AC 2008-1421: USING TECHNICAL ENTREPRENEURSHIP AND SERVICE LEARNING TO PROMOTE AN INTERNATIONAL PERSPECTIVE IN AN UNDERGRADUATE ENGINEERING PROGRAM

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Using Technical Entrepreneurship and Service Learning to Promote an International Perspective in an Undergraduate Engineering Program

Introduction

Promoting an awareness of the international aspects of engineering practice is not a simple task. At our university we believe that our students need to learn how to practice engineering in an international setting. Our plan to accomplish this has several new educational opportunities for our students.

The first opportunity is engineering service learning experiences in developing countries. These projects have all been based on prior contacts with a poor community that needs some engineering help. We have gone only to places where the people in the local community indicate to us that they have a need our students can help fulfill. With this prior contact our students are able to design the project here on our campus and then the international trip allows for on-site implementation as well as rewarding contact with the "customers."

Our students have created a student run organization to promote such experiences. Over the last three years students have gone on service learning trips to Kenya (2 trips), Armenia (2 trips), Papua New Guinea, the Philippines, Honduras (2 trips), and Vietnam. These trips help out poor communities in other countries. Even more, they change our students' perspective about themselves and our world.

A second opportunity is our students providing engineering design services for a partner organization overseas. For example, our students have worked with Bridging the Gap-Africa. We have provided analysis for 45 meter long pedestrian bridges that BTGA is currently building to verify the safety factors. Currently we are helping to design a 90 meter long pedestrian bridge for Kenya that will allow a disenfranchised community on the far side of the river to access markets, medical care and schooling. Working with partners thousands of miles away has been a challenging experience for our students. Helping improve the quality of life for very poor people has been a very rewarding experience.

The third opportunity has been the creation of an option for our students to take a two course sequence focusing on technical entrepreneurship. We have created a new course entitled *Global Business: Economics and Communication* that introduces students to engineering economic analysis, professional speaking and technical writing. A term project requires the preparation of a feasibility study of a technical project, requiring students to use library and Internet resources, appropriate writing and formatting skills, engineering economic analysis and a professional presentation. In a sequel course taught by the business school entitled *Technical Entrepreneurship*, students use these skills to do a feasibility study for a technical company. The technical entrepreneurship class can be taken on campus in the spring or during the summer in east Asia.

These three opportunities are all part of a strategy to encourage our students to think and act globally.

Engineering Service Projects—Preliminary Work

Up to this point, our engineering service projects have not been done for academic credit. Some students have taken a related technical elective in Appropriate Technology that helped to prepare them for their international experience. By doing this on a volunteer basis, we are able to recruit students from the freshman year through the senior year to work on the projects, each one at his level of knowledge and ability. This would be harder to do if it was done for academic credit. On the other hand, if done for academic credit, perhaps we could do projects of larger scope. We are currently evaluating how we might add academic credit to some of the projects while still preserving the freedom we have by doing them as an extracurricular activity.

These projects are an outgrowth of a student created service organization. This group promotes engineering service projects in other countries. It is loosely patterned after Engineers Without Borders from whom we have learned a great deal.

For a project to be successful, there are some things that need to be done before the project can be implemented. They are:

1. Have contacts in the country who are interested in having us do the project and who can act as a resource.
2. Know enough details about the project so that the design work can be done during the academic year at our university.
3. Raise enough money to pay for travel to the country and to purchase the needed equipment.
4. Have someone from our university handle logistics on the ground in the other country so that the faculty member and students can concentrate on the engineering project and not get overwhelmed by just surviving in that country.

<u>Local Contacts</u>

This is a critical component for the trip to be successful. For this to occur, there may need to be a small exploratory trip occur before the major trip can be organized. For example, six students and three professors from our university went to several locations in Kenya in spring 2005. These locations were based upon prior contacts that the professors had with people in the country. While there were some minor engineering projects completed during that trip, the main purpose was to explore future possibilities. We have previously reported on this trip at the spring 2006 ASEE regional conference in Baton Rouge[1].

This exploratory trip resulted in two groups of students going to Kenya in 2006. One group installed a wind powered electrical system in the Kibera slums of Nairobi[2]. The other one put in a water purification system at a Deaf School in the western Kenyan town of Oyugis. This school did not have a permanent source of electricity to run the purifier. Therefore, part of the project was to design and install a solar powered electrical system for the school. This was reported on at a 2007 ASEE regional conference in South Padre Island[3].

