

2006-2207: INTERNATIONAL CITIZENSHIP AND GLOBAL SERVICE LEADERSHIP – THE ROLE OF INTERDISCIPLINARY TEAMS IN ENGINEERING EDUCATION

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International Citizenship and Global Service Leadership – The Role of Interdisciplinary Teams in Engineering Education

Abstract

Interdisciplinary design teams are seen as an alternative to traditional engineering department-run capstone design experiences. Tufts University is recognized for providing service opportunities for students in association with host local communities in Massachusetts while engineering service organizations, such as Engineers-Without-Borders, have given students the opportunity to expand this experience to locations beyond the US border. This paper describes how a team of students with backgrounds from many different schools and departments were brought together to implement an engineering project supporting county health education in Gyatsa, China (Tibet Autonomous Region). The value of this experience is discussed with particular emphasis on the contributions to the engineering student education by team members with a non-engineering background. It is concluded that the interdisciplinary team approach provides a valuable pedagogical tool for educating engineering students.

Introduction

Tufts University aspires to achieve an international reputation for educating engineering leaders with an emphasis on communication skills, interdisciplinary technical preparation, management skills, globalization, and the societal impact of technology. The University mission statement asserts that the schools are “committed both to pursuing disciplinary-based education and scholarship and to exploring the critical, developing areas at the interfaces among and within disciplines. Our goal is to generate, disseminate, and advance knowledge within the ever-changing international, multicultural, and technological context of today's world. The close relationship between the College of Liberal Arts and the School of Engineering creates a special opportunity for joint educational and research programs that can educate engineering students on the importance of the liberal arts, and liberal arts students on the importance of technology.” To this end, the School of Engineering (SOE) sponsored a chapter of Engineers-Without-Borders (EWB) in an effort to provide students with an opportunity to combine learning experiences in the application of technology to socially relevant challenges. This Service Learning initiative is based on successful programs implemented by the Tufts Civil and Environmental Engineering Department both locally in Massachusetts¹⁻⁴ and internationally⁵. Community-based service learning (CSL) is a pedagogical tool that helps students develop a deeper appreciation of engineering as well as to communicate their engineering solutions to both technical and lay audiences.

Mechanical Engineering undergraduate students were particularly active in organizing the student EWB chapter and solicited projects that required skills in mechanical design. The allure of service learning attracted a broad range of students and a conscious decision was made to structure the organization such that a multidisciplinary approach was nurtured and encouraged. The faculty quickly recognized the value in this unique approach to engineering education and integrated this pedagogical evolution into the curriculum as an alternative component of the senior design project.

Students from several departments in the School of Engineering invited members of the School of Arts and Sciences and the Museum of Fine Arts to participate as equal partners in the design of culturally appropriate and technically sustainable solutions to real-world engineering problems. In the first year, the EWB team grew from 28 to 60 students of varying background and skills and the group decided to investigate how to support health education in Asia.

Background and Project Description

The Tibetan Plateau has long been a region of semi-nomadic peoples. For centuries, the livelihood of those who inhabit this plateau has been predominantly based upon freedom of mobility, and inhabitants have adapted their culture to this harsh environment relying on herding and, to a lesser extent, seasonal agriculture. Through the adoption of rotational grazing and agricultural patterns, they have succeeded in managing these difficult conditions, but recently, due to the settlement into communities, inhabitants are now being confronted with new problems of depletion of natural resources and sanitation associated with become a stationary population.

In February of 2004 The KunDe Foundation, a non-profit organization of British doctors responsible for health education based in the Shannan Prefecture of China, proposed to EWB-USA a project based in Gyatsa, Tibet. The goal was to support World Health Organization (WHO) priorities for global sanitation including provision of sufficient quantities of safe water, basic sanitation arrangements and promotion of good hygiene behavior⁶. Tufts undergraduate students banded together in an effort to establish an interdisciplinary overseas service-learning opportunity over the 2004-2005 school year. Students took the technical lead in projects aimed at water quality assessment^{7,8}, solar decontamination of medical wastes⁹ (a modified solar cooker), and construction of composting latrines⁶. This work culminated in organization of a traveling team to assess needs and perform pilot investigations in Tibet over four weeks during the summer of 2005.

