' responses, ISD affords students the opportunity to identify, formulate, and solve engineering problems.

> "Each student team was assigned an engineering project to undertake an engineering problem. The whole process epitomized the ability to identify, formulate and solve engineering problems. That required determining areas that flooded in our project site. The solution required us to collect data, evaluate it, and conduct research. Only then,

> could we formulate an applicable solution to the problem that we identified…. Several design options were determined. The different design options were evaluated in terms of construction cost, life cycle cost, impact on the locals, and maintenance required for each design. A final design was selected that performed best under the selection guidelines."

Students further recognized the "soft side" of solving engineering problems as noted here:

> "To identify our engineering problem it was necessary to determine the social and political stance in our neighborhood. By doing this, we were able to think about fixes to their problem in a politically and socially accepted way."

Perhaps most importantly, students recognized that the complexity of engineering problems extends from the technical to the human:

> "Lastly, the culmination of these two classes was in itself a collaboration of many engineering problems rolled into one final design. All of the intricacies that are involved with appropriate onsite wastewater treatment design required a certain application of engineering problem solving, even logistical parts of the project such as scheduling project work during an already busy class/homework schedule."

From the STC perspective, engineering problems are solved by asking more and more questions, the more probing, the better:

> "Analyzing context in an engineering project entails uncovering its background information: what do we already know? What information do we need to find out, and how will we do that? Data is either the unknown or functions to solve one. What data collection method should the students use? Why? Is another more efficient?"

Criterion 3f: Demonstrate an understanding of professional and ethical responsibility to a design project.

As in the previous criteria, the engineering students went beyond the traditional ethics examples related to their specific project designs and design decisions to include the following, each again relating to recognition of the importance of communication and sensitivity to the socio-cultural aspects of their projects.

In one case, the students commented that as they worked on their design project, they were careful to consider a variety of stakeholders—those who wanted to see the project completed and those who the project would benefit: "who we are doing a service or disservice to." In this way, they concurred with the STC student who commented that "only when engineers understand audience can they ethically design a project."

Closely related to the previous report is this observation by a second design group about how they resisted expediency, combining Bolivian and U.S. standards to come up with a product that would be the safest and most useful for the local Bolivian community: "When doing the actually design work we used a combination of Bolivian and US standards. We did not choose to apply the standards that were most convenient for our design, but those we thought would be reasonable yet still entirely safe."

One group understood the practical intersection of ethics and credibility in communicating with clients: "We understood that the credibility of our report depended upon the professionalism it exhibited and that the better we were able to display this, the more likely the design would be considered for implementation."

And finally, one group commented explicitly on the ethical responsibility that engineers shoulder with their specialized knowledge: "With the specialized knowledge engineers gain through experience and training, there comes an added responsibility of using those skills to uphold a high standard of human health. The beam reinforcement is an example of understanding professional and ethical responsibility, and putting that understanding into action."

Criterion 3g: Demonstrate the ability to communicate effectively.

This criterion clearly deals with communication so it is important that the students recognize the breadth and extent of their communications and the importance associated with each. The following student's response suggests that this goal has been met:

> "Communications was a major part of this course, an ability to do it effectively was a prerequisite for succeeding in this course. Prior to departing the U.S. we were required to contact industry professionals that offered us guidance about necessary tasks to complete. Effective communication was essential in understanding what we needed to do, to be prepared for our projects. After returning from Bolivia, we as a team, needed to converse with industry professionals and professors at two universities. Communicating with these people allowed us to create a design that was optimized through their insight."

The obvious and ever constant language barrier serves to slow the communications and necessitate a more carefully planned approach. One student commented on how important it was to communicate effectively with neighborhood resident and city officials in order to understand the problem that they would work to solve. Another student observed that "hectic schedules and full days" in Bolivia made it imperative to communicate important information efficiently, a task that required "focused thought beforehand." The ability to speak Spanish was noted by another student, who also commented on the difficult task of translation:

> "Translating one language into another word for word is a simple method of conveying a message and not necessarily the most accurate. What is really needed is an interpretation of the language, or a translation taking into account societal and cultural differences and relaying them in a manner that can be easily understood by the receiving party without distorting the message of the conveying party. In many cases, simply understanding that the languages differ is enough to adequately interpret the given message."