In January 2007 a professor led a small team of students to Honduras to examine the possibility of installing a small hydroelectric system in a mountainous village. This led to a larger group going in the summer of 2007 to do the actual installation. We have since received a grant from a foundation that will allow us to replicate this in other villages.

One of the authors went to Rwanda in January 2008 to examine potential projects. There are several electrical and water projects that could engage and challenge our students. This includes helping out the Sonshine School near Ruhengeri, Rwanda, and a medical clinic in Shyira, Rwanda. Good contacts were established at these two places. They are very interested in our coming back with students to help them out, probably in late spring 2009.

Design work done ahead of time

Engineering design work takes time, and this needs to be started at least six months before the trip. This will allow a tentative final design to be completed and all items that cannot be purchased in country obtained. Recognizing the nature of the developing world, students should expect that some things will need to be changed once they get to the project site. To save shipping, and to help the local economy as much as possible, most equipment should be purchased in the country where the work will be done. From a maintenance perspective, it is also important that replacement parts be readily available. These constraints may well change the nature of the design itself.

Raising money for the trip

Engineering service trips are not cheap. For example, the per person cost of the 2006 Kenya trips was about $2,500. In addition to that each group had to raise about $2,000 of equipment money. The faculty and the university need to be ready to help the students raise the funds for the trip. Some student families can pay for the trip, but many are not able to do so.

Cost should be something that goes into the decision making process about which trips to undertake. While we will continue to do work in East Africa one of the reasons we have begun to work in Central America is that it is much closer and the costs will be less. The time involvement will also be less. For example, to get to Rwanda, it is an 8.5 hour flight from Atlanta to Brussels and then another 8 hour flight from Brussels to Kigali. On the other hand, it is only a three hour flight from Houston to Tegucigalpa, Honduras.

Logistics

Logistics in a developing country can be quite complex for a group of students and faculty members who have never been there before. For them to be productive there needs to be someone in the country who can handle some of these issues. When we went to Kenya in 2006, the two engineering teams were part of a much bigger set of service projects organized by our university, involving about 100 people. Two staff people from our university went ahead of time and organized hotels and vans with drivers for each group. On the author's recent trip to Rwanda our host provided us with a car and driver for the week and also made all of our hotel reservations. Having these details done for us made the trip much more productive. If the team members are trying to do all of these things by themselves, they will be much less productive doing their engineering projects.

Engineering Service Projects—Examples

Our students have completed projects in a variety of different countries. Among there are:

- Four projects in Kenya (two in 2005 and two in 2006).
    - Wind powered electrical system, a simple solar powered lighting system, a bridge construction, and a water purification system.
- One water purification project and one hydro power project in Honduras (two trips in 2007)
- One project in Armenia (2007). This was building a demonstration home using Styrofoam bricks
- One project in the Philippines (2007). This was assisting a small company in the development of products from coconuts.
- Two projects under development in Rwanda for implementation in 2009.
- Small projects in Vietnam and Papua New Guinea (without faculty present from our university).

In this paper we will illustrate some of the work in Kenya. In spring 2005 three professors and six students went to Kenya. They explored a number of potential projects, and helped out with a few. They installed a rudimentary electrical system at a Deaf School in Oyugis. This contact led to a more complex project in 2006. They helped build a pedestrian bridge with a group called Bridging the Gap—Africa. A photograph of this bridge is shown below. More details about the trip are reported in reference 1.

Figure 1—Building a 135 foot long pedestrian bridge over the Nzoia River in Kenya

Contacts made while working on this bridge project led to the engineering design collaboration described in the following section.

In 2006 we took a team to Oyugis, Kenya. We installed a water purification system in a Deaf School that did not have a source of electricity. We installed a second solar panel, a charge controller, and a battery to run the purifier. More details are described in reference 3. We also improved the basic lighting system that had been installed the previous year. Along with the engineering team were two other service teams from our university. The Deaf Education team worked with the students and staff at the Deaf School. The medical team provided needed medical services to the school and to nearby villages. The photo below shows us installing the water purification system.

