2006-891: OUR FIRST EXPERIENCE WITH INTERNATIONAL SENIOR DESIGN PROJECTS – LESSONS LEARNED

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Our First Experience with International Senior Design Projects – Lessons Learned

Abstract
The advantages of international experiences for engineering students are well documented. With this in mind, we decided to take our 18-year-old, client-based, senior design class "on the road." This foray into the realm of international projects did not come without some anxieties:

- Could we properly manage such a long-distance project?
- How much of a sacrifice would it be to forego a site visit?
- Would codes and regulations be nonexistent or difficult to obtain?
- Would our student team experience frustration from communication challenges?
- Would we sacrifice technical depth for international breadth?

And these are just a few of the many questions and concerns we anticipated.

This paper seeks to share our answers to these questions and to provide lessons learned for others to consider. Our focus in this paper is on a project in an underdeveloped country: Trinidad. We start out by addressing how we obtained our first international project and how we selected the student team. The student authors are the project team, and they supply the student perspective on the challenges and rewards. Results of surveys of the students who did domestic senior design projects are also included to show their perspective of their classmates' project (based on oral reports given to the class). The faculty authors are co-instructors of the senior capstone design course, and they provide insight into administration of the project. The paper ends with a list of lessons learned that may help others to avoid the pitfalls the authors experienced.

Introduction

The Rose-Hulman Civil Engineering Department began to use client-based projects for the capstone design experience in 1988. Initially, the project sponsors included the campus facilities department and Rose-Hulman alumni companies. However, confidence in the course structure and the student's designs increased after a few years, and the range of clients, type of projects, and location of client companies began to expand. In fact, project solicitation is rare; more project requests come in each year than can be fulfilled.

The client-based projects are vetted and teams are selected early in the academic year. Project proposals by potential clients are received in August. The best projects are retained based on scope of work, variation in civil engineering disciplines, and faculty and client interest. Students vote on their top five choices based on project abstracts during the first week of class (more projects are available than teams). Teams of four are selected by the faculty based on student interest and team considerations.

The capstone design experience lasts a full year. The projects commence with a client meeting and a site visit. Full proposals to the client are due in the middle of the fall quarter. This provides students with a proposal writing experience and clarifies the project for the student team and the client. Progress reports are due in the middle of the winter quarter. These reports include data collection efforts, mapping, soil testing, codes and regulations research, design alternatives, and alternative evaluations. This sets the team up for the final design process. Final

reports are due in the middle of the spring quarter. All reports undergo a report review by the course instructor and a technical review by the faculty coach before being sent to the client. Oral reports of the proposal and progress report are made to the senior class by each team. A final oral report is made at a professional meeting and to the client.

In recent years, some Rose-Hulman faculty felt that the foray into international projects would be beneficial to our students. There are many reasons to support this. The National Academy of Engineering report on the engineer of 2020 (NAE, 2005) suggests that the explosion of knowledge in the global economy and the way engineers work, as evidenced by the outsourcing of engineering services, will be increasingly dependent on an international talent pool. The New York Times editorialist Thomas Friedman calls upon America to recognize that global competition for engineering services will be fierce in the near future with developing powers like India and China in his book entitled "The World is Flat" (Friedman, 2005). This is not something to be feared, but embraced as the shift in the world's technological economy takes place. Another futurist, David Heenan, warns us that we must watch closely for an environment that changes quickly as we prepare our technological workforce of the 21st century (Heenan, 2005).

Models for International Capstone Design Projects

International capstone design projects have taken a variety of forms over the last few years: joint project, travel overseas, and stay at home.

Joint Project

One model is to have student teams partner with student teams from another country in order to accomplish the project jointly (Boronkay *et al*., 2002; Jones *et al*., 2002). Some of the advantages noted by those authors include the following:

- Increases technical skills.
- Teaches teamwork over international borders.
- Links two teams over cultural boundaries.
- Provides international experiences for students who cannot afford to travel.
- Reflects modern reality that products are designed in one country and manufactured in another.
- Teaches international project management.
- Teaches communication through technical media.