And, one last student engineer noted the challenges and rewards of communicating across ages and cultures:

> "To determine the flow that the septic systems are under, the team developed a survey to be used to gather the information. The survey had to be understood by all of the grade levels at the school so it had to be simple in language but also had to be complex enough to get us all of the information we needed. We were able to achieve a good survey by using simple Spanish, simple drawings, and having students choose from answers provided."

The following reflections show the student recognition of future use of their final product: the engineering report. In one instance, a student comments on the importance of audience analysis:

> "Preparing the final engineering report and presentation also improved my ability to communicate and analyze audiences. The report went through many revisions by technical and non-technical readers alike, so that by the end of the revision process I could guess who would change which parts with some accuracy. Audience analysis was also necessary during the presentation, and effective communication was further required during the second presentation recorded for the Bolivian officials."

In another instance, a student comments on the importance of recognizing that different audiences have different information needs. For the client and community members, the student says, the report had to communicate the importance of building the project. For the city officials, the report had to communicate cost effectiveness so that they would be willing to support it. And for those community members who might finally build the project, the specifications and project drawings had to be useable. Finally, one student commented on future audiences—students who might be interested in joining ISD: "For the [project] poster, we had to communicate what we did down in Bolivia and make it sound exciting and fun so that [future] students would like to join the program."

The STC student, too, documented her communication effectiveness in working with her peers. She reported that in order to help her engineering counterparts understand audience analysis, she asked them to analyze a rap that one student had composed.

In her learning log she noted the following lesson in communicating across languages:

> "We walked to their [project] site… and arrived to the barrio (neighborhood) president attempting to communicate with [an ISD student]. [ISD's Spanish translator] fervently began to speak to the president, and proceeded to translate; he wasn't nearly as confident speaking English, so I used my little knowledge of Spanish to aid communication.…. For example, we can use several words to describe a man-made drainage tunnel: ditch, canal, trench, conduit, waterway, and finally, the sole word to describe the structure in Spanish, channel. [ISD's translator] couldn't understand a question [the ISD student] asked about a drainage "ditch." We have so many ways to phrase a question, and similar words. Communicating with Spanish speakers is actually a good English exercise."

Criterion 3h: Demonstrate the broad education necessary to understand the impact of engineering solutions in a global and societal context.

The international aspect and unfamiliarity with local culture, health issues such as malaria, and politics and society automatically catch student attention. Students quickly realize for project success, which entails sustainable implementation, they must develop a clear understanding of the interplay of culture, society and politics as it relates to their project.

Students reflected on the need to understand the volatile political situation of their project location as it related to project funding and increased possibility of implementation both on a governmental and neighborhood level.

International Implications

Students are able to see the need for accurate assessment and understanding of similar issues, once recognized in their own developing world projects, for projects within the United States. For example, a student understood the universality of developing engineering solutions in an international context: "Engineering in a developing country gave us a deep understanding of the creativity necessary to fix familiar problems under completely different circumstances."

Conversely, a student learned how to appropriately differentiate between engineering in different contexts, and stated "Designing a system for one country while working in another gave us experience in dealing with the great variance in design standards. We gained experience in choosing which ones are most ethical and reasonable to use and when we should choose to compromise between the two. (also 3f)"

Another student recognized how solutions on a micro-societal scale can affect macro-society: "Although the neighborhood that we created a design for is very small in a global scale, the impacts of creating a design for it are analogous to creating a design that effects a larger populous. Providing engineering solutions to world problems starts with providing engineering solutions to one neighborhood at a time."

Communication

Although this criterion is focused on the socio-cultural and political aspects, nearly 50% detailed how meetings and communications played a key role in their understanding of these issues as they specifically relate to their projects.

Nearly all students recognized the need for community education or risk communication with respect to their projects, as without this their projects would not be sustainable and succeed. For example, one student identified the importance of an educational flier, which her group had composed as a project supplement, in the sustainability of their storm water drainage project: "The maintenance plan that was recommended is an effort to address societal problems which can adversely affect the performance and safety of the canal. A key part of the maintenance plan is the informational public service flier which can be distributed to residents living in the vicinity of the canal immediately."