Figure 2—Installing the water purification system

In addition to the water purification system, we completed a number of smaller projects. We installed a water catchment system to catch rain from the roof of their building. We also improved the infrastructure by adding additional supports to the roof of the classroom building. We added brick steps to their building so they would not have to climb up a pile of rocks to get into the building.

There are many issues we had to deal with in Western Kenya. Western Kenya introduced a number of unpredictable variables into our project and required some creativity and a lot of patience. During our two week trip, ordinary activities in the U.S. quickly became challenges. We stayed in the Monarch Guest House on the outskirts of town. Electricity and running water made these accommodations phenomenal according to local standards. We slept under white mosquito nets, which took engineering to hang, and only ate "safe" food at the guest house for breakfast and dinner to avoid getting sick. More than discomfort, our conditions gave a panicky sense of remoteness that required a level head. Little things like brushing our teeth with bottled

water were constant reminders of our foreignness (the only non-bottled water we drank was shared from the first glass purified at the deaf school).

Communication and mobility also became factors in our work. Kenya is more difficult to navigate than the U.S. Six hours of our drive from Nairobi to Oyugis passed by giraffes and acacia trees over smooth two-lane roads. The other two hours moved through overcrowded, impoverished cities and beside roads too pockmarked to drive on. Driving in Western Kenya could be beautiful but cumbersome. The nearest major city was 3 hours away. We communicated by cell phone with the Engineering team in Nairobi. On one occasion one of our team members called the electrical engineering professor in Nairobi for design advice. We did not have access to the internet.

Western Kenya hosts all sorts of diseases unknown in our home state. These became a major factor the last three days of our stay in Oyugis. On Wednesday night of our second week several members of the Deaf Education team got sick. By the next evening, only 14 people of the thirty people staying at the guest house were healthy. Eighty per cent of our team were too sick to work on Friday of the second week. Fortunately, most of our projects were finished by Thursday afternoon and the remaining members of our team had enough perseverance to finish.

Procuring the materials for most of our projects was also a challenge. Despite the suitcase of tools we brought to Oyugis, we needed additional tools for the water collection system and the steps. For our projects we also had to make several trips to the Western Kenyan home improvement stores. Oyugis' small hardware store was a counter in the open-air market wedged between a mattress/clothing store and an ATM with an armed guard. There we bought tin gutters and heavy linked chain. We drove thirty kilometers to Kisii for the Kenyan Wal-Mart, Nakumat. At Nakumat we bought an 80 watt solar panel. Also in Kisii, we bought pipe and an elbow for the collection system at a building supply store with a caged-in cashier and a basement full of plumbing pipes.

A second engineering team worked in Nairobi on an energy project in a large slum known as Kibera. (Kibera was one of the areas that experienced severe post-election violence in December 2007, but our work there occurred before that.) Though Kibera can be a frightening place, our partners served as guides and even provided us with unarmed and unpaid security guards. Faculty from our university partnered with a small business, an NGO, and a community organization in Kibera to construct a small wind generator. The power from it and from a solar photovoltaic panel was used to charge a centralized battery. A small distribution system was installed for some nearby homes and lights were installed in a public latrine which housed some of the equipment. See photo below of the wind generator. More details of this trip are given in reference 2.

Figure 3—Wind power system in Nairobi slum

Engineering Service Projects—Significance

Projects such as the one in Western Kenya are significant for the local Africans, for our students, and for our university.

Significance for the African students

The most important result for the Deaf School students is a potential improvement in their health. Most of them have worms because of their only source of water was contaminated. This hurts their health as the worms absorb what little nutrients they are eating. Treating for worms could have been done earlier, but the deaf students would only get them back by drinking more dirty water. As part of this project, the medical team treated the students for worms. With a clean source of water these students have a much better chance of avoiding getting worms in the future, which should significantly improve their health. See Figure 4 below of a deaf student drinking clean water for the first time in his life.