Those authors also noted the following disadvantages:

- Partner schools must acquire computers, workstations, and communications tools.
- Difficult to coordinate the design effort.

From those papers, we observed the following additional disadvantages:

- Best to find a partner school with the same technologies and goals.
- Requires faculty that are prepared to lead a pioneering group through a distance learning project.

Travel Overseas
Another model is to send student teams abroad to work on projects in the host country (Ault and Barnett, 2001). The following advantages come from their paper:
• Hands-on international experience.
• Real design problem (realistic timeline, guidelines).
• Results in quality project due to hands-on experience.
• Face-to-face interaction.

Ault and Barnett (2001) and Jones *et al*. (2002) identified the following disadvantages:
• Expensive.
• Constraints of curriculum; don't want students to fall behind in progress to graduation.
• Potential for loss of faculty control over educational process.
• Trip must be well organized.
• Trip should not last full semester; compacting into seven weeks helps expenses.
• Sponsor must donate significant time over short period in order to provide substantial technical, administrative, and cultural help.
• Requires more preparation than other models.

Stay at Home
Yet another model is for student teams to work on the project while at their home institution (Zitomer and Johnson, 2003). This is the model explored at Rose-Hulman for our first experience with international capstone design projects. Many of the advantages and disadvantages we discovered are highlighted in this paper.

Obtaining Our First International Project
The opportunity for Rose-Hulman to venture into the international arena was fortuitous. One of the capstone design course instructors had contacted Engineering Ministries International to explore the possibility of collaborating on a senior design project. That organization, however, does not organize projects in a manner conducive to a senior design course. Therefore, he set aside the idea.

Then, in the summer of 2005, the senior author made a mission's trip to Trinidad. The purpose of the trip was to build a health clinic in an impoverished area south of Port-of-Spain. For a 10-day period, a reinforced concrete and masonry clinic was constructed under the direction of a Trinidadian, Dr. Brian Lushington, and his architect. This was practical civil engineering at its best. Even though the senior author had conversations with Dr. Lushington and the architect of the building, the thought of a potential project was not even considered until later in the summer.

Upon returning to the states, the senior author and co-instructor of the capstone design course began to talk about international capstone design projects. In addition, two or three of the rising seniors had expressed interest in international work, and a few had expressed interest in overseas missionary work. It wasn't long before the desire to proceed led to action, and our first international design project was initiated.

Dr. Lushington was interested in developing a missionary compound that would contain a free medical clinic, a home for battered women, a soup kitchen, and an orphanage. The specific tasks included a floor plan, site layout, structural design, and foundation design. These tasks met our criteria for a viable civil engineering project. In addition, the client wanted the student team to be sensitive to cultural and economic constraints, which met our criteria for an international design experience. Communication was not anticipated as a problem since Dr. Lushington was accessible by email and English is the national language of Trinidad. Everything seemed to fall into place even though we knew we were in for some challenges.

Launching the Project

In order to assign students to projects, the instructors have each student rank his or her top five project choices on the first day of class (5 = highest preference). The students are provided a one paragraph description of each potential project. Figure 1 contains an example description. The instructors review the descriptions with the seniors and answer any questions before the students submit their preferences. The instructors compile the rankings as demonstrated in Table 1. The projects with the highest total score are selected, then the instructors assign students to projects in an attempt to maximize the number of students receiving either their top or second choice. To do so, the instructors first assign students with the strongest preference for the selected project with the lowest total score (the projects with the lowest scores were not selected). They then assign students to the second lowest scoring selected project based on strongest preference among the remaining students. This process continues until the last students remaining are assigned to the highest scoring project. The project teams are then reviewed for potential switches that would increase the number of students obtaining their top or second choice. Once the instructors determine the project teams, faculty members from throughout the department preference which project(s) they will advise as a coach.