The STC student reflected on the importance of considering a community's values in engineering design recommendation:

> “Inner context include beliefs that a society may hold. For example, one group would not be able to effectively design their project without considering their stakeholders’ belief that parks are sacred. Another important belief relates to a Bolivian value: having a job is sometimes more important than efficiency. ISD students should carefully assess how their design could affect locals’ jobs or roles.”

Upon her return to the United States, the STC student viewed engineering project presentations at ISD’s annual symposium, and began to understand the correlation between the health of people and the well being of their society, as it relates to ISD experiences.

> “After viewing ISD students’ presentations, I realized how their projects could positively impact developing communities; however, funding may not always be available. If only developing countries could experience monetary support.
>
> This is true for ISD students’ projects: cleaning up septic systems and canals could greatly improve the health of residents. When people run their residential sewage into the canals, it mixes with rainwater, causing illness. Also, if Bolivian students can study in a cleaner, healthier environment attained by improving a septic system, they are more likely to positively affect society.”

Criterion 3i: Demonstrate the recognition for the need and ability to engage in life-long learning.

Traditionally this criterion is given the cursory, “yes, it’s important” student response, but stretching the ISD students’ comfort zones with respect to culture and language as well as physical construction work with local residents emphasizes the point.

Students easily see the need to grow as they appreciate and respect the construction workers’ wisdom gained without formal education and witness the continual struggle to truly learn a new language. One student with a previous background in the Spanish language commented on linguistic evolution: “I have learned the importance of not only studying a language but also learning to speak fluently. Learning new languages is a life-long process.”

Several students commented on their increased motivation to learn Spanish and most of those have enrolled in a Spanish class.

Within their ISD learning experiences, students discussed the recurrent theme of cross-cultural learning as exchange among people within groups of differing cultural, generational, hierarchal, and educational backgrounds: learning from, as well as about, people.

One student first recognized the need for broad cross-cultural understanding: “In order to solve a problem in another culture it was necessary for us to first learn about that culture and what their lives are like.”

Many students value the opportunity to learn "people skills" in ISD: "I have come to realize the extent to which engineering work involves human interaction. People cannot be learned in a book or studied in college, only slowly understood over a lifetime of encounters."

One student commented specifically on understanding a diverse client base: "ISD has shown me that working as an engineer will bring me in contact with a great diversity of people from various cultures, economic statuses and age groups. In order to operate in the most beneficial way I will need to continue to learning about life though the eyes of these diverse clients."

Learning processes that occur within ISD facilitate understanding across cultures. One student recognized this reciprocity of cross-cultural exchange, and concluded on the importance of ingenious thinking that it fosters:

> "The need for life-long learning was most vividly shown to me through our meetings with the school [project site] and its neighborhood councils... Coming into the situation as a student, it is clear that one of our objectives was to learn and expand our knowledge of engineering and cross-cultural exchange. However, I realized that the people we were working with, often parents or grandparents of students or directors of the school, were learning from us as we learned from them. For many of them, the concept of international students coming to Bolivia for service work was new and exciting. The recognition of the need to think outside of the box for solutions is one that must never end."

Learning about people is of course paired with the need to stay up to date on materials, techniques, and design processes and procedure. Another engineering student advanced this idea of engineering creative solutions and its relationship to continual learning:

> "While researching the different design alternatives, I ran across new/innovative ideas that are being developed (including such things as the Piranha system and constructed wetlands) but are not widely used currently as a means to treat wastewater. This shows me that reading, researching, and learning will be needed to stay on top of the new technologies in the field. So even after I'm out of school, I will need to keep learning."

Recognizing that individual learning experiences are recurrent components of an engineering career, one student wrote,

> "The design procedure was a humbling experience because it allowed the group to evaluate our professional confidence. Therefore, the design procedure for the project showed that one must continuously learn from each project in order to build confidence for future designs. It also reinforced the idea that continued learning allows the engineer to evolve their procedures over time, thereby hopefully becoming more efficient."