Figure 4—A deaf student drinking clean water for the first time

Significance for our students

This project was significant for our students who participated. The following comments were made by students who were on the trip:

- Human suffering is very ugly. I cannot end it or even dent it. But I cling to the hope that there is something greater than hunger and AIDS and my ability to save people.
- The opportunity to use our schooling and problem-solving skills in engineering first-hand is an incredible medium for learning new applications of science and technology as well as for retaining what we've learned. Putting effort into understanding problems and their solutions and then personally seeing the end result has an incredible compounding effect. Experiences stick with you more than facts, but when facts are coupled with experiences it allows you to better understand both the principles and their applications.
- The implementation of these projects both blessed the children and staff at the Kenya Christian School for the Deaf and enhanced our knowledge of practical engineering in poorer countries. This experience in service was a great complement to our education.

Significance for our engineering programs

This program was a significant step in our goal to make service learning a larger component in our engineering program. This project is also one step along the process of expanding our research work in appropriate technology.

Engineering Design Collaboration

The contacts made in Kenya in 2005 when our students assisted in the construction of a pedestrian bridge have led to a further collaboration. Bridging the Gap-Africa has been approached about building a 420 foot long bridge (345 feet between towers) to go over the Galana River in southeastern Kenya. This is much longer than they have ever done before, and they contacted our university to find out if we can give them some engineering guidance. We have had a group of four students and two professors work on this project for the past year. Details of our preliminary work are reported in another location[4]. This remote location has led to difficulties in obtaining the data needed to make the final design. While the river is not always deep, there are frequently crocodiles in it, and someone recently died while trying to cross the river. The photo below shows some people measuring the river's dimensions. Note that they are also carrying weapons to protect themselves.

Figure 5—Making measurements on the Galana River in Kenya

The complexity of the project has been a challenge for our students. They have learned to search out additional information. They have obtained Google Earth photos of the bridge site to help in understanding the design issues they face. They have obtained wind data from nearby locations to aid in designing how much wind resistance needs to be built into the bridge. We hope to have some of the students and faculty go to Kenya for the actual building of the bridge in late 2008. However, the current political instability in Kenya (as of January 2008) may cause the construction to be delayed.

Creating New Courses in Entrepreneurship

One approach being taken to introduce engineering students to entrepreneurship is to have students do technical development or assessment of new product ideas suggested by a company, including a feasibility study of the technical and economic viability of the potential product. A full business plan is produced when the feasibility study looks promising. For example, Brown University has a two semester course where teams of engineering students work closely with companies to explore commercialization[5]. Cooper Union, working closely with the their engineering alumni, friends and extended family, is delivering authentic opportunities for engineering students in teams of about four students to develop a business plan for a product or service of their choice[6]. Case studies, guest lectures and off campus visits are used to provide students with the necessary tools and motivation. The College of Engineering at Penn State University, with support from GE's Learning Excellence Fund, is developing undergraduate engineering courses that integrate product conceptualization, design, technical and economic feasibility in the context of industry sponsored engineering design projects[7]. Business, Engineering and Information Science and Technology students work together on interdisciplinary teams. The University of Pennsylvania has developed two Engineering Entrepreneurship courses that receive the highest student ratings of all the courses offered in the School of Engineering[8]. The premise of these courses is that "engineers create and lead great technology companies, hiring managers where needed to execute their vision."

The two-course sequence that is being developed at our university to introduce engineering students to technical entrepreneurship will use interdisciplinary teams of engineering and business students to do feasibility studies and create business plans for companies who propose projects or product ideas. This sequence is described in more detail in a presentation to be made in spring 2008[9] at the NCIIA conference in Dallas.

<u>The New Two-Course Sequence</u>

Engineering students currently take a course in engineering economic analysis and a course in technical writing. Students completing the proposed two-course sequence must achieve similar mastery of engineering-related economics and technical writing compared to the current courses. However, they will also be introduced more broadly to principles of professional speaking, technical entrepreneurship, and the global economy. How is this possible?

The design of the new two-course sequence is based on two reasonable assumptions: first, engineering students can achieve a high level of proficiency in "engineering economics" in less time than the 45 hours of classroom instruction currently required in the stand-alone course; and second, that teaching technical writing, professional speaking, engineering economics and technical entrepreneurship can be done with a great deal of synergism and realism if done in a fully integrated two-course sequence.