Mission Compound in Trinidad *Missions International*

The client is a physician in Trinidad who has organized various mission trips throughout the Caribbean to build medical facilities. This project is to design a mission compound that has a free medical clinic, home for battered women, soup kitchen, and an orphanage. The team must be sensitive to cultural and economic constraints when developing the design. Key tasks include floor plans, site layout, structural design, and foundation design.

Figure 1. Example project description reviewed by students when preferencing their capstone project.

Table 1. Example of process used to determine which capstone projects will be assigned students and which students to assign to the selected projects.

Student	Project A	Project B	Project C	…
Baker	5		3	
Jones	4	5	1	
Little		1	4	
Smith	5		4	
…				
Total	14	6	12	…

In this first year of offering an international project, the international project received the highest total score of the eleven potential projects. In fact, 9 of the 31 seniors preferenced the project as either their top or second choice. However, only four seniors could be assigned to the project.

Instructors inform the students of their projects and faculty coaches on the second day of class. At that time, each team is presented with the full page proposal submitted by the client (see Appendix A). The teams then have three weeks to prepare a detailed Project Proposal Report that describes the client and project, identifies the design requirements, explains in detail the approach the team will take to the project, and a timeline for the team's progress.

By the end of the 13th week of the course, teams submit a Project Progress Report that includes a description of design options investigated and a recommendation of the option that should be designed during the remainder of the course. The Final Project Report is due in the 24th week.

Initial Project Challenges

The most significant challenges that the team faced when beginning the project were communicating with the client and obtaining information from sources within the country.

Communicating with Client

Although the team had a phone number for the client, reaching him by phone proved to be very difficult. A site visit was not possible until after the 10th week. Face-to-face communications through videoconferencing were not possible either. Therefore, the team was limited to communication primarily via email. The client typically required three days to respond.

The instructors note that such difficulties can and have occurred with domestic clients over the 18 years that we have been conducting client-based capstone projects. These difficulties are more likely, however, when the client is managing a charitable organization abroad. Therefore, our client was unable to devote much time to communicating with the student team. A result is that the team had difficulty developing a scope of work for the Project Proposal Report. They were unable to obtain photos or maps of the site from the client.

Understanding the Culture and Economics of the Country
The student authors took the initiative to learn about the culture and economics of Trinidad for this project. They began by asking questions of the client. They consulted additional published and human resources. The team gathered information from the CIA Factsheet (Central Intelligence Agency, 2005) and from websites about social welfare programs in Trinidad. The team consulted people who went on the mission's trip with the senior author in the summer of 2005. They also spoke with someone who currently lives near Rose-Hulman and is from Trinidad.

Obtaining Engineering Information from within the Country
Since the client was not an engineer, the team had to seek civil engineering information from other sources familiar with the country. Most student teams have little difficulty finding design information such as wind speeds, earthquake intensities, and rainfall amounts for project sites in the United States. In the case of international projects, such information can be difficult if not impossible to find. With some effort, most student teams are able to determine the governing codes and regulations, the prevalent methods of construction, and the availability of materials for projects in the United States. The student team on this international project was able to find some of the necessary information from the sources in Table 2. The information that they could not obtain from those sources became a priority during the site visit.

Table 2. Sources of engineering information for the project in Trinidad.

Internet
Extrapolation of data from nearby countries
Engineers from the country but currently living in the United States
Local engineers in the country
Engineering faculty at schools in the country

Another of the challenges that the team encountered was that, even though English was the primary language in the country, people in the country use different terminology for some things. For example, a "soak away" is a common form of waste water treatment in Trinidad. The client was unfamiliar with the term "septic system", but deeper investigation suggests that they are very similar systems.

Faculty Coach Perspective
Every project team is assigned a faculty coach who serves as a mentor to the team. The coach meets with the team at least once every two weeks to provide guidance and to assist the team with finding resources. Therefore, the coach has valuable insight into some of the challenges and benefits of working on an international capstone project.

