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International Civil Engineering Capstone Projects—Benefits, Challenges and Lessons Learned*

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For the past 27 years the capstone program in the College of Science and Engineering at Seattle University has required all engineering students to complete a nine month long, team based, externally sponsored capstone design project. The Department of Civil and Environmental Engineering has completed nearly 150 projects since the program's inception. In the past decade eight of these projects have been for clients outside the United States of America focused primarily on infrastructure improvement in developing communities. This paper first provides an extensive literature review of international capstone projects completed at other US universities and then describes the international capstone projects completed at Seattle University. Details related to project recruitment, relations with partner organizations, and cultural exchange experiences are provided. Some of the benefits and challenges encountered by the teams reinforce what is reported in the literature, namely, the importance of site visits, dependable local clients in the partnering country, and awareness of local codes, material and construction practices. Assessment results from an alumni survey showed that the participants found the international project experience to be valuable in their professional engineering practice. However, they valued the professional skills they acquired through the capstone project more than the international experience itself.

Keywords: international capstone project; civil engineering capstone

1. Introduction

The practice of engineering is becoming a global partnership between nations. Many US companies are working on a wide range of projects around the globe. The infrastructure growth around the world, especially in countries like China, and India, opens up a wealth of opportunities for civil engineering graduates [1]. Success in these contexts requires engineers to possess global competency, including an ability to work in cultures other than their own, work on teams with engineers and non-engineers who approach problems differently, and to work across language, social, and ethical boundaries [2]. Simultaneously, many communities in the world lack many of the most basic human needs such as clean water, sanitation, healthcare facilities and schools. These communities can benefit immensely from global knowledge sharing while also providing US engineering graduates with human centered and transformational experiences [3].

ABET criterion 3 requires that engineering graduates have a 'broad education necessary to understand the impact of engineering solution in a global, economic, environmental, and societal context' (outcome h), 'an understanding of professional and ethical responsibility' (outcome f), and 'a knowledge of contemporary issues' (outcome j) [4].

International service learning and international capstone projects are a great venue to address the above ABET student outcomes as well as prepare engineering students for the global market-place. Such projects are especially attractive for engineering majors who, because of their demanding coursework, are often unable to participate in more traditional study abroad or student exchange programs. Furthermore, studies have shown that service oriented projects help to retain women and underrepresented minority students in engineering [5, 6]. International non-capstone service learning projects which are common in engineering programs across the US have been the subject of several studies [3, 7–10]. In general, these projects, which occur in curricular and extra-curricular formats, have underlying benefits to the students, international clients and universities. However, literature on international capstone projects is limited, which is surprising given the importance of capstone programs in achieving many of ABET's broadest educational objectives.

This paper summarizes the literature available on international capstone projects completed at various institutions around the US. It then describes eight international capstone projects completed by Seattle University's Department of Civil and Environmental Engineering over the past decade. Student assessment results and the lessons learned by Seattle University faculty members are provided, with emphasis on issues that may benefit other institutions that are considering implementing international projects in their senior capstone programs.

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2. Literature review of international capstone projects

While the peer-reviewed literature regarding international capstone projects is limited, individual projects or university programs are regularly described in the proceedings of conferences focused on engineering education. A summary of several of the more extensive descriptions is provided in Table 1. These international capstone projects include joint projects between institutions from different countries [11, 12], projects that involve travel outside the US [11, 13, 14], and projects with no travel [11, 12]. The duration of these capstone projects ranged from a single semester (or quarter) [1, 12, 15, 16] to an entire academic year [13, 17, 18]. Documented challenges encountered during the execution of international capstone projects relate primarily to language and cultural barriers [1, 11], difficulty scheduling meetings across time zones [11], and delays obtaining necessary project data in a timely manner [13, 15, 17]. Institutions report the overall global experience, exposure to international business practices and various design codes as the main benefits of the international capstone projects [13]. The lessons learned that are common to these documented international projects include the importance of having a dedicated US client or client representative who can serve as a resource to the design team [17], and the importance of building personal relationships with the client [17, 18].

There is very little literature focusing on the assessment of student learning in international capstone projects [12, 15, 17, 18]. Esparragoza et al. [12] focus primarily on the development of a survey to assess the duration and effectiveness of multinational interaction, the type of information exchanged, and motivation created by the working environment in an international project setting. The authors have not implemented the survey as of 2014 but plan to do so in the future. At Villanova University [15] student learning was assessed through a survey that listed eight technical and professional objectives related to structural engineering (such as communication, team work, and professional work ethics) and eight non-technical objectives (such as global and service awareness, spiritual growth, and interpersonal skills). Results from this survey revealed that although students met the goals for both categories, the technical objective scores were marginally higher than the non-technical objectives. Interestingly, nontechnical and technical objective scores for those students who traveled to the project site were significantly higher than those who did not. Student assessment results obtained at Rose-Hulman Institute of Technology after an international capstone experience revealed that despite the challenges, students were very pleased with their assigned project. Results also showed that students selected the international projects not primarily for the international experience or the humanitarian components but because of their interest in the specific civil engineering subdiscipline required by the project. While students perceived the work load was the same for both domestic and international projects, faculty advisors felt that the latter required much more time because of the difficulty to collect the required information for the design. Only a third of the class indicated that they would pick an international project within their desired civil engineering subdiscipline [17].