It is worth noting that teaching these topics together is also much more efficient than teaching them separately. Technical writing classes, professional speaking classes, engineering economics classes, and entrepreneurship classes each spend significant time doing the necessary digging to have something to write about, speak about, analyze economically, or prepare business plans

around. If projects can be carefully selected to allow the usual goals of a technical writing class, professional speaking class, engineering economics class, and entrepreneurship class to be achieved using the same project and associated information, then the total learning experience can be achieved by practicing the various disciplines using the same project details. How are these learning objectives and experiences divided between the two classes?

First Course: *Global Business: Economics and Communication*

Creating and implementing the course design was itself an exercise in cross-disciplinary collaboration, with faculty from engineering, liberal arts (English), and business participating. The goal is to fully integrate the learning experience for the three disciplines. The key is to keep the focus on what each student needs to learn and how to integrate the learning experiences in the three areas using a few carefully-designed projects. Secondly, keeping the desired outcome in mind is crucial: participating students will combine principles and skills developed in the first course with their engineering expertise in the sequel course in *Technology Entrepreneurship*. In this second course students will expand and refine their understanding as they apply what they have learned in the first course to industry sponsored projects, while receiving constant mentoring as they go through the process for the first time.

In the first course of the two-course sequence, the course objectives focus on achieving proficiency in economic evaluation of engineering projects using time-value of money principles, writing formal reports to both technical and non-technical audiences, and making professional presentations to technical and non-technical audiences. Since most of the writing projects and presentations involve results from engineering economic analysis, students and teachers are able to focus on developing, expanding, and integrating skills and knowledge from the three subject areas.

The major project for this past semester involved three four-student teams each doing feasibility studies of various renewable energy options for a hypothetical oil company whose oil wells are gradually playing out. The company has done well over the years and wants to reinvest some of its accumulated capital in alternative energy as it seeks to diversify its energy business. One team did a feasibility study of wind power, a second team considered solar power, and a third team evaluated bio-fuels, including ethanol and bio-diesel. Their written reports are similar to what is typically done in a technical writing class as the major writing project. These reports required engineering economic analysis to determine what return on investment each of these technologies might provide and what scale of investment is required to be efficient and economical. The students performed their own independent economic analysis and wrote their own reports based on the pooled information that they collected as a team, thus maximizing time spent in research. Finally, each team prepared and delivered a PowerPoint presentation to communicate their recommendations.

Smaller writing projects also incorporated engineering economics and professional presentations, making each project as synergistic as possible. For example, the assignment preceding the major project challenged students to use a dataset from an already completed lab experiment they did as freshmen engineering students and write a report that recommended a course of action. Students used analytical skills being discussed in engineering economics; they used ASME

guidelines for their reports; and they gained experience with drafting, revising, and editing. During the drafting process writers consulted with engineering faculty and with the English faculty member for assistance with problematic aspects of the assignment. This process prepared them for the more complex major project.

The professional presentation time in class is used for lecture/discussion on principles of professional presentations and for actual presentations, requiring students to practice implementing these principles. Classroom presentations were video-taped, reviewed immediately in class with critique, and then repeated during the same class period. Preparation and practice of presentations was done outside of class. The oral communication component complemented the written communication component in the course and also prepared the students for the professional presentations they made at the end of the second course in the sequence.

Three lectures cover communication principles, barriers, solutions, skills, and strategies to follow, plus time to practice the new skills to ensure understanding. Each team then received a different PPT presentation slide set on a single classic business case. Over the next two weeks, each team practiced using its new individual and team presentation skills. Since the content was provided, each team focused on delivery only. In class, the teams gave their presentations, and all were video recorded. Faculty provided critique and non-presenting teams provided peer feedback. Then, all teams watched the video recording. Finally, all teams repeated their presentations. The lead faculty for professional speaking supplied final written feedback, in addition to the team grade.

One week later, each student team prepared a second presentation, this one based on course content that is coordinated with the writing assignment just completed. Three more presentations, all content-based, followed throughout the semester, reflecting the students' growing body of information and analysis on their engineering projects. Each one was video-taped, critiqued, and repeated in the same session, as time allowed, following the same rigorous pattern established in the first prepared presentation.