The ground rules for sustainability required that all materials be locally available and that important decisions were to be made by the client population after trade-offs were explained. These tasks were found to be significantly complicated by the language barrier but this experience only enhanced the student appreciation for pre-trip planning with an emphasis on adaptability and design flexibility.

All students who are involved with this project, traveling or not, have the opportunity to expand their knowledge of a foreign culture and build global awareness as international citizens. All technologies implemented were to be sustainable, re-creatable, and acceptable within the social, political, and economic contexts of the community. The students worked towards improving the standard of living without being culturally intrusive. In the process the team empowered both the community and the individual students involved.

Implementation

The traveling team consisted of six students and a faculty member. Three students were from the Mechanical Engineering Department, as was the faculty advisor, one from the Civil and Environmental Engineering Department, and two from the International Relations Department .

The group included two sophomore, one junior, and three seniors and was half male – half female. The goals for the visit were to meet with KunDe officials and establish a working rapport with the local Chinese officials and the Tibetan community to allow the traveling team to initiate pilot-scale implementation of proposed technology. Thus, a major task for the non-engineering student members of the team was to observe team interaction with village elders and community members to gauge acceptance of Western technology and implementation strategy in hopes of improving the effectiveness of future visits. In particular, we were wary of unintentionally attempting to impose our views on an established community to either cause social damage or delay acceptance of a solution the community had embraced.

Before the trip, students worked at Tufts University to develop the designs that were then presented to Chinese officials and Tibetan villagers to ascertain what direction the program should take to best support the target community. Students researched water quality problems in the developing world and defined methods to test for pathogens and contaminants. Since it was unclear, before the visit, what problems the community may be experiencing, the students developed a strategy to test for basic watershed parameters for the assessment visit. Plans to include more advanced tests, such as arsenic, were to be accomplished in later visits. Students also constructed two prototype solar cooking devices and tested them to compare to an analytical transient heat transfer model developed by the team. After validating the model, students conducted sensitivity analyses to develop a strategy to respond to differences in materials available in Massachusetts and in Tibet. Pictorial versions of construction plans for the composting latrine were also produced in order to show leaders in the community various design options and trade-offs that might influence performance of their community toilet. Students stressed developing a methodology to understand local preferences toward key design attributes so that decisions could be streamlined despite challenges in communication due to language differences. Again, an emphasis on reacting to design changes imposed by local conditions was emphasized.

During the visit, KunDe and local officials were unbelievably supportive. They encouraged full implementation for all projects and offered invaluable assistance by providing translators, supplies, and water quality assessment kits. In an example of the need for flexibility, the kit provided included an arsenic test and thus the students were able to expand the range of analyses performed. Of particular satisfaction was the ability of the team to study the documentation in the kit and teach the translators how to conduct their own future assessment activity. We were able to train the trainers. The translators were particularly motivated to do water quality work so that our contributions could be sustained long after we left.

The solar cooker was designed to function either as a cooking device or for disinfecting medical wastes as part of an ME senior honors thesis by team member Hoi Yee Lam. One criticism of many previous efforts is focusing on changing local behavior by providing a technology that is subsequently abandoned due to lack of acceptance. Under the direction of KunDe, the students decided on a new tack prior to leaving Tufts. Our team concentrated on providing a method to decontaminate medical wastes. By getting a health professional involved, we hoped that once a community leader adopted the techniques, others would see new uses for the energy-saving technology (such as supplementing cooking tasks or drying of produce). The immediate advantages to the community would be the ability to dispose of sanitized needles

instead of the current direct-ground dispersal technique. The long-term advantage was a reduced dependency on wood for cooking applications.