3. Capstone program at Seattle University and international projects in civil engineering

Seattle University is a Jesuit Catholic institution whose mission is dedicated to "educating the whole person, to professional formation, and to empowering leaders for a just and humane world." The College of Science and Engineering has a well-established capstone program that has been in existence for nearly three decades. All engineering students are required to complete a team based, nine month long, externally sponsored capstone project under the supervision of a liaison engineer from the sponsoring organization and a faculty advisor.

The capstone program, since its inception in 1988, has completed close to 150 projects in the Civil and Environmental Engineering Department. In the past decade the department has completed eight projects for international clients around the globe, at the locations shown in Fig. 1. For each of the eight projects, Table 2 provides a brief description, including year of completion and external sponsors. Briefly, the projects involved the design of two pedestrian bridges in remote parts of Tibet, a wastewater treatment system for the coffee processing waste of two farmers in Nicaragua, a flood control system for a farming community in Haiti, an orphanage/community center in Ethiopia and Colombia, and a fountain intended to provide water to a community a safe distance away from a crocodile habitat along the Zambezi River in Zambia.

3.1 Project recruitment and partnerships

Various organizations have partnered with Seattle University to provide the international capstone project experience. Organizations include Engineers Without Borders (EWB), local engineering companies, international foundations, non-profit organizations and non-governmental organizations (NGO).

Table 1. Summary of International Capstone Projects Found in Literature

US Institution	Engineering Departments Involved	Countries Involved	Travel Details	Project Details, Challenges & Lessons Learned
Florida A&M, Florida State University [11]	Mechanical/ Electrical/ Industrial/ Computer	Brazil	Fall semester	Exchange program in partnership with two Brazilian universities. Students worked on capstone projects at partnering university for one semester and then returned to home institution and joined on-going capstone work. US-based students studied Portuguese prior to travel in order to bridge the language gap.
		Armenia	No travel	Two Armenian students worked remotely with five US students. In Armenia instructions are in English and hence language was not a barrier, but scheduling meetings across time zones posed problems.
University of Boulder Colorado [1]	Civil/ Environmental	Information not provided	No travel	Benefits: students exposed to broader range of design constraints, greater understanding of the impact engineering solutions have in a societal and global context, ability to communicate with non-technical clients, ability to function in a multidisciplinary team, encouraging creativity, applying sustainability principles to design, and developing cultural sensitivity. Challenges: inability to visit site or financial implications of a site visit, timing of visit during academic year, culture and language differences.
University of Pittsburgh [3]	Civil/ Environmental	Information not provided	Information not provided	Project was in partnership with Engineers Without Borders (EWB) and various domestic and international partners. Benefits: exposure to international design codes and standards, familiarity with different ways engineers function across the globe. Challenge: change in scope by client in middle of project is harder than in a domestic project because of distance and language barrier.
Villanova University [15]	Civil/ Environmental	Honduras	1 week—mid semester	Three projects were completed for an orphanage compound. Some were muti-year projects. Design was done according to US standards. One student from each team was required to travel to site. These students took a concurrent 1-credit service learning course focusing on social elements of project host country. Benefits: Students who traveled to site scored higher on both technical and non-technical assessments. No challenges were shared.
Villanova University [16]	Electrical/ Computer	Nicaragua, Philippines, Indonesia, Democratic Republic of Congo, Tanzania	No travel	Three projects related to micro-hydro power and solar power for rural electrification, and cell phone access for improved healthcare. The healthcare project included collaboration with business students to help develop a business model to make the healthcare system sustainable. Challenges: Finding local weather data and estimating solar insolation.
University of Calgary [13]	Civil	Portugal	Fall and Spring	Non-service learning type project; student teams partnered with developers to design and manage a sub-portion of a major urban development project. Some students and faculty members traveled to the site on an initial assessment trip in September and again in May to present the final design to the developer. Benefits: Exposed students to different learning, business, architectural and construction practices in Portugal. Challenges: getting proper information early on in the project; due to lack of knowledge of local standards, several design iterations were taken that could have been avoided with proper knowledge upfront.
Rose-Hulman Institute of Technology [17,18]	Civil	Trinidad	1 student for a week	Development of a missionary compound for a local physician. Students developed floor plans, site layout and structural and foundation designs. Benefits: Students enjoyed project and did not feel that work load was greater than domestic projects. Challenges: long response time from client slowed progress; difficulty obtaining necessary information from non-engineering partner; team had to get used to the local dialect of English; difficulty importing soil into US for testing. Study shares an extensive list of lessons learned.
		Ghana	Summer preceding project	Design of an agricultural training facility with a computer training center, conference hall, care taker house, hostel, poultry building, office space, executive chalets, and providing electricity and water to the facility; scope included development of floor plans, site design, structural and foundation design; project was partnership with EWB student chapter. Lessons learned from Trinidad project were helpful in Ghana. Group traveled to site to collect soil data, pertinent design codes, prior land use, rainfall data, common building materials, local construction techniques and practices. Soil was sent to a university in Ghana for testing; most data was obtained prior to beginning of capstone project. Improvement for future projects: Improve communication through telephone and/or video conference via phone line and web conference; establishing long term relationship with Ghana for future projects.
Michigan Technological Institute [14]	Civil, Environmental & Mechanical	Bolivia, Dominican Republic, Panama	Variable	The international senior design program and later iDesign. Projects include bridge and structure designs, bio charcoal, aqueducts, and hydropower. From a study of iDesign, the following benefits and challenges were explored. Benefits: intercultural, professional and personal development. Challenges: students could use better training on culture, language and community practices in host country before travel.