Stand-alone oral communication courses provide many opportunities for students to present and receive feedback on a wide variety of topics. Students in this course gave five presentations. Repeating them a second time following faculty, peer, and video feedback intensifies the progress. Coordinating the topics with content from the course themes ensures maximum effectiveness as well as efficiency. Students understand that both content and delivery of the course presentations will prepare them for collaborating with business students on real-world projects involving innovative technology in *Technology Entrepreneurship*, the second course in the sequence. At the end of this second course, cross-disciplinary student teams will present their findings in extensive written reports and business presentations to company executives or venture capitalists. Knowing this is their ultimate goal provides the students with a practical focus that helps them coordinate and value their efforts in the first course.

Less than 20% of the classroom time is used for writing instruction. Instead, writing instruction is provided in one-on-one tutorials that focus on student work-in-progress, enabling the English professor to tailor instruction and feedback to the particular needs of each student. Considerable research in writing instruction suggests that this is an optimal situation for learning, especially

for learning to write in specific disciplines. Students are required to meet with the English faculty member to discuss revision options for first and subsequent drafts. These one-on-one conferences focus on instruction (formative assessment) rather than summative assessment. Most speaking and writing projects for the course are suggested by the engineering professor in consultation with the other professors and are also used for doing engineering economic analysis.

This course is a prerequisite for the second course, *Technical Entrepreneurship*, where students will have multiple opportunities to further hone their skills in engineering economic analysis, technical/professional writing and professional presents.

The assessments in the *Global Business: Economics and Communication* class have been very encouraging. The mid-term exam on engineering economic analysis for the Fall 2007 using primarily questions from the FE exam resulted in a class median of 90. Students in the class had some common final exam questions with students who have taken a three semester course in Engineering Economics. Their performance on the topics we covered was as good as those who took the class dedicated to the topic.

The writing projects in *Global Business: Economics and Communication* have produced work that is comparable, possibly even superior to that being submitted for stand-alone Technical Writing classes, including one that is also being taught by the same professor (Dr. Blalock). The students' experiences as writers in the new course are at least equivalent to and as valuable as their experiences in technical writing. Further, considering the differences among the various sections of technical writing and the lack of a discipline-specific focus in assignments (even in the section set aside for engineering and computer science majors), students in this course had the opportunity to learn more about how to use writing as an engineering professional than they would have learned in an entire semester of technical writing. Anecdotal evidence from students supports this claim, and several of this initial group of students had already completed their "required" technical writing course. We are planning further assessment of the writing gains at the end of the two-course sequence. Finally, when we consider the writing they will be doing in the second of the proposed two-course sequence, students who complete those two courses will have experienced more effective writing instruction than they would have in technical writing, if we define "effective writing instruction" as focus on and preparation for the kinds of writing students will do in their professional careers.

Second Course: *Technical Entrepreneurship*

Technology Entrepreneurship is a capstone, experiential learning course that is deliberately cross-disciplinary and project-oriented. Its learning objectives overall are centered in the preparation of both business and engineering students (undergraduate as well as graduate) for strong participation in and leadership of technology commercialization projects and processes, regardless of setting; i.e., corporate or start-up ventures. The design employed to achieve these objectives has two platforms – learning the keys to success for high-tech business ventures and demonstrating that learning by applying all the keys to a real-world project for a company or inventor who needs their insights. This design readily incorporates the application and assessment of the engineering students' skills in economic analysis and professional communications.

The most direct and comprehensive assessments are made directly from the quality of what is in effect a junior consultancy engagement at the end of the semester. In each case a business decision will be significantly influenced by the results of the student's work, and thus it is always a requirement that sound engineering and market economic analysis is completed, that the implications of the findings are communicated, and the recommendations to the sponsor are effectively defended. Another critical skill that is embedded into this learning journey is the ability to deal with incomplete and often contradictory data while still being forced to make a judgment that can be defended. Especially for engineering students, this is new ground, and the role of one-on-one coaching of the project teams by faculty and sponsor throughout the semester is essential. It is typical for each team to meet weekly with the professor, and to hold a weekly conference call with its sponsor.

The global flavor of this course is brought in via two mechanisms. First, many of the projects have a global scope – technology being commercialized includes pieces from outside the U.S., the target market is global / multi-national, or in some cases the sponsor's location is an international one. Examples of this include a global market feasibility assessment performed for a drug research firm in Belo Horizonte, Brazil and a new-product value equation analysis for a semiconductor process chemicals supplier based in both Indiana and Suzhou China. Conference calls at strange hours just become part of the routine, in the same way they do for engineers at work all over the world today. Secondly a summer study-abroad version of *Technology Entrepreneurship* was launched in 2007 in which all the same practices are followed and objectives are accomplished, but with teams that are culturally mixed. The projects are for China-based enterprises and all are executed by the students while in-residence in China.