This project required more time from the coach than domestic projects. Part of the additional time is spent helping the students obtain the necessary information. The faculty coach typically knows where or how to find information on codes, local practice, etc., for a domestic project. When the student team approaches the coach with questions in those cases, the coach can provide suggestions right away. In the case of this project, the coach spent additional time

researching information while the students also researched information. An important benefit is that the faculty coach learned more about the challenges experienced by the students and about engineering practice in another country.

Because of the difficulties the student team experienced in obtaining information, the faculty coach chose to have weekly meetings with the team. This allowed the coach to better monitor progress, and to more quickly identify where the coach's efforts would help most. The result, however, was more frequent meetings.

An important observation by the faculty coach is that the students appeared to be highly motivated by working on this project. With that came a satisfaction of knowing that they are making a difference.

Student Perspective from Entire Class

Before pursuing more international projects in the future, the instructors wanted to know the impressions and opinions of the entire capstone design class. Therefore, the instructors developed two questionnaires: one during the 7th week of the course, and one during the 15th week. The first questionnaire contained several questions about the general conduct of the course, but one of the questions was complete the following sentence: "I am … pleased with the project to which I was assigned." Students responded on a scale of 1 to 5 with 1 being "absolutely not" and 5 being "extremely". The purpose of the question was to determine if the international project team would experience a drop in satisfaction once they experienced some of the challenges unique to international projects. The results are presented in Table 4. Throughout the class, most students were at least "very" pleased with their project. The satisfaction ratings from the international project team were even slightly higher.

Table 4. Results of student questionnaire during 7th week of the capstone engineering course.

Question : I am … pleased with the project to which I was assigned.	1: abs. not	2: not	3: somewhat	4: very	5: extremely	Average
Members of International Proj Team	0	0	0	2	2	4.5
Members of All Other Teams	0	0	7	13	7	4.0

The second questionnaire focused more on the issue of domestic versus international projects. The responses from the entire class are presented in Table 5. Based on the student's responses, the international aspect of a project is not a great motivator, nor is a humanitarian or charity project. The students are motivated most by the subdisciplines of civil engineering involved. When asked about working on an international project in their preferred subdiscipline, only one third of the students indicated that they would probably want to work on such a project. The results also indicate that students believe the workload is the same for domestic and international projects. The implication might be that the team working on the international project works the same amount, but spends their time overcoming different difficulties than teams working on domestic projects.

Table 5. Results of student questionnaire during 15th week of the capstone engineering course.

Questions	1: Not a factor	2: Small factor	3: Some factor	4: Important factor	5: Most important factor	Average
1. Indicate how much the international aspect of a potential senior design project would affect your choice of a senior design project	4	9	9	8	0	2.7
2. Indicate how much the humanitarian/ charity aspect of a potential senior design project would affect your choice of a senior design project	5	2	10	11	2	3.1
3. Indicate how much the civil engineering specialties aspect of a potential senior design project would affect your choice of a senior design project	0	0	4	6	20	4.5
	1: Abs. not	2: Prob. not	3. Possibly	4. Probably	5: Absolutely	Average
4. Rate your desire to work on an international senior design project if one was available in your preferred area of civil engineering	0	6	14	7	3	3.2
	1: Much less	2: Less	3. About same	4. More	5: Much more	Average
5. Indicate how much work your project requires compared to the Missions Compound project [domestic project team members]	0	2	16	7	1	3.3
6. Indicate how much work your project requires compared to the other projects [international team members]	0	0	3	1	0	3.3

Summary of Final Design

Despite the initial challenges noted previously, the team was able to achieve the project objectives for the client. Contacts within Trinidad indicated that Trinidad will adopt the International Building Code; therefore, the team chose to use the 2000 International Building Code (International Code Council, 2000) for the project. They designed a reinforced masonry wall to surround the compound. Each of the facility's buildings are reinforced concrete frames with masonry infill walls. Two of the buildings, the orphanage and battered women's shelter, are two stories; the other buildings are single story. The floors of the two story buildings are reinforced concrete cast on a web-pan system commonly used in Trinidad. The roofs for all of the buildings are corrugated metal supported by open web joists. The foundations are shallow

spread footings made of reinforced concrete. Square footings support the columns, and a continuous foundation supports the masonry walls.