Table 2. Details of International Civil Engineering Capstone Projects Completed at Seattle University

Design of	Location (Year)	Project Description	Sponsor
Pedestrian Bridge	Tibet (03–04)	Children from the village of Shoda were forced to walk three hours to find a safe river crossing between the village and the nearest school. This forced them to remain in school the entire week. To address the problem, a non-profit relief agency, World Concern, sponsored a student team to design an approximately 75-m span cable suspended pedestrian bridge.	Herrera Environmental consultants
Pedestrian Bridge	Tibet (04–05)	Two local villages, Gyibu and Jayng, were isolated from markets, healthcare facilities and schools by a 65m wide deep gorge. The closest safe crossing was down the river valley two to three miles from the villages. World Concern desired a safe crossing for the community. The student team designed a suspended pedestrian bridge.	Herrera Environmental consultants
Coffee Wastewater Treatment System	Nicaragua (07–08)	Wastewater produced during coffee processing is acidic, high in Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Total Nitrogen and Phosphorous. The processed water in most cases is directly released into local streams, adversely impacting the water quality and also posing health hazards. The student team designed a wastewater treatment system for a new coffee "*beneficio*"or wet processing mill, for use by five coffee farming families in the town of La Suana.	Tetra Tech Inc.
Community Fountain for Safe Water	Zambia (08–09)	The lack of municipal water distribution system in the small town of Chirundu forced residents to collect water from the Zambezi river at a location where crocodile attack was a serious concern. The student team designed a mechanical pumping system and a community fountain to provide a safe place to collect water. The team also designed a water treatment system to remove pathogens from water intended for potable use.	Seattle University
Diversion Channel for Flood Control	Haiti (09–10)	A farming community along Riviére des Moustique was adversely affected by flooding due to frequent hurricanes/ tropical storms, sediment accumulation and poor drainage in lower parts of the floodplain. In 2007 a European non-governmental organization partnered with Herrera to develop a comprehensive flood control plan for the region. The design team completed the design work for a portion of the master plan. The team designed the diversion channel, inlet and outlet structures and prepared construction ready drawings.	Herrera Environmental consultants
Orphanage, Community and Learning Centers	Ethiopia (10–11)	An Ethiopian immigrant living in Seattle wanted to use the property she owned in Ethiopia to develop an orphanage and a community center for a nearby village. She requested the design of a dormitory and learning center for the orphans and a community center to host various activities and training sessions for the villagers. The design team developed architectural/structural designs and cost estimates of a typical dormitory that could house a maximum of 50 children, learning center that could accommodate 25 children, and a community center that could house 300 people.	Engineers Without Borders
Community Center	Colombia (10–11)	Poder Joven Foundation (PJF) in Colombia planned to build a community center to host their educational programs with underprivileged children, offer job training for adults and to conduct community meetings. The capstone team carried out the architectural and structural design of a three story reinforced-concrete building. The design had to be simple enough so that it could be completed by unskilled labor and in phases as funds become available.	Tetra Tech Inc.
Coffee Wastewater Treatment System	Nicaragua (13–14)	Project is similar in scope to the 07-08 project in Nicaragua but was completed for a farming community in the town of San Antonio. This team expanded on the previous design by including filtration and nutrient removal.	Kennedy Jenks Consultants

The two Tibet pedestrian bridge projects in 2003–04 and 2004–05 academic years were sponsored by a long-time supporter of SU's senior design program, Herrera Environmental Consultants (HEC), which is a local civil engineering company that is actively involved in humanitarian efforts around the world. HEC partnered with a non-profit relief agency, World Concern, to construct pedestrian bridges in remote areas of Tibet. Both of the bridge design teams were mentored by a civil/structural engineering faculty member and an HEC engineer who had visited the site and had performed topographic surveys prior to the start of the capstone project.

