Abstract - Every engineering educator grapples with the challenges of globalization in the profession and how to prepare students. The typical reaction is to look into forging links with Asia, especially China. Look at all the bilateral agreements between engineering schools in Europe and North America with engineering schools in China, often involving the exchange of students and faculty and even the opening of campus locations in China. We propose, and have developed, an alternative that meets nearly every objective of these programs but that has its own additional benefits: collaboration with Latin America. At Santa Clara University the School of Engineering has established a collaboration with El Salvador taking advantage of the University’s longstanding tie with the University of Central America in San Salvador. Through this program, which includes exchanging students, we provide our students with exposure to a different culture, language, social environment, economy, and time zone. Importantly, our students encounter students who despite quite disadvantaged backgrounds excel academically, work extremely hard, and cost far less to employ in a climate that values engineering as a national priority. Is this not what all the China programs strive for? Our program, fully integrated into the engineering curriculum, includes coursework both local and remote, local laboratory assignments, community-based learning, and senior design projects. In particular, the student projects, some of which have already gone into deployment and manufacture in El Salvador, are relevant to local needs and achievable under the constraints of the local economy. Throughout the experience, the students consider economic and environmental sustainability and strive to benefit society in real terms. In this paper, we describe the local and remote elements of the program, its relevance to Santa Clara University’s mission of advancing the cause of social justice, the learning outcomes and educational objectives, and lessons we have learned.

Index Terms – Engineering education, globalization, study abroad.

INTRODUCTION

The specter of globalization looms large in the minds of engineering educators and students everywhere. Reports, however exaggerated, that all engineering jobs are moving to India and China cause some students to flee the profession and others to desperately worry if they will be employable when they graduate. Wise educators seek the advice of engineering employers, who often feel compelled to establish their own R&D facilities in Asia for fear of becoming uncompetitive. Who has not heard the message trumpeted by New York Times foreign affairs correspondent Thomas L. Friedman in his book The World is Flat [1] that communication technologies and the Internet make it possible for well-educated people anywhere in the world to compete on the global job market?

We are daunted by the number of engineering graduates from Asian countries. In 2005 the U.S. graduated 72,911 B.S. degree candidates in engineering [2], not that different from South Korea, which has around one-sixth the population and one-twentieth the Gross Domestic Product [3]. We have all heard estimates of the number of B.S. engineers graduating in China every year, some as high as ten times the U.S. figure, and we know that they earn a lot less than their U.S. counterparts.

U.S. universities react in many ways, from changes to engineering curricula, new ways of teaching engineering, broadening the education of engineers to include topics not considered hard-core engineering, providing engineering students with international experiences, and attempting to attract foreign students and their tuition money. Advice, like that of Stephen D. Bechtel, Jr., chairman emeritus of Bechtel Group, Inc., is on target: “You must be highly effective communicators, especially cross-culturally. You need to know the world and the other people who work in it” [4].

A number of engineering programs have reported on design projects with international components. In some cases, these have involved structured programs between a group of universities, such as the Global Product Realization course begun with Delft University of Technology, University of Michigan, and Seoul National University [5-6]. This type of program has students from each institution participating in a common design project and communicating through the Internet and other remote means, with possible face-to-face meetings as well. The various programs report considerable overhead costs in sustaining these collaborations. Another approach that has been proposed involves establishing a
generic framework for international projects that is open to interested schools to join [7]. In this case, a common project is established each year and those who are interested join in and adhere to the constraints and a somewhat flexible timeline (to allow for the high variability between academic calendars around the world). Results from the implementation of this proposed scheme have not been reported.

The main objective of these meritorious programs is to infuse globalization elements in the educational training the engineering students are receiving. Training engineering students to think globally has become a necessity, and has been recognized as one of the major challenges in engineering education today [8-9]. An engineer trained for the world market place must be equipped with basic attributes that include awareness to different cultures and economies, team orientation, excellent communication skills, and social and environmental conscience. There are however, significant barriers in providing global awareness to engineering students, particularly undergraduates in the U.S. institutions. When these experiences are based in Asia, numerous challenges of significant magnitude face their participants. These range from the extreme challenge of learning most Asian languages and the absence of reliable legal systems to the massive distance and the high costs that must be borne if students and faculty are to live in a manner even remotely resembling that of their home environment, especially with respect to safety and health.