Lessons Learned from Our First International Capstone Design Project

Based on this first experience with an international capstone design project, the authors have compiled a set of lessons learned. These lessons encompass all phases of the project: purpose, acquisition, planning, site visit, and design. The authors acknowledge, however, that this list is not exhaustive. It is intended to add to available literature.

Purpose

• Evaluate the program outcomes to determine what need an international project will meet.
• Develop clear course objectives to be met by adding an international project.

Acquisition of Project

• Ideally, only take projects from clients who seek your help. They will tend to devote the time necessary to provide the student team with the information they need.
• Consider working through an organization such as Engineers Without Borders. The organization has extensive experience in helping plan and guide capstone projects. Unfortunately, the authors did not discover this resource until this project was well under way.
• A personal relationship with the potential client is invaluable. The client will tend to be more responsive to student needs, and the faculty coach will better understand the project. This personal relationship, if not already existing, should be cultivated before the start of the project by either visiting the client or having the client visit the school. Working on projects for the same client in successive years would probably help this relationship as well.
• If possible, choose a local engineer as the client or develop a relationship with an engineer in the country who is willing to be a resource to the student team.
• If such a project meets the objectives, consider working with a US based design firm that is performing a design in another country. The students can parallel the activities of the design firm. The design office will have already invested the additional time of locating information about the project site and would probably have visited the site.

Planning

• Expect that students and/or faculty will need to make a site visit. Build a budget.
• Check with the university administration to evaluate what liabilities the school might take by sending students and/or faculty to a developing country for a site visit.
• Evaluate the potential risks to students and/or faculty if they make a site visit. Develop a plan to mitigate those risks if a site visit will be made.
• If the program decides that a site visit is not feasible, develop a plan for assisting the student team with assumptions about site conditions, soil conditions, construction methods, etc.
• Develop a list of questions for the student team to use to initiate communication with the client since communication might not be as easy as with a domestic client. Therefore, the team will be able to maximize the productivity of their initial communication.

Site Visit

• Begin planning the visit right away. Ensure that passports are in order. Determine whether visas are required. Research local customs and courtesies.
• Plan the amount of soil needed to bring back into the US for laboratory testing. Then contact the USDA at least 2 months in advance to determine the required permits and procedures to bring the samples back.
• Prioritize activities to obtain the following information (in priority order): geotechnical investigation, site layout and surveying, meeting with a local practitioner, material availability and supplier information, construction practices.

Design

• Remind students that methods of construction, types of materials, and technologies available might be very different at the location of the project. That is an important consideration for international capstone projects, and requires the team to search for information.
• Consider that quality control in that country might not meet the standards assumed in the selected codes. Therefore, an increased factor of safety in design might be appropriate.
• Consider that the client might not have the design reviewed by local officials even though the design has not been reviewed by a P.E.

Conclusions

Acquiring, mentoring and completing an international capstone design project is more time consuming for instructors than a domestic project. Therefore, a program considering an international project should carefully evaluate what benefits the project will provide and compare them with the anticipated costs and risks. Note that the educational risks are affected by a variety of things: source of the project, availability of in-country assistance, potential for site visit, etc.

Based on this first experience, we believe that several items are critical to a highly effective international capstone project. (1) Work with a client that is familiar with the capstone project process, or work through an organization such as Engineers Without Borders that has successful experience with international capstone projects. (2) Plan carefully for a site visit early in the project. (3) Partner with an engineering firm local to the project site. They can assist with obtaining pertinent codes, engineering data, and information on common design and construction practices. (4) Partner with a local university. They might provide laboratory facilities and test equipment for use during the site visit. They can also assist with obtaining pertinent information.

As the faculty at Rose-Hulman evaluate the costs and risks of international capstone projects, they will also be considering the importance of enabling students to appreciate the challenges of completing projects in a global economy. Clearly we have challenges to be overcome, but an efficient and effective solution might still exist.