The Haiti flood control project in 2009–10 was also sponsored by HEC. In 2007 a European NGO partnered with HEC to develop a comprehensive flood control plan for the region that formed the basis for the student project. The student team was mentored by two engineers from HEC, a civil

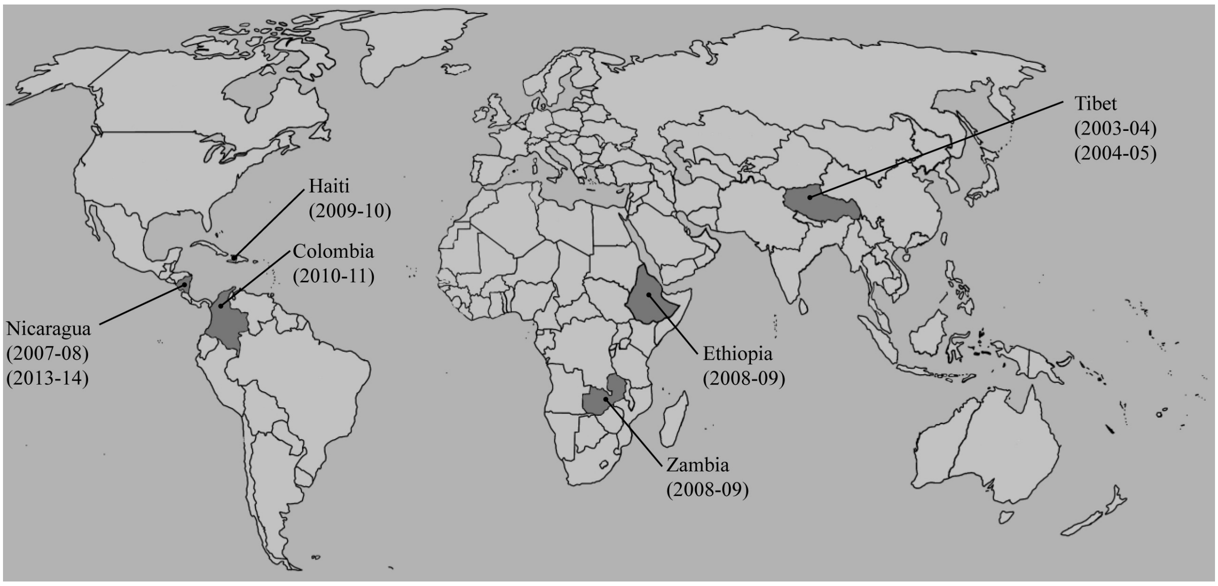

Fig. 1. Location of International Civil Engineering Capstone Projects Completed at Seattle University.

engineering faculty member, and an NGO representative with 30-years of development experience in Haiti and an engineering degree from an American university.

The Nicaragua coffee project in 2007–08 was initiated by a faculty member in the department of Chemistry at Seattle University who had worked with the local farmers for more than ten years on improving the quality, consistency and sustainability of coffee. Through her work, she had developed a close partnership with Catholic Relief Services/ Nicaragua, Central Cooperative Services Multiples "Aromas Café" (CECOSEMAC) and the University of Central America, Managua (UCA). A civil engineering faculty member and the chemistry faculty member served as advisors to the team in 2007–08. The former also advised another team in 2014–15. Funding for these projects was provided internally by Seattle University, student clubs (e.g. EWB), and two local civil engineering companies—Tetra Tech and Kennedy Jenks Consultants. These companies also provided sponsor liaisons for the projects.

The Ethiopia orphanage project in 2010-11 was initiated through the Engineers Without Borders (EWB) Student Chapter at Seattle University. An Ethiopian immigrant living in the US approached the EWB Student chapter with a vision of developing an orphanage in a property that she owned back home. Three Ethiopian civil engineers practicing in the US and an architect who has worked as a volunteer on similar projects in other parts of Africa were professional mentors to the team. The Civil Engineering Department of Addis Ababa University (AAU) was a project partner and provided the necessary field data to the team. A structural engineering faculty member served as the advisor to the team throughout the duration of the project.

The Zambia Community Fountain project was initiated by a retired electrical engineering faculty member from Seattle University who is also a Jesuit priest living in that country. The project was supervised by a civil engineering faculty member, while HEC provided a liaison engineer to work with the team.

The Colombia community project in 2010-11 was proposed by a faculty member from the department of civil and environmental engineering who is also a member of the board of directors of a private foundation in Colombia called Poder Joven Foundation (PJF). This faculty member served as an advisor while the executive director of PJF in Colombia served as a resource to collect information for the team. A civil engineering company in Seattle, Tetra Tech, provided financial support and a liaison engineer.

3.2 Formation of student teams

The faculty project coordinator formed the teams based on the results of an interest survey that was administered to the students during the spring quarter immediately preceding the project year. In this survey, students listed their top three choices of civil engineering sub-disciplines for the capstone project placement. In addition, the students indicated any engineering internship experience, construction or laboratory work, and familiarity with engineering software and any hobbies or skills that may be of value in a specific civil engineering project.