LUATIN AMERICA INSTEAD OF ASIA

At Santa Clara University, we are proposing a different model to address globalization in engineering education, focusing on collaboration with Latin America. We believe that our program, which is fully integrated in the curriculum, offers all of the benefits of Asian-based programs (except for the specific familiarity with Asia) and addresses the challenges of educating engineers for a globalized workforce including cultural, social, and economic differences, team effort, and understanding of new and often quite different customers. Latin America offers eye-opening, thrilling, and humbling experiences for engineering students (and faculty). Most economies are on the upswing with massive investment in technology and education. Engineering is viewed as a profession essential to raising the quality of life in the country, with attendant prestige accorded engineers (something sorely lacking in the U.S.), and engineering students can witness needs on a daily basis that their skills can address. Engineering students there are motivated, skilled, and inexpensive. English is not widely spoken, but Spanish (or Portuguese) can be learned fairly quickly.

We have also chosen Latin America because Santa Clara University enjoys a long-standing and substantive relationship with a university and community there, one that reflects the University’s values of compassion and social justice, which we feel the profession of engineering aligns with and advances. Our main partner in the collaboration is the Universidad Centro Americana José Simeón Cañas in El Salvador, known as “the UCA”. The UCA is a Jesuit-based University located in San Salvador with a strong tradition of social involvement for the benefit of the underserved in El Salvador. The UCA played a major role in ending the civil war of the 1970s and 1980s, and the school is now focusing on the reconstruction of civil society. Santa Clara University, also a Jesuit school, maintained organizational and personal ties to the UCA during the civil war, and the tragedies of the professors there serve today as examples of education as an instrument for social justice carried to the extreme.

Today these ties are embodied in a program called la Casa de la Solidaridad (Solidarity House), an academic initiative between the Association of Jesuit Colleges and Universities, the UCA in El Salvador, and Santa Clara University, dedicated to promoting social justice and compassion among students and faculty of different schools. The Casa program brings students and faculty from SCU to El Salvador for immersion programs of typically one or two weeks’ duration as well as study-abroad students from across the U.S. to El Salvador for entire semesters. Both the immersion experiences and the study-abroad programs include community-service activities with the many people and organizations with which the Casa has relationships. Santa Clara University maintains permanent staff and facilities in El Salvador, which provides the School of Engineering with a foundation upon which to build its globalization program.

SUSTAINABILITY: OUR GLOBALIZATION THEME

Also anchoring our approach to globalization is the theme of sustainability in engineering. The developing world uses vastly fewer resources than the developed world but the former’s use is accelerating at a greater rate than that of the latter. We know this use by both world communities is unsustainable, and we also realize that we have an opportunity to establish better practices before theirs become as wasteful as ours. Moreover, we believe that the road to prosperity in the developing world will be faster if they establish sustainable practices with indigenous resources than if they have to compete with the developing world for scarce resources, especially those that are expensive to transport. To this end, the UCA’s engineering school is promoting sustainable development as well.

Compatible with this, the School of Engineering at Santa Clara has been engaging students in socially significant projects for many years. Santa Clara has a long tradition of activism through community involvement to improve the human condition and expose students to the lives and needs of the less fortunate. This tradition arises naturally from the Jesuit educational philosophy of a comprehensive education as a means to promote social justice and compassion, particularly for the underserved.

Promoting social consciousness and compassion may be a more challenging task in technical disciplines such as
engineering, compared to the humanities and social sciences, though we believe there is no profession better suited to improving the human condition than engineering. SCU’s School of Engineering has introduced these values most pointedly through the Senior Design Project sequence, which all engineering students must complete. Past examples of projects that have highlighted these values include construction and design of a low-cost prosthetic manipulator for amputees and a specialized tricycle for juvenile victims of Cerebral Palsy.

With the support of the SCU Bannan Center for Jesuit Education, the Arrupe Center for Community-Based Learning, and the Center for Multicultural Learning, we have now initiated cooperation with Central American institutions, centered on the UCA, in sustainable engineering technologies and practices with the intention of developing methods to implement sustainable engineering practices serving societal needs while providing students and faculty with a globalization experience.

A series of joint activities with institutions in Central America have been initiated that are leading to a profound understanding of sustainable engineering practices in developing countries. These activities include joint workshops to review on-going practices for implementing sustainable engineering methods, community-based learning projects in which students identify needs of the communities and suggest sustainable engineering alternatives, bidirectional distance learning for the transfer of knowledge and social awareness, collaboration among faculty members and both governmental and non-government organizations to find sustainable alternatives to identified problems, and identifying international resources to implement solutions to problems of highest priority.

**ACTIVITIES BETWEEN SCU AND THE UCA**

The first major activity of the SCU-UCA collaboration was a joint workshop on sustainability for Central America held at the UCA in August 2004. This workshop included a comprehensive review of sustainable engineering methods and practices in the following topics: energy, water resources, disaster-resistant structures, transportation, and environmental monitoring. Around 40 faculty members, students, and others participated, including people from Lawrence Berkeley National Laboratory, Universidad Nacional Autónoma de México (UNAM), United Nations Development Program, the US Agency for International Development, the Peace Corps, and the Interamerican Development Bank.