Of particular interest to the Chinese health ministry was the adoption of group latrines for handling human waste. Current practice involves use of remote areas surrounding the community (based on a culture developed successfully over many centuries as a nomadic people) – a tradition that becomes problematic when fixed communities grow. The alternative is use of personal pit latrines where waste is open to the air, spreading disease through animal vectors, and prone to anaerobic decomposition (with the associated foul smell) due to mixing of solid and liquid waste. Composting latrines work best by separating out the liquids and adding absorbent solids, in the form of barley stalks after each use, to promote aerobic decomposition. Additionally, by providing twin stalls for both men and women, one side can decompose during a one-year fallow period while the other side is in use. Our greatest contribution was to assist in the design, modified by the village to suit their specific needs as part of an ME senior honors thesis by team member Sarah Freeman, and conduct training on the benefits to the community. Non-engineers on our team were particularly effective in taking a lead in the education of our clients on the use of the new technologies.

The visit was a success beyond our most optimistic projection of what we could get done in the short time we were in Tibet. These accomplishments pale in comparison to the personal growth and leadership skill development experiences that the students were able to take from this trip. Real-world problems require an ability to adapt to local constraints that could not be anticipated. How do you make a building out of rocks and mud? Are there supplies available in remote locations for liquid waste handling (PVC pipe), venting (aluminum stove pipes), lumber for structures (hand hewn logs), mortar (concrete with sifted sand), or reflective coatings (thin aluminum tape with adhesive)? How do changes in material affect the performance of the design that was optimized at Tufts and later altered significantly in Tibet? One particularly poignant exchange occurred during mixing of the concrete for the floor of the latrine. Villagers were using about twice the water than is required in order to “stretch” the recipe and get “more” concrete for the price. Jonny Crocker, a sophomore civil engineer, stepped in and taught them our methods. He was ecstatic about his ability to pass on what would seem to be an obvious procedure and talked all evening about how his experiences in the lab were now making so much sense. Later, the head builder was shocked at the strength that could be achieved using concrete and thanked Jonny for the lessons.

It was particularly satisfying to conference with village leaders and come to consensus on how to proceed based on communication that was funneled through the translators and augmented by hand-gestures and pantomime. Talking with ordinary people who had no significant education in basic health issues, at least from a Western perspective, and learning how changes in lifestyle could influence their lives was of prime concern. We were not there to tell them what to do but rather to pass on skills that they could adapt to their needs. We were particularly aided by the support given by village elders, augmented strongly by directives from the county health officials. We were warmly welcomed for both our knowledge, as technical experts, and for the money we could contribute by providing basic construction supplies. Costs were low by our Western standards but to subsistence farmers in remote villages, it represented a significant portion of their disposable income.

The role of the faculty was to act as a design consultant to assure adequate reality checks throughout the process, mentor the students in project engineering skill development, monitor team dynamics, and provide university oversight. The design team included faculty from both the Mechanical Engineering Department and the Civil and Environmental Engineering Department based on the needs of the community. The current project has been successfully integrated into the curriculum of the Mechanical and Civil & Environmental Engineering Departments through senior capstone design coursework, senior thesis credit, and underclass special topics courses. Students from the School of Arts and Sciences can obtain elective credit for research conducted in the School of Engineering.

The role of the students was to develop the team organization and personal leadership skills necessary to support the ambitious tasks associated with implementation of an international design project. All aspects of program management and technical screening were conducted by non-traveling team members. The group handled all logistics, scheduling, risk management, contingency planning and travel team selection tasks. Fund raising was also an issue; the value of the trip toward enhancing the educational experience of the students is well worth the investment – given that both are high.

The application of classroom knowledge to hands on, project-oriented activities reinforces classic book-knowledge as well as answering the student-posed question “why am I learning this?” There is often a perceived disconnect between theory and practice, and this unstructured type of activity takes students through the entire design process and into implementation of a solution. The power of a capstone experience is in not telling students what must be accomplished next. They must set their own priorities and rely on theory as a tool to lighten the load instead of as an abstract concept to be memorized.