All ISD members learn from one another, regardless of their employment position or ISD hierarchy. A student noted the exchange of information and experiences between mentors and project groups:

> "During the course of our project we were in contact with our mentors sharing ideas and discussing the use of different options. Working with industry mentors was a humbling experience, both in term of knowledge differential between the mentors and [me], and also in the observation of how the mentors would learn and grow through their help to us. This was inspirational as well as information[al]. We also were able to introduce some new ideas to our mentors. We learned it is important to keep an open mind and share ideas with others to continue to learn."

Another student defined one form of ISD learning as inter-generational exchange:

> "Over the course of gathering data and completing the project, the client and the design team have an opportunity to learn from each other. This provides for inter-generation learning. Interaction between the design team and industry mentors, university professors and course instructors also provided an opportunity for inter-generation learning."

ISD also facilitated conversation and learning within a student's family: "My work on this project opened the eyes of certain family members of mine to a world different than they were used to, allowing the opportunity for lifelong learning. A relative's comment, "Oh, I didn't even know anybody did that." We never stop learning."

The STC student valued that she learned about the engineering discipline, and how it allowed her to learn about STC in return. Her experiences elicited a learning log response placing value on knowledge discovery: "…I don't know everything about writing and no one expects me to. It's more important to figure out how to learn: how do you find information? Learn a process?"

As a result, she was also able to create cross-disciplinary connections:

> "Although I had no background in engineering, construction, and surveying, I learned applicable techniques/jargon. I found that my specialization relates very closely to engineering. Learning how rhetoric applies to engineering allows me to do the same in other fields. Communicating with ISD students has allowed me to learn more about my major; I feel as though I know how to better instruct my peers."

She similarly recognized the need for cross-cultural interaction: "Through working on the construction site, as well as elsewhere, I have learned how to begin communicating cross-culturally; conversely, locals learn how to interact with us."

Upon returning to the United States, she discussed specifically what she learned about her major, and professionals that she had utilized, such as mentors and literature:

> "I had taken a journalism class prior to traveling to Bolivia; however, writing the news releases challenged me in new ways. I had to summarize ISD for a general audience, and use several different appeals for sub-audiences …. I had never submitted news releases before, but I researched the newspapers and contacted them myself, a process that piqued the interest of a considerable number of newspapers.

…Overall, I learned how to successfully design a marketing campaign…I sought the mentoring of several professors… Without them, my campaign would not have been as successful. In addition, I consulted references, such as The *Associated Press Stylebook* and graphic design resources."

Criterion 3j: Demonstrate knowledge of contemporary issues.

Engineering students automatically again referred to the socio-cultural issues, health (diseases such as malaria and dengue) and safety, economics, material selection for availability and sustainability and the current political implications to their projects as well as lifelong learning. These are covered in previous criteria. The success and possibility of project implementation was important to the students, as was opinion on foreign aid.

One student was able to construct an opinion about this issue based on her ISD project:

> "There is an ongoing discussion whether giving aid to foreign third world countries is actually beneficial to the people or if it makes them more dependent on that aid…. We have been working with the local people to help themselves and also offering technical assistance is quite different from offering financial aid."

The role of ethical engineering surfaced again, in that innovative or technological solutions are not always best, especially if unfamiliar to its users, "The culture and traditions of Bolivia are very strong. With this in mind the community is unlikely to accept a design that is vastly different from the one they are used to." Thus, the realization of appropriate technological implementation also increased cultural understanding.

Students were encouraged to research issues surrounding Bolivia before the actual in-country experience. In the process, one student was introduced to global media outlets. While interacting with Bolivians in Santa Cruz, students felt a heightened awareness of issues affecting the area and specifically their projects, "Santa Cruz's fight for autonomy from the central government of La Paz, Cochabamba's water wars, and opinions on President Evo Morales were just a few of the issues I was exposed to." And after returning, another felt compelled to stay updated on global news after returning to the United States, and stated: "I think that classes such as ISD help students develop a lifelong desire to educate themselves above and beyond the required."