The main outcome of the workshop was a comprehensive list of potential projects and opportunities in sustainable engineering in which academic institutions could collaborate and have a significant societal impact. The scope of application of the projects is concentrated in El Salvador; however, a great majority of them involve technologies that can be applied at other locations in Central America and elsewhere. Follow-up activities from this workshop have included identification and execution of engineering senior design projects, collaborative courses between SCU and the UCA via distance learning, collaborative research projects among faculty from several institutions; and a two-way traffic of students and faculty members between SCU and the UCA.

**Senior Design Projects**

Engineering Senior Design Projects were initiated after the conference on sustainability. Each project involves a small group of senior engineering students supervised by one or more faculty. The projects respond to specific needs of the communities (of El Salvador in this case), and are providing unique opportunities for students and faculty to interact with and learn from members of the communities, while adapting their engineering training to present sustainable solutions to real life problems in different parts of the world [10]. Indeed, we feel that if we can find solutions that make economic sense in the developing world there is no reason they cannot apply worldwide. Some of the projects are sponsored by international governmental and non-governmental organizations.

The collaborative engineering senior design projects centered on sustainability and with an international component have proven to be a unique experience within engineering education. There are other engineering programs that have reported on design projects with international component [5-6], but few of these were in sustainable engineering. A program closer to the one established between UCA and SCU is the one at the University of Arizona, where a team of students undertook one design project in the cross-border towns of Nogales, Texas and Sonora, Mexico [7].
One exciting is the Human Powered Utility Vehicle. El Salvador is a small Central American country that is still recovering from a significant period of civil strife. Standards of living and civil infrastructure have suffered accordingly. Both the government and various Non-Governmental Organizations (NGO’s) have launched programs to encourage the development of a sustainable economy. One such program is headed by Centro Salvadoreño de Tecnologia Apropriad (CESTA), and it promotes the use of human powered transportation. It is common to see three-wheeled cycles in the rural villages that are used to transport goods and people from place to place. Figure 2 is a typical example. CESTA currently manufactures some of these vehicles for sale to villagers.

CESTA initiated a project to have a student team redesign such a vehicle so that it could be made cheaper and more durable. They outlined basic requirements and turned it over to SCU faculty. One of the major constraints was that these vehicles had to be made primarily using parts from existing bicycles, which CESTA receives from US organizations, such as Pedals 4 Progress. The goal was to have a design that was able to use a wide range of frame types and sizes without compromising the strength or functionality of the HPUV, and to minimize the original fabrication that was needed.

A team of six mechanical engineering seniors (Willy Arroyo, Cody Bedell, Robin Bell, Andrew Leland, Charlie Leone, and Francisco Prado-Cervantes) took on the project in the fall of 2004. Near the end of the fall quarter, two of the students traveled to El Salvador to meet with CESTA personnel, speak to potential users, and see the existing vehicles in action. They returned with a realistic set of requirements and constraints. Further refinement of the design soon followed with a sharper focus on manufacturability and cost, especially to use existing bicycle parts.

During winter quarter, the team manufactured a usable prototype of their new design, the Road Runner. This was based on a simple cargo container of steel tubes and angles, attached to the rear frame of a bike. The front wheels were two steerable front fork assemblies welded to the sides of the cargo bay. This was a departure from the vehicles currently in use, such as shown in Figure 2, which have fixed axle front wheels and articulate the whole cargo container to steer. The steering linkage for the new design was based on a four-bar linkage system and took some fine-tuning to make stable.

Additional team effort was focused on the braking system and on means to reduce tire puncture frequency. Disk and other brake systems were investigated, but standard cantilever brakes were eventually chosen for cost, simplicity and familiarity reasons. An innovative activation system for the two front brakes was designed to allow both brakes to be applied simultaneously and evenly. Testing and cost analysis pointed toward tire sealants for puncture resistance.

During the spring quarter, a second-generation vehicle was manufactured. This not only represented a system with a number of design improvements, but also was used as a manufacturing model. A series of simple jigs and fixtures was made to aid mass production, and these were used in construction of the new prototype. Also, an extensive and detailed manufacturing manual was created with step-by-step instructions and illustrations. In the Spring quarter, four students returned to El Salvador with the custom jigs and fixtures to train the CESTA employees. Manufacturing time was reduced from 15 days to one.
Island in El Salvador. The students developed a novel control mechanism for a system with multiple solar panels and multiple pumps to ensure continuous pumping of some water during all daylight hours. Figure 4 shows the system under test in Santa Clara; Figure 5 shows the students landing on the island. The system is currently being deployed there, funded by the United Nations Development Program.