References

Ault, Holly K. and Barnett, Jonathan R. (2001). "Development and Implementation of Senior Design Projects at International Sites." *Proceedings, 2001 ASEE Annual Conference and Exposition: Peppers, Papers, Pueblos and Professors*. Jun 24-27 2001, Albuquerque, NM.

Boronkay, Thomas G., Dave, Janak, and Al-Ubaidi, Muthar. (2002). "International Senior Capstone Design Initiative." *Proceedings, 2002 ASEE Annual Conference and Exposition: Vive L'ingenieur*. Jun 16-19, 2002, Montreal, Quebec.

Central Intelligence Agency (2005). *The World Factbook: Trinidad and Tobago*. Retrieved September 2005, from http://www.odci.gov/cia/publications/factbook/print/td.html .

Friedman, Thomas L. (2005). *The World is Flat: A Brief History of the Twenty-first Century*, Farrar, Straus, and Giroux Publishers, New York, NY.

Heenan, David. (2005). *Flight Capital: The Alarming Exodus of Americas Best and Brightest*, Davies Black, Mountainview, CA.

International Code Council (2000). *International Building Code*. Falls Church, VA.

Jones, Russel C., Oberst, Bethany S., Siller, Thomas J., and Johnson, Gearold R. (2002). "International Exposure for Engineering Students Using Distance Learning Techniques." *Proceedings, 2002 ECI Conference on e-Technologies in Engineering Education: Learning Outcomes Providing Future Possibilities*. Jack R. Lohmann and Michael L. Corradini, Editors. August 11-16, 2002, Davos, Switzerland.

National Academy of Engineering, Committee on the Engineer of 2020. (2005) *Educating the Engineer of 2020*, the National Academies Press, Washington, D.C.

Zitomer, D. H., and Johnson, Paul. (2003). "International Service Learning in Environmental Engineering." *Proceedings, World Water and Environmental Resources Congress 2003*. Paul Bizier and Paul DeBarry, Editors. June 23-26, 2003, Philadelphia, PA.

Appendix A: Example Project Proposal

Missions International Compound - Trinidad

Port of Spain, Trinidad (August 2005)

Client

Dr. Brian Lushington
P.O. Box 3246
Diego Martin, Trinidad and Tobago

Contact: Dr. Brian Lushington
Phone: …
Email: director@missions-international.com

Background Information

Dr. Houghtalen (and two of his sons) went on a short-term mission's trip to Trinidad this past summer through Men for Missions International. While there, they began the construction of a two-story health clinic in the city of Chaguanas (just south of the capital, Port of Spain). The clinic was being built using reinforced concrete and block, common construction materials in Trinidad. The health clinic will be used to serve the poor people of Chaguanas by Dr. Brian Lushington, director of the Missions International work in that country.

Dr. Lushington's dreams do not stop with the health clinic project. He wants to build a mission compound that has a free service medical clinic, a home for battered women, a soup kitchen, and an orphanage to house 40 children. In addition, there will be an 8 bedroom guest house for visiting missionaries who will work at the compound. Dr. Lushington requests the services of an engineering design team to prepare design plans for development of the site and the associated facilities. Project elements will include significant client interaction to establish building use and floor plans, architectural considerations, site layout, appropriate technologies, local codes for buildings and utilities, accessibility, and project element costs. (This is the first international senior design project ever proposed by the civil engineering department, and it will provide our students with a cross-cultural design experience.)

Proposed Deliverables

The proposed deliverable products to be contained in a final summary report (and public presentation) will include (1) architectural schematics and floor plans, (2) site design including utility connections, (3) foundation designs, (4) structural designs and drawings of the buildings, and (5) a phased implementation plan with cost estimates. The deliverable products will be used by Dr. Lushington to determine the feasibility of the project and initiate fund raising. Expenses will be covered by Dr. Houghtalen.

Note: Project proposals are either submitted by the client or prepared by the instructors based on communication with the client.