ISD opened up a dialog within a student's family to discuss the contemporary issues of Bolivia, about which they inquired, "…This project truly became a way of life, affecting not only me and my grades, but also those around me who were curious and wanted to learn more."

STC recognized the crucial role of understanding the global context and the importance risk communication plays in a successful and sustainable developing world project:

> "Understanding society is vital to engineering, such as how funds are allocated. Santa Cruz craves autonomy, which eventually effects funding. Garbage disposal is also an important issue: without future education and risk communication, engineering designs risk failure." She also mentions population of Santa Cruz, which continually increases

> and poses a contemporary dilemma, "[Santa Cruz's] Infrastructure cannot support the boom; thus, this is important to evaluate."

Criterion 3k: Demonstrate the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The engineering students cited traditional tools and techniques, such as team and mentor meetings, time management, computer programs, surveying and onsite testing and data gathering.

The STC student originally did not feel that her discipline applied to Criterion 3k, but in the final report stated that she had learned how to further operate presentation and graphic software that professional communicators use: "I learned how to utilize Photoshop better…the only way to learn how to operate that program is to actually use it." Since she was a part of the ISD "firm," it contributes to modern engineering practice.

As in the previous criteria, communications was noted as an "engineering skill that was used and will be used again" by several students. For example, one student said that writing a report for an audience, such as city officials, is an integral part of engineering communication practice and also states, "Compiling the report serves as an examples of our proficiency with modern engineering tools and practices."

Time management was a useful skill in ISD due to the amount of coursework, as one student pointed out, "This course served as a time management lesson that forced us to prioritize… This is a skill that no doubt will be used in our professional careers."

Learning techniques and skills typically used in a culture allows engineers to ethically practice within that context, "Although unorthodox for the United States, [the techniques, tools and skills] were common practice with the Bolivians and extremely applicable for engineering practice in Bolivia."

Conclusions

Our flat world and global marketplace demand a new breed of engineering professionals; and thus, a new approach to engineering education. New engineers need to be culturally sensitive and recognize the need, value and synergy of interdisciplinary knowledge and collegiality.

Courses, such as ISD, that remove students from traditional and often blinding US comforts, such as ISD, foster a more rapid and thorough integration of socio-cultural sensitivity and interdisciplinary components and values than traditional courses. Combining the conventional, yet unfamiliar corporate culture of the ISD "firm" resonates with students and allows them to "rehearse" a professional engineering experience.

The international service learning setting requires students to consider more carefully unfamiliar social and community issues that impact the success of their engineering projects as well as those projects' technical, environmental and economic implications.

The ISD model allows students of different disciplines to recognize the value of interdisciplinary synergy while working together to resolve community needs in developing countries.

The hybridization of engineering and STC majors in ISD demonstrates the advantageous nature of interdisciplinarity. Creative solutions integrating engineering and communication, especially risk communication, are beneficial not only in the developing world, but also here in the United States as international business and practice continues to globalize. Additionally, as students noted, many engineering methods and principles students gain from ISD are applicable in other practical engineering contexts.

This paper has demonstrated how ISD students fulfill each ABET 3a-k criterion regardless of their chosen study discipline. The ABET 3 criteria effectively serve the STC major as well as engineering majors.

Furthermore, one can argue, judging from student feedback, local community engagement as well as ISD alumni involvement, that this is not a typical course. It obliges students to think more deeply about personal and professional issues than does traditional coursework. Students categorically say they now feel ready and eager to enter the workforce. This eagerness along with risk taking and the ability to think simply but ingeniously combines with a new sense of self confidence, creating traits that have been recognized and sought by recruiters. As one student concluded:

> "Above all, through hard work I have earned the confidence I need to take on whatever challenges life (engineering or not) may present. I have no doubt that this experience will stay with me for my lifetime and that had I not partaken in this experience, I would not have the same outlook on life. These classes are those that I most highly recommend to prospective students and those that are viewed most respectfully when I speak to future employers."

In addition, at a rate double the national average, ISD courses attract civil and environmental engineering female students, who, according to their comments, truly feel a "comfortable fit" into engineering for the first time. Hopefully this will translate into increased retention of women engineers in the field: a future study topic.