In the classroom, educators are also often unable to provide the human element where constraints and tradeoffs have real consequences to a person’s life. From the perspective of being an engineering student, they view the experience as being incredibly gratifying. The design process is made real – they are able to go from technical drawings, to redesign in the field, to actually construction and subsequent use.

Student reflections

Jen Crawford – sophomore physics major, non-traveling team member

“Using the principles and theories I learned in my physics classes to build a functioning tool was something I don't think I had ever done before. I generally work on a much more theoretical level; I know the way something should function but I don't usually act on it. For example, I'd say "I wish we could find a way to determine the angle of the sun so that we can point the solar cooker in the right direction." Then the engineer would tape a paper towel roll to the edge of the cooker so that we knew the cooker was pointing in the right direction when the shadow was a perfect circle.

This project in Tibet, though, adds another component. In school, the engineers build devices such as speakers that they can actually play music out of. It is one thing to make something that works ... but it is an entirely different experience to design a solar cooker or latrine that is not only functional, but also useful and beneficial to real people in a community. The long hours spent studying and working out problem sets actually make sense after seeing a family relying on something I helped design.”

Elliot Hirshon – International relations major, traveling team member

“We loaded a Land Rover and drove 8 hours over high mountain passes, across fields of barley, along winding and age-old rivers and through Gyatsa county until we finally arrived in the community of Gyapthang, a village of 750 people that had only existed as such for six years. The Chinese government had built an irrigation system and granted housing to nomadic Tibetans to encourage settlement. There was a town meeting to offer introductions, explain our goals, listen to the priorities of the community and ask and answer any questions.

I learned about group dynamics on an international scale ... and learned that helping also means being helped, strengthened my views on our responsibilities as international citizens with the available means, and witnessed the incredible strength, cohesion and possibilities achievable through *community*.

Engineering needs to be more immediately incorporated into development, and engineers should not simply be told what to do, but must find themselves higher on the decision making scale. With my experience this summer, I will remember, in any position, the strength and potential the many fields of engineering can offer our societies, to incorporate engineering wherever possible into my responsibilities, continue learning about engineering personally, and engage engineers to partake in all levels of discussion. This summer, Engineers Without Borders, took its first step in what all of us believe is an incredibly important direction for the discipline in order to break down its walls. I finished the trip having been challenged by group relations, bureaucracy, health and cultural integration, and what evolved was a marvelous and enriching summer, where I, among others, find myself still digesting and understanding the experience.”

Sarah Freeman – Mechanical engineering senior, traveling team member and EWB president

“The integration of real world experiences into any classroom, particularly those of engineering, proved to engage me in the classroom. Prior to this experience I accepted the idea that I would be graduating and working in a cube. While this was not my idea of what I would ideally be doing with my life, I settled for this compromise. With the discovery of Engineers-Without-Borders came the discovery that engineering can be applied toward the bettering of communities both on the local and global level. Classes suddenly had more meaning through their newly discovered relevancy to what I wanted to be doing with my life. I also discovered my ability to be a leader and inspire others into becoming engaged. The idea of inspiring others to get involved and think beyond both physical and mental borders has now become a central driving force for my activities. This past year I have found myself in positions I never would have imagined a

year and a half ago. I had the incredible opportunity to lead a group of inspiringly dedicated students, and in turn developed my own concept of what it means to be a global citizen. It has been an amazing to see that I could go from the quiet girl in the back of the classroom to the one in the front, asking questions and helping others to step out of their own timidity through engagement in a cause.”

Grant Sharpe – Mechanical engineering junior, traveling team member

“One of the strongest aspects of our team was the diverse nature of the project members. Our differences provided us with many of our best ideas. Often we worked to bring numerous different ideas to the table, and then generally discussed the issue until a consensus was decided upon. These approaches, albeit time consuming and often frustrating always provided the best results. The liberal arts students that were part of the project viewed many of the challenges we encountered in a different manner than I did. As a mechanical engineer in training I have been taught to utilize the engineering design process when I come across a situation that requires a solution. This approach has been extremely valuable to me on numerous projects I have worked on, and was invaluable throughout my work with EWB. However, those students that have been taught without this methodology are often taught other means of viewing the situation. More often than not, our fellow students not only viewed the situation in a different manner, but also asked different questions. These questions ranged from asking us why we were designing a certain aspect of a project a certain way, to asking the community very different questions than we typically did. The constant questioning of the “why” behind a decision kept us honest. These students were instrumental in helping to assure that our projects would be culturally acceptable as well as functional.