Student skills, communication strengths, personality traits and team diversity are taken into account to form well balanced teams. This is possible due to the small class sizes in the department (20–35 students/year), quarterly advising for all students with faculty members through all four years, and a small department that allows professors to teach students in multiple classes before the senior year. Typically each team has three to four students. Student teams are assigned in the first week of the fall quarter.

3.3 *Capstone project experience*

In the fall quarter, the students work on a written proposal covering the project background, scope, tasks and deliverables. In this quarter, the students develop the proposal iteratively through both internal and external review cycles. In the winter and spring quarters, they work on the project and submit a final written report. The teams have weekly meetings with the faculty advisor and biweekly to monthly meetings with the project partners.

3.4 *Benefits and challenges*

The international projects performed at Seattle University over the past decade provided the teams with experiential learning in global, societal, and economic issues. The students were exposed to other cultures, customs, and the importance of working with clients who are not engineers. Many project challenges varied from project to project and were dependent upon the specific civil engineering sub-discipline, but some challenges were common to all.

3.4.1 *Site visit*

An initial site visit was important, especially for a civil engineering project outside of the structural sub-discipline. Non-structural civil engineering projects seemed to be more context based, therefore the students benefitted more from a site visit in that it helped them to visualize how the end product fit into the existing conditions. However, the cost of student travel and travel advisories against some of the countries posed concerns.

In the Nicaragua projects, the student teams and the faculty members traveled to the site to conduct field reconnaissance, observe a coffee processing mill and to sample and analyze coffee wastewater. The 2007–08 team traveled to the site during Christmas break in the project year, and spent two weeks at the project site. The 2013–14 team spent two weeks on-site during Christmas break prior to the project year. The field reconnaissance and the land survey of the site helped the team to better decide where the water treatment facilities could be located, a task that otherwise would have been difficult. The cost of travel was shared by Seattle University, sponsoring company, and the students.

In the case of the Haiti flood control project, the faculty advisor travelled to the site in January 2010, in the middle of the capstone project, to carry out a field reconnaissance and to meet with the NGO representative. The students could not join the trip because of cost, a travel advisory that was in effect, and because classes were in session. The faculty advisor's travel cost was covered by the university. The faculty advisor fully documented the site with photographs and performed soil and water tests to help the students develop their design.

Because the Ethiopia project involved structural design of buildings and there was contact with the Addis Ababa University (AAU) for data collection, the department decided that a site visit was not critical. Photographs of the site provided by the client showed no steep slopes at or near the site so there was no concern in regards to soil stability issues. In addition, soil tests performed by a graduate student at AAU were sufficient for the team to determine the foundation requirements and further carry out the structural design of the three facilities for the orphanage.

The Colombia, Tibet and Zambia teams did not visit their sites. For the Tibet project, the pictures and the topographic map provided by the sponsor were sufficiently detailed to provide the information required for the design of the superstructures. Because the land to build the Colombia project was purchased during the academic year, a visit would have primarily been a cultural experience rather than a field reconnaissance. Members of the Zambia team delayed their visit until immediately after graduation in order to have a chance to build their project.

3.4.2 *Local contacts in other countries*

For international projects to be successful it is imperative to have local contacts, both professional and personal, willing to work with the team throughout the academic year [17]. The civil engineering projects executed at Seattle University reinforced this notion.

Site visits to Nicaragua by the team and faculty members strengthened the connections with the farmers and helped the team during the execution of the project. Partnership with Catholic Charities supported local travel and lodging needs, and partnership with CECOSEMAC cooperative provided potential project site locations, access to farms, and formed a positive working relationship with farmers. The Haiti-based NGO representative provided invaluable advice to the team regarding appropriate construction methods in the region.

Collaboration of the Ethiopian orphanage team with AAU was instrumental in obtaining the necessary geotechnical data and site information for the team to create regionally appropriate structural design. In this case, the team specified the locations and number of test pits to be dug, the types of lab tests to be performed and the data to be collected. In addition, a licensed civil engineer and an architect from the EWB professional chapter who had previously designed similar facilities in other African countries served as resources to the team by reviewing the preliminary design and provided feedback.

The Tibet bridge projects were successful despite the team not interacting with an international liaison from World Concern because the sponsor had collected all the necessary information in an earlier trip to the site. For the Colombia project, the close connection between the faculty advisor and PJF was very helpful in getting the necessary project information. The Zambia project was a multidisciplinary partnership between Mechanical and Civil Engineering departments. The four person team consisted of two students from each department and a faculty member from each department serving as advisors. A retired electrical engineering faculty member living in Zambia served as the local contact. With different course schedules, requirements and deadlines for deliverables from each department and multiple advisors, the project coordination turned out to be quite challenging. The team also found it hard to connect with their local contact throughout the project due to lack of regular phone access.

3.4.3 Building materials, construction practices, local codes and standards

The Seattle University projects supported the observation that for designs to be implemented successfully, teams have to be aware of local design codes and standards, cultural factors, material availability and local construction practices.