FIGURE 4: SOLAR WATER PUMPING SYSTEM FOR ISLA ZACATILLO.

FIGURE 5: ARRIVAL OF STUDENTS ON ISLA ZACATILLO.

To facilitate and maintain close communication between SCU and UCA Schools of Engineering, a distance learning/teaching program has been initiated. Two equivalent videoconference facilities were installed, one at each institution, to allow meetings between students, faculty, and members of the communities where the senior design projects are taking place. The facilities have also enabled SCU students and faculty to increase residence time in El Salvador. Some regular engineering courses at SCU are now broadcasted directly to and from the UCA allowing students and faculty to attend or teach their regular courses while in El Salvador. UCA students are also taking advantage of these facilities, and are joining SCU students for regular courses being offered in SCU. Courses such as Fundamentals of Aerospace Engineering and Heat Transfer have been offered to both groups of students since the facilities were first installed in the winter 2005. Figure 6 illustrates the class in San Salvador.

FIGURE 6. UCA STUDENTS TAKING SCU’S PROFESSOR MARK ARDEMAS AEROSPACE COURSE (AS SEEN IN THE VIDEO FACILITIES)

STUDENTS’ EXPERIENCE

Since the fall of 2004, more than forty engineering students have participated and benefited from the SCU-UCA collaboration for sustainable development. The fact that these students tailor their engineering designs to directly benefit the underserved has not hindered the quality of their projects; rather this has enhanced their learning experiences. Some of their designs have received the highest awards in national competitions [11], as was the case for the team which developed the human powered utility vehicle for villages in El Salvador during the 2004-2005 school year. The most recent story includes five senior mechanical engineering students who are designing and constructing an underwater autonomous vehicle to monitor the water quality in the Lempa river, the main fresh water source of the country. These students spent half of their fall 2005 quarter in El Salvador working with UCA faculty and members of local communities, adjusting their design to the specific needs of the El Salvadorian people. The students maintained the same curriculum as their classmates, thanks to the distance learning equipment now available at SCU and UCA. The academics of this group were not negatively affected by this experience, as they all performed at the same, or higher, levels as their classmates. They are now preparing to complete their system, test it, and deliver it to their customers, the Salvadorian Communities. Returning students speak of being “transformed” by their experience.

LEARNING OUTCOMES AND EDUCATIONAL OBJECTIVES

We feel that our collaborative program with El Salvador on the basis of contributing to a sustainable society has all the
elements that globalization in engineering requires. The core engineering courses and projects meet the established ABET outcomes a-k for the students’ respective disciplines (which included mechanical, civil, and electrical engineering). They also meet the Santa Clara objectives for working in teams, appreciating the interdisciplinary nature of practical engineering, understanding contemporary issues, being committed to professional ethics, having compassion for the less fortunate, communicating well with people of other disciplines, cultures, and languages, and valuing lifelong learning.

LESSONS LEARNED

As we encourage our students to think globally as engineers, experiences such as those described here can be extremely helpful in opening eyes and minds as to what that really means. These projects would have been challenging on their own, so it may have taken exemplary teams to complete them to such high standards. Nevertheless, all students in the senior class benefited from hearing about these projects and many of this year’s juniors are looking forward to taking part in similar projects next year. We feel it important for all students to believe they can do it.

Both universities are committed to continuing this global cooperation in the future. The collaboration is cemented under the umbrella of sustainable engineering practices which has been a very important initial step to promote the conscience, compassion, community-based learning within a global perspective. The collaboration is clearly beneficial to both SCU and the UCA. On one hand, SCU students and faculty appreciate the opportunity to channel their efforts into projects that will have immediate social global impact, benefiting from the UCA’s experience and strong tradition of practicing social justice in El Salvador. The experience gained through this collaboration is providing the faculty members involved with further opportunities for scholarship while strengthening the aspiration of the school of engineering of making sustainable development an integral component of our curriculum. On the other hand, UCA students and faculty benefit from the updated knowledge and practice in state-of-the-art topics and technologies residing within SCU. The fact that a valuable cultural exchange and flow of ideas is taking place adds lure to these initial steps. We are careful, however, not to give the impression that when we go to El Salvador we are the saviors. Their students are as competent as ours, and we learn as much as, or more than, we teach.

We also learned how to improve the program. The students who spent fall quarter there felt they needed better language skills and suggested we incorporate a summer extension for intensive Spanish. They also found that the community service projects from the Casa program left them insufficient time to do their regular engineering homework and projects. Indeed, the mainly liberal-arts majors in the Casa program gained a new appreciation for how hard engineering students work. This was an unexpected positive outcome.

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