ISD courses are a model for educating the socially conscious engineer: one who values disciplines traditionally considered "outside" engineering project boundaries, respects and appreciates the importance of socio-cultural issues and is inspired to service and stewardship. It is also a model for breaking the long established and well-built departmental boundaries of our universities. If students are to appreciate interdisciplinarity, we, as educators, must as well.

For almost all ISD students, it is an experience of a lifetime and for some; life changing.

> "The collective International Senior Design experience has been incomparably influential in my life. This experience has given me so much confidence in myself as a person interacting with other people and as engineer. I feel that I am ready to enter the world as a professional and make a difference. It has also given me great

excitement for the future."

"I have found something to be passionate about and it helps to give my life more meaning. …These past few months have been the best of my life and I have become a better engineer and human because of them."

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Appendix 1

International Senior Design Assessment Tool (ISDAT)
Department of Civil and Environmental Engineering

Please answer the following 90 questions. There is no right or wrong answer; simply state what feels best to you. Your input will help us determine what is working and what needs to be refined. All responses will be kept confidential. Only group results will ever be shared with others.

Background Information

1. Name:
2. Major (civil, environmental, etc.):
3. Age:
4. Gender (circle one): M F
5. International experience. Rate your prior experience. Use a 0-10 scale, 0 is no prior international travel/living, 10 is frequent experiences (e.g. annual trips, or living abroad for more than a year total). Put answer in box at right.
6. Reasons for taking this senior design option. *Rank* the following criteria as they influenced your decision to do this Senior Design (1 most important, 2 next most, and so on)

_8___cost
_3___design experience
_4___travel experience
_1___chance to make a difference
_7___counts for 6 credits
_2___to challenge myself in new ways
_5___comments from past participants
_6___employability
_____other (please specify, if applicable):

For each of the following questions use the 0-10 scale below and place your response in the blanks, unless otherwise directed.

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Strongly disagree					**Neutral**					**Strongly agree**

About You (Questions 7-65):

7. ____ I have confidence in my ability to interact effectively with my team members
8. ____ I have confidence in my ability to interact with industry mentors
9. 24% I have confidence in my ability to interact with local constituents (villagers, mayor, etc.)
10. 15% I have confidence in leading a project team
11. ____ I have confidence in working as a productive team member
12. _6%_ I have confidence in my technical problem solving skills

13. _10%_ I have confidence in framing a problem and organizing a possible solution approach
14. _14%_ I have confidence in preparing a complete engineering report
15. _17% I have confidence in preparing and presenting a formal oral client presentation
16. _9%_ I have confidence in preparing design alternatives
17. _7%_ I have confidence in analyzing feasibility of design alternatives
18. ____ Learning throughout my life is important
19. ____ Ethical behavior in my engineering work is always important
20. ____ Local culture is an important influence on engineering design
21. _14%_ Political influence in engineering issues or project delivery is important
22. _11%_ I understand the definition/meaning of sustainability
23. _5%_ Sustainability is important to all engineering projects
24. ____ Safety is critical in my work
25. _11%_ This experience will be greatly valued by prospective employers
26. ____ This experience will be of great value to me as a person (non-professional reasons)
27. _5%_ This experience will provide skills that can be transferred to my next/first job
28. ____ This experience will provide cultural wisdom to help me better understand the world
29. _5%_ This experience will help my understanding of the political climate in my project site country
30. _7%_ This experience will help my understanding of the socio-economic issues in my project site country
31. ____ This experience will help me understand how others view my own country
32. ____ This project will require excellent teamwork to succeed
33. _19% This senior design experience meets all the criteria that ABET expects
34. _5%_ My marketability in the job market will be much better because of this experience
35. _17% I am confident in assessing the social aspects of my project on the local community
36. ____ I am confident in analyzing technical aspects of project alternatives
37. _10%_ I am confident in analyzing economic aspects of project alternatives
38. ____ I am confident in analyzing sustainability aspects for project alternatives
39. _17% I am confident in assessing the political aspects of project alternatives
40. _18%I understand cultural preferences and their impacts on project alternatives
41. _5%_ I understand potential environmental interactions of project alternatives
42. _25%I understand constructability issues for project alternatives
43. _14%_ I understand health and safety issues for project alternatives
44. ____ Listening skills are important for the success of my project
45. _5%_ Speaking skills are important for the success of my project
46. ____ The amount of work for this project is fair for the rewards gained
47. ____ I value past class work
48. _9%_ Presentation skills are important to the success of my project
49. _11%_ Report writing is important to the success of my project
50. -28%Life is much better in the U.S. as compared to my project site country
51. _15%We have much to teach/show the people in my project site country
52. ____ We have much to learn from the people in my project site country
53. _-38% I wish I could work on my project alone rather than on a team
54. _15%I know how I could volunteer my time
55. _13%_ This experience will change what I value in my own life
56. ____ This experience will change my career plans