The Nicaragua project had a number of constraints: the farm lacked electricity and therefore the design alternatives could not include pumps or aeration; the design had to be compatible with sustainable and organic standards as required by the local farmer's cooperative, CECOSEMAC, and by the Nicaragua Fair Trade program; the final effluent to be discharged to surface waters had to meet or exceed local standards of the Ministerio del Ambiente y los Recursos Naturales de Nicaragua (MARENA) which was equivalent to the US-Environmental Protection Agency (US-EPA). The team had to specify locally available materials, such as concrete, plastic liner, gravel, PVC pipe, and wood.

In the Haiti flood control project the team analyzed rainfall data that had been collected by the sponsoring NGO during hurricanes Hannah and Ike and used this information to update a hydraulic model for the site that had previously been developed by HEC. The discharge and hydraulic information developed from these models guided the design of the flood control channel. The team researched appropriate construction and channel lining technology available in Haiti. In consultation with the NGO sponsor, they specified locally available clay, gravel and sand for levees at the channel inlet and outlet. In addition, the team specified the use of gabion baskets (rectangular wire mesh baskets filled with rocks) for the diversion channel lining.

During the early stages of design of the Ethiopian orphanage facilities, the team researched the climate and hazard conditions, local architecture and local construction materials, in order to define the basis of design for the project. Later in the project, AAU provided information on local construction practices and standard local materials which helped the team's structural design and cost analysis. The team learned that the prevailing structural system for the region was reinforced concrete framing with infill masonry. They also found that roof systems commonly consist of timber (Eucalyptus) trusses for spans of up to eight meters and steel for longer spans. The students based the design on the Ethiopian Building Code Standards of 1995.

For the Tibet projects the sponsor liaisons provided the required information on available construction materials and transportation conditions (such as road width) to the nearest village, and labor and machinery availability for construction. The teams produced a design that took these constraints into consideration.

3.4.4 Proficiency in foreign language

Foreign language proficiency is helpful in international projects for multiple reasons, but in all eight Seattle University projects, the language barrier was not insurmountable. In the Nicaragua project, design drawings for the wastewater treatment process and maintenance were drafted in Spanish to be useful for the farmers. This team had a member who was proficient in Spanish. The second Nicaragua project included a technical liaison who also served as a translator. This greatly facilitated communication during the site visit, improved clarity, and saved time. In the Haiti flood control project much of the survey data provided to the team was in French. The team relied on the NGO sponsor, an American engineer who understood the local dialects of French, to clarify the meaning of the data. In the Ethiopian orphanage project the students were able to complete their design without any knowledge of a

Table 3. Alumni Survey Response Rates by Project

Project	Year of Graduation	Responses out of Team
Tibet Pedestrian Bridge	2004, 2005	5 of 8
Nicaragua Coffee Wastewater Treatment	2008, 2014	5 of 7
Zambia Community Water	2009	0 of 2
Haiti Flood Control	2010	1 of 4
Ethiopia Orphanage	2011	3 of 4
Colombia Community Center	2011	2 of 4

foreign language because the codes and other documents were in English. In the Colombia project, the team had difficulty communicating with the international liaison due to the language barrier. However, because the faculty advisor was fluent both in Spanish and English, he was able to serve as a translator. Language was not an issue for the Tibet and Zambia projects because the students did not have much interaction with the international partner.

3.4.5 Working with non-engineering clients

International projects usually involve non-engineering clients who have a vision and/or interest in the social benefit to the community. The students have to translate the client needs and constraints into functional requirements and measurable design parameters. They also face the challenge of explaining engineering terms and constraints to a non-engineering client. In the first Nicaragua project the clients were not amenable to treatment methods outside of what was common practice in the region. Therefore to enhance the project and provide creative design opportunities, rather than only a reinterpretation of existing methods, the students prepared multiple design solutions. In the end the team was able to provide a design largely similar to common practice, but with small changes that improved performance. In the Ethiopia project the client often focused solely on the social benefit an orphanage would bring to the community during meetings with the engineering design team. It was important for the faculty advisor to recognize the depth of social context that was important for the students to understand the project, but also to recognize and help facilitate obtaining specific design constraints from the client, even issues as simple as how many children the orphanage would need to house.

4. Student assessment results

Alumni who had worked on international projects over the past decade were surveyed in 2014 to assess the effects of the student's experiences and their perceptions. A total of 29 students had worked on the eight international projects described above. The survey was sent out to 21 of those alumni whose email addresses were available. Sixteen alumni responded to the survey. Table 3 shows the breakdown of the respondents by project.

The first part of the survey focused on if the project scope was well defined, if the international project was helpful in their current professional career, and how they perceived their project compared to the concurrent domestic capstone projects of their peers. The survey results are tabulated in Table 4. The participants agreed that the project scope was well defined at the beginning of the project, irrespective of whether they visited the site or not prior to beginning of the project. The alumni found the international project experience to be valuable in their professional career. Additionally, they did not feel that having an international service-oriented project was any less applicable to their professional work than if they had had a domestic project similar to their peers.