The students apply what they have learned about engineering economics, technical / professional writing and professional speaking in *Technology Entrepreneurship*, the second of the two-course sequence. The students research, compile data and perform analyses related to the value of a given technology-based business opportunity as specified by their project sponsor. In addition they write four formal assessments of current vs. best practice with recommendations, prepare and discuss a mid-term interim findings report, and at end of term deliver a comprehensive report along with an extensive presentation with Q&A. The writing professor on our team will consult with these students as they work on their written reports.

Conclusions and Contributions

It is important for engineers to be able to practice in a global environment. More and more engineers are going to be involved with companies in other countries. ABET recognizes this is important. One of its mandated program outcomes is[10]:

> *Engineering programs must demonstrate that their students attain:*
> *(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal impact.*

Achieving this outcome is not simple. To do this we have adopted an approach that has several components. Among the components are:

- Engineering service projects in developing countries
- Engineering collaboration with colleagues in other countries
- New courses in global business and technical entrepreneurship.

We believe that this effort better prepares our students for the global practice of engineering in the 21st century.

Another important ABET mandated outcome is[10]:

> *Engineering programs must demonstrate that their students attain:*
> *(g) an ability to communicate effectively.*

We believe that this approach is a more effective way to accomplish ABET's communications objectives. The students learn how to be better communicators while also learning about the global practice of engineering.

References

[1] Kelley, B., Bradley, W., and Thomas, B., *Student-Aimed Appropriate Technology Engineering Projects in Kenya*, presented at the 2006 A.S.E.E. Southwest Regional Meeting, Baton Rouge, LA, March 2006.

[2] Thomas, Brian, "A Wind Powered White LED Lighting System for the Kibera Slum of Nairobi", *International Journal for Service Learning in Engineering*, Vol 2, No. 1, pp. 16-31, Spring 2007.

[3] Jordan, W., Ballard, B., Morton, A., Sanders, B., and Wakefield, J.K., *Implementing a Service Learning Engineering Project in East Africa*, presented at the Gulf Southwest Regional Meeting of A.S.E.E., South Padre Island, TX, March 2007. In CD based *Proceedings* (no page numbers).

[4] Jordan, W., Parker, H., Eppink, J., Hemmen, S., McGhee, R., and Eberhardt, M., *Building Bridges for a Better Future: "Bridging the Gap"*, presented at the Annual Meeting of the American Scientific Affiliation, Edinburgh, U.K., August 2007.

[5] Creed, Christopher J., Suuberg, Eric M., Crawford, Gregory P., *Journal of Engineering Education,* v 91, n 2, April, 2002, p 185-195.

[6] Gallogly, Vincent, "Utilizing engineering entrepreneurs to instill and enhance entrepreneurship in today's student population", *ASEE Annual Conference Proceedings, 2001 ASEE Annual Conference and Exhibition: Peppers, Papers, Pueblos and Professors,* 2001, p 11285-11294.

[7] Kisenwether, Elizabeth C., Matson, Jack V., "Launching an undergraduate engineering entrepreneurship program", *ASEE Annual Conference Proceedings, 2002 ASEE Annual Conference and Exhibition: Vivi L'ingenieur,* 2002, p 8599-8606.

[8] Cassel, Thomas A.V., "Engineering entrepreneurship at Penn", *ASEE Annual Conference Proceedings, 2003 ASEE Annual Conference and Exhibition: Staying in Tune with Engineering Education,* 2003, p 12665-12678.

[9] Bradley, W., Grinols, A., Blalock, G., Jordan, W., Leman, G., and Fry, C., "Incorporating Global Entrepreneurship Courses Into An Engineering Curriculum", accepted for presentation at the National Collegiate Inventors and Innovators Alliance (N.C.I.I.A.) conference, Dallas, Texas, March 2008.

[10] 2007-2008 Criteria for Accrediting Engineering Programs, ABET, Baltimore, MD, p. 2.