57. ____ I wish we could spend more than two weeks at the project site
58. _8%_ I wish we could see our project built
59. ____ I am confident about interacting with the local population at my project site
60. _7%_ I need to understand the language, art, religion, philosophy, and material culture of my project's country to offer the best design possible
61. _35% I understand the culture of my project's country
62. ____ I am working on this project mostly for my benefit
63. _23% I am working on this project mostly to benefit my "clients" at the project site
64. _-15% I am working on this project mostly to fulfill degree requirements

65. How do you think your involvement in this international senior design experience will be valued by industry (e.g. in their perception of you as a potential employee)? *Rate* the following reasons (4=extremely valued by industry, 3=somewhat valued, 2=no value to industry, 1=discouraged by industry).

_6%_ Ability to work well with people of diverse backgrounds
____ Ability to be a valuable project team member
____ Ability to work in a demanding location
____ Ability to integrate the human element (e.g. social, political, cultural) into design
____ Flexibility required to cope with unexpected events influencing my project or life
____ Ability to take a project from start to finish
____ Ability to work autonomously
____ Passion about my work, life, and ideas
____ Ability to take risks
_13%_ Ability to continuously learn, challenge my perspectives, and grow
_7%_ Ability to recognize need then respond with effective action
____ Ability to come up with creative solutions
____ Ability to ask good questions
____ Confidence to handle any problem I encounter
____ Other (please specify, if applicable):

The Project (Questions 66-90. Use the 0-10 scale above, except Question 90):

66. _7%_ Required application of knowledge and skills acquired in earlier engineering coursework
67. _11% Was focused on the process of designing a system, component or process to meet desired needs
68. _6%_ Incorporated decision making involving choices between alternatives
69. _14% Is relevant to civil or environmental engineering (i.e. prepared me for professional practice)
70. ____ Required me to work in multi-disciplinary teams (i.e. people with different professional training)
71. _9%_ Contributed to my ability to formulate and solve engineering problems
72. ____ Contributed to my ability to communicate in writing effectively
73. ____ Contributed to my ability to orally communicate effectively
74. _24% Contributed to my ability to use modern engineering tools and techniques
75. _11%_ Contributed to my ability to apply engineering principles to solve problems

76. _11%_ Contributed to my ability to analyze information from diverse sources
77. _6%_ Contributed to my ability to assess the quality of information from sources
78. _5%_ Contributed to my ability to interact with professionals
79. _7%_ Contributed to my professional understanding
80. _18%_ Had significant practitioner involvement
81. _14%_ Required me to consider economics on project design
82. _6%_ Required me to consider the environment on project design
83. _9%_ Required me to consider sustainability on project design
84. _9%_ Required me to consider constructability on project design
85. ____ Required me to consider ethics on project design
86. _14%_ Required me to consider health and safety on project design
87. _8%_ Required me to consider social issues on project design
88. _9%_ Required me to consider political issues on project design
89. ____ Required me to be creative in the project design process
90. *Rank* the following nine criteria regarding their importance to your project's final design (1 is most important, 2 is next most important and so on down to 9 which is least important)

Economic _____
Environmental _____
Sustainability _____
Constructability _____
Ethical _____
Health and safety _____
Social _____
Political _____
Creativity _____

Any additional comments may be written in the space below.