Of the sixteen respondents, seven had traveled to their project sites. Of those, five travelled to Nicaragua either the winter prior to the beginning of the project or during the academic year. The other two traveled to Tibet to participate in the construction of the bridge after graduation. Table 5 shows the survey results pertaining to the importance of site visit. Only the responses of the teams that travelled to Nicaragua are included in Table 5 because the site visit to Tibet did not affect their project success. Table 5 clearly shows that the students rank the site

Table 4. Survey Results of Project Scope and Value of international Project in Professional Career

Question	Mean rating[1]	Range
The project scope was clearly defined at the start of the project	4.19	1–5
My experience working with an international project has been valuable in my professional engineering practice	4.31	3–5
My international project was less applicable to my professional work than my classmates' local projects	2.13	1–4

[1] Rating based on a Likert scale (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).

Table 5. Importance of Site Visit from Teams that Visited the Site

Question	Mean rating[1]	Range
Visiting the site was important to my understanding of the project scope	4.80	4–5
Traveling to the project site was mainly just a fun experience but did not influence the project success	1.50	1–2
The project would have been just as successful had our team not traveled to the project site	2.40	1–4

[1] Rating based on a Likert scale (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).

visit to be of high importance and believe that the project would not have been successful without it.

In student surveys of this nature, the written feedback is often much more meaningful than the numerical rankings. The students who traveled to Nicaragua had the following feedback on site visit.

"Seeing the need and effects of letting the wastewater go untreated made our team realize the importance of the project. Since every site is unique, having a site visit allowed us to know and understand the area and constraints that we had to address. Not only that, but getting to meet the farmer and our local partners ensured that the project was more successful and sustainable since we know that we have someone that can check in on the project more often than we could from Seattle."

"Layout of the treatment system relied heavily on understanding of the topography of the site. Having traveled to the site and conducted a basic survey was critical to the layout of the system (hydraulic considerations of the system were influenced by the topography). A site visit also influenced report writing. While the background site information is not the most critical component of the report, it is a section that is present in almost all professional-world engineering reports. Without a site visit I think there would be some loss in clarity and detail in report writing and also presenting. Visiting the site is helpful for visual learners like myself who better connect the engineered/designed solution with aspects of the site."

Nine of the respondents did not travel to their project sites, namely, Tibet, Ethiopia, Haiti and Colombia. Table 6 shows the survey results of these respondents. Interestingly, the respondents believed that they did not have difficulty understanding the project scope in the absence of a site visit. They also felt confident that the solution that was proposed with their design was appropriate. They disagreed with the idea that they had to make assumptions which may have been answered if they had had a site visit.

Some of the written comments of students who did not visit the site are presented below:

Tibet Bridge Team Member: "Our mentor had travelled there before and given us all the required information from materials available, mode of transportation (by feet / trucks), logistics (how far is it from the nearest village to the project site and how wide the road is), laborers (is there any machinery / crane available and how many construction workers are available), and etc. Had they not been there before, we might have been specified materials that aren't even available there and asking them to build something that is impossible due to limited resources."

Ethiopia Team Member: "To get a good understanding of the scope of work, we had to communicate with the property owner and collaborate with a local university that made project site visits for our team. The local university surveyed the property and sent us their information using AutoCAD. The AutoCAD files with all the surveying points made it a lot easier for us to design the layout of the community center and the dormitories. Without the help of the local university, our project would have not been as successful."

Haiti Team Member: "For us, I think a visit would have been useful in order to gather additional information and get a feel for what we were actually designing and construction methods that would end up being used. It helped that we had people working with us that were able to go to the site and take photos and provide us with the information that we needed."

Colombia Team Member: "A site visit was not conducted for my senior design project and I do not feel a site visit was necessary. We had a very helpful point of contact in Medellin (Colombia) who was able to provide us with any site specific information. I actually think not having a site visit is very realistic to young professional life as junior level engineers are not always able to travel to distant job sites."

The following are some of the alumni responses when asked what the most valuable aspect of the

Table 6. Importance of Site Visit from Teams that did not Visit the Site

Question	Mean rating[1]	Range
It was difficult to understand the project scope, having not been to the project site	1.89	1–3
Though traveling to the project site may have been fun, it did not influence the ultimate success of our project	3.78	3–5
We had to make assumptions about the project scope which may have been answered if we had visited the project site	2.44	1–4
Our team was confident that the proposed solution was appropriate, despite never having been to the project site	4.22	4–5

[1] Rating based on a Likert scale (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).

international senior project experience was for their professional career:

> Tibet Bridge Team Member: *"The best part of the senior project was working on a long term project with peers. Developing a plan, designating a PM (project manager), and coordinating with the same team for 9 months was the most valuable experience. This would be true if it was a local project as well. The fact that it was an international project made it more exciting to talk about to peers and at interviews."*
>
> Ethiopia Team Member: *"My professional career has required me to work on projects in areas I have not visited. The senior project experience has prepared me to tackle time zone differences, communication hindrances, and extensive coordination between two project teams in two different locations."*
>
> Colombia Team Member: *"The most valuable aspect of my international senior project was learning how to work on a team for a long duration. Knowing when to lead and when to follow was a new lesson that I didn't realize I had to learn. Most of my engineering education was spent working on assignments by myself and never delegating tasks to others. Now as a project manager I understand the value in letting go of control over details and letting others use their own method they find efficient in producing accurate results."*
>
> Nicaragua Team Member: *"This opportunity gave me a glimpse of what Design Build is like. One of my passion is to work on international engineering projects. This was the first opportunity I had, from which I was able to confirm that international projects is what I want to work on later in my career. Lastly, I was able to see how our engineering work can affect the community and help people, which is a reward in itself."*

Overall, the respondents found that the professional skills they had developed through the senior design were the most valuable take away from the project rather than the international experience or the technical skills they exercised in their engineering designs.

5. Faculty perspective of lessons learned

The above projects provide good examples of the pedagogical potential of international projects. Lessons learned from these projects, mainly from the faculty advisors' perspective, are summarized below.

- Working with a Seattle-based liaison who has a vested interest in the project was a critical element of success in the Tibet, Haiti, Ethiopia and Nicaragua projects. Conversely, the projects in Colombia and Zambia did not have knowledgeable Seattle-based liaisons. Both projects had liaisons stationed abroad, a member of PJF Foundation in Colombia and a retired faculty member living in Zambia. The lack of regular meetings and smooth information flow made the projects more challenging.
- The Tibet and Haiti projects had a reasonable lag time between the design phase and the construction phase. On the other hand, the site for the community center in Colombia was under negotiation during the summer prior to project initiation. However, by the end of the fall quarter a different site was purchased. Due to the lack of permitting requirements in that isolated zone of Colombia, construction progressed rapidly and almost ahead of the design. This became a frustrating and stressful experience to the team as they had to constantly check that the construction met design code requirements.
- Site visits are crucial, especially for non-structural projects. The Haiti team took a while to understand the watershed wide context of the project because of the lack of site visit. Conversely, despite the lack of a site visit, the Tibet and Ethiopia structural projects were successful because of the available field data and pictures of the site. The Nicaragua projects would have been difficult without a site visit.
- Students should be required to address social, health and safety issues because codes and regulations in developing countries may not address these adequately. Nevertheless, students should be required to respect and abide by the local codes and governmental framework without assuming that the US codes are superior to others and should be applied in any country without any further questions.
- Universities should continue to follow up with project partners either during construction or monitoring phases. The trip to take part in the construction of the bridge after the first Tibet project in academic year 2003–2004 led to the second bridge project in academic year 2004–2005. Similarly, the continued partnership in Nicaragua since 2007 led to a project in academic year 2013–2014.
- Prior to team placement, students should be polled if they would like to be placed on an international project. If the project involves travel, students should be given time to research and prepare for local living conditions, food, language and cultural differences. Furthermore some students may feel more comfortable traveling to certain parts of the world than others. Issues related to expenses, such as cost sharing between university and potential funding partners should be discussed early or prior to the project. Some students may thrive in an international project but may not have the finances needed for travel.
- Identifying students with the appropriate language skills will be valuable during travel, for interpreting and preparing documents.
- Projects that are expected to be built with unqualified labor and/or with insufficient mechanisms

of quality control should be designed to be simple and conservative to accommodate local construction tolerances.

- Multidisciplinary international projects involving different departments may require closer scrutiny and coordination with respect to schedules, deadlines for deliverables and frequent follow up with students to ensure adequate progress.

6. Summary and conclusions

The Department of Civil and Environmental Engineering at Seattle University has completed eight international capstone projects in the past decade. The projects have had multitude of partners: Engineers without Borders, non-governmental organization, private companies in the US, non-profit relief agency, and private foundation in the partnering county. Benefits, challenges, and lessons learned in these projects are consistent with what has been reported in the literature. In addition the eight projects completed at Seattle University highlight the following: (1) limitations to the ability to conduct site visits, either because of cost or travel advisory restrictions, makes the execution of the project more difficult, especially for context-based civil engineering projects; (2) establishing reliable local contacts, both professional and personal, is imperative to the success of the projects; (3) investing effort and resources to investigate codes and standards, cultural factors, material availability and local construction practices is very important for the success of international projects; (4) working with clients who do not have an engineering background is difficult and may require more effort; (5) foreign language proficiency by any member of the design team is advantageous but not absolutely necessary as many resources are available today for technical translations. From the faculty perspective, international projects are most likely to be successful when they have a reliable US based liaison with vested interest in the project, reasonable lag-time between design and construction, teams consisting of students with appropriate skills and interests and keep designs that are sufficiently simple to accommodate local construction practices. Student assessments carried out of the alumni who had worked on international capstone projects show that the important take away for the students from the capstone experiences are the various professional skills developed through the experience and not exclusively the international experience itself.

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