This project was an amazing compliment to my traditional class work. It provided a real world setting, where real world results were expected, during a limited time and under stresses that typically don’t exist in a classroom setting. My time spent in Tibet not only allowed me to experience a foreign culture firsthand, but it also made me a better engineer overall. ”

Discussion

The unique combination of foreign travel, engineering design, and interdisciplinary teamwork make service learning a particularly rewarding experience for engineering undergraduate students. The participation by non-engineers is enabling to the success of the project. If an engineer cannot explain how to implement a design to a peer on campus, the likelihood for success in a foreign environment, with associated cultural, technical, and language barriers, is nil. Engineering students readily develop an ability to adapt to local conditions based on pre-trip brainstorming, attribute definition, and technology scanning but they must learn to communicate alternatives to their clients. In a world where issues are nearly always complex and interdisciplinary in nature a similar approach to solutions must also be taken. Creating an organization where individuals of a variety of backgrounds may work together for a common outcome provides a unique environment for this sort of thinking. Challenging perceptions and stimulating student to think about a design issue from a multifaceted global perspective is of increased relevancy as information transfer and globalization strongly plants itself in society.

Students wrestled with what their position in the community was going to be and if it was their duty to tell people how to act, and thus significantly change their everyday practices. They realized that while it is not appropriate to tell people how to fix a “problem”, it is possible to give them the appropriate information to make an informed decision that could be implemented and sustained within their existing cultural framework. To educate and give the villagers the tools to evoke change was far more satisfying than dictating procedures out of context.

Interdisciplinary team building also became important as students were forced out of their comfort zone and set patterns of reaction were rendered impotent. By taking a community viewpoint, order was restored and students could release themselves from their parochial tendencies. The problems are real-world; the students were not at school anymore. Students became the educators and mentors guiding decisions that would impact entire communities. The realization of potential impacts was not limited to students on the travel team as all members embraced pre-trip planning tasks. Social and technical issues were anticipated and discussed. During this process differences in student skill sets were particularly important to vet all facets of potential difficulties that might be encountered during international travel. This built confidence and an understanding of how students can contribute as global citizens. The personal growth afforded by interdisciplinary service learning experiences will serve them well in their future capacity as leaders and professionals.

Conclusions

The interdisciplinary team structure works well as an engineering capstone design project- although it is not for everyone. This approach is particularly attractive to students seeking enrichment through global service. The synergistic effects of combining traditional mechanical engineering coursework with service learning-based pedagogy are evident in the enhanced education received both by traveling and non-traveling students from both an engineering and non-engineering background. For example, a number of benefits to student learning are evident.

1. Traditional design pedagogy plus interdisciplinary service learning provided students complimentary vehicles in which to refine their designs in ways that deepened their understanding of the impact of technology on people while enhancing communication and leadership skills.
2. Projects with far-reaching social implications causes students to “think outside the technical box” to develop appropriate designs within constraints that are not easily reproduced in the classroom experience. The added dimension of building for sustainability provides students with challenges beyond that experienced in conventional capstone design courses. The knowledge that this program significantly impacts the client population builds commitment by students to ensure that all aspects of the design are well planned, well documented and feasible in the real world.
3. Foreign travel complicates the implementation of the application phase, but this experience was considered to be one of the highlights of the project by both engineering and non-engineering students.
4. Non-traveling students can have the same team building experiences, leadership, personal growth and feelings of accomplishment as those that travel
5. Students come to realize that professional and social responsibilities go together.

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