BUILDING ENGINEERS AND CONSTRUCTION MANAGERS: THE IMPACT OF INTERNATIONAL SERVICE PROJECTS ON THE DEVELOPMENT OF UNDERGRADUATE STUDENTS

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University students' involvement in curricular and co-curricular international service projects continues to become more prevalent. If such involvement provides the student outcomes which much existing literature asserts, these activities fill a much-discussed skills gap for entry-level engineers and construction managers. Exploring student outcomes from involvement in a year-long team-based design and build project with the Milwaukee School of Engineering (MSOE) chapter of Engineers. A multi-disciplinary research team with backgrounds in engineering, construction management, the humanities, and international development addressed this research gap by implementing an IRB-approved project to observe students during a 2017 trip. Qualitative field data was obtained via 10 days of ethnographic observation of four of the ten student participants during the construction of a 165-foot cable suspended bridge alongside host village members in El Temal, Guatemala. With a guiding question of "What impact does an EWB-USA international construction project have on the development of college students?" and a sub-question of "What professional, technical, and social skills do students engender in an EWB-USA international construction project?", the most salient discovery is that not only are all three skill sets developed, but also that said skill development is interconnected on such a project in a way which would be difficult, if not impossible, to replicate in a classroom setting.

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INTRODUCTION

The EWB-USA student chapter of the Milwaukee School of Engineering (MSOE) is an extra-curricular international project-based LTS[1] program which has worked alongside Guatemalan communities since 2008 in accomplishing their own development goals via specific infrastructure projects such as schools, bridges, and water distribution systems. A typical project duration is one year, during which the students work as a team in project design and construction planning, with oversight from faculty, professional mentors, and EWB-USA Guatemalan staff. The in-country construction trip is typically ten days and is the culmination of a year's work.

The host village, municipal government, and student chapter all contribute financial and/or material resources towards the project as well as providing hands-on labour. The students, faculty, and professional volunteers work side by side with an EWB-USA Guatemalan contractor and approximately 40 community volunteers each day.

The focus on community empowerment and student mentorship illustrates EWB-USA's two-fold mission to build "…a better world through engineering projects that empower communities to meet their basic human needs and equip leaders to solve the world's most pressing challenges" (https://www.ewb-usa.org/mission-and-history/). Any holistic impact assessment of such partnerships would investigate the project's impact on the community itself. EWB-USA has developed a Project Monitoring and Evaluation (PMEL) program which aims to evaluate impact for every project, and this has been conducted for the project discussed in this study.

Regarding student impact, MSOE's EWB-USA faculty advisors had empirically observed how projects contribute to developing well-rounded engineering and construction management students with professional, technical and social skills. Therefore, "What impact does participation in an Engineers Without Borders USA (EWB-USA) international construction project have on the development of college students?" was chosen as the broad guiding question, and the sub-question articulates specific metrics: "What professional, technical, and social skills do students engender in an EWB-USA international construction trip?"

This work is relevant to employers and accrediting agencies who stress the importance of strong professional, technical, and social skills, and it relates to previous work by incorporating direct field observation to what is predominately comprised of self-assessment and reflection.

LITERATURE REVIEW

Professional, Technical, and Social Skills

While the accreditation requirements of both the Accreditation Board for Engineering and Technology (ABET) and American Council of Construction Education (ACCE) heavily weigh technical skills, non-technical (professional and social) skill proficiencies are emphasized as essential by the National Academy of Engineers (2004) and the American Society of Civil Engineers (2019) (Ahn *et al.,* 2012).

[1] As a variety of service programs and activities exist, Bielefeldt et al. (2013) provide a beneficial framework for categorizing university student service activities: Service Learning (SL) is curricular based, whereas Learning Through Service (LTS) encompasses Service Learning (SL) as well as extracurricular service activities.

Construction and engineering industry employers consistently emphasize that entry-level professionals lack the necessary non-technical skills to be effective (Mahasneh and Thabet 2019, Brunhaver *et al.,* 2018). Engineering graduates themselves highly ranked specific non-technical skills as the most important ABET competencies in their current professions (Passow 2013). Furthermore, non-technical skills were ranked highest in importance in a survey of recruiters from over 100 construction companies in the eastern United States (Ahn *et al.,* 2012). Among 14 technical and non-technical competencies, the top six were non-technical skills: ethical issues, problem-solving skills, interpersonal skills, leadership, adaptability, and collaborative skills.

Meanwhile, an abundance of literature, the most comprehensive of which is Astin et al.'s (2000) work, posits that curricular and co-curricular service activities equip students with those very skills.

Assessment Methods

Among the first endeavours to assess student outcomes from service participation is Giles and Eyler's (1994) work which surveyed 72 undergraduate students at Vanderbilt University which specifically assessed civic attitude development. Students reported an increased belief that people can make a difference and should be involved in community service, especially in leadership.

A much broader survey of over 3,400 college undergraduate students from 42 universities, which assessed multiple metrics, demonstrated that community service participation positively affects a student's academic development, life skill development, and sense of community responsibility (Astin and Sax 1998). Expanding even further, Astin *et al. (*2000) performed a longitudinal mixed-method study involving over 22,000 university students from a national sample of U.S. universities who were involved in service learning, extra-curricular community service, or neither. Service activities positively impacted academic performance, values, self-efficacy, leadership, choice of service career, and plans for service participation after college. Student interest was the most important factor in having a positive experience, indicating that service should align with one's major.

As LTS among construction and engineering students became more common, literature examining student outcomes began to emerge. McCormick *et al. (*2008a) administered a simulation exercise with 44 students from Tufts University to assess any differentiation among students involved in service-learning in three skill categories: Analytical, practical, and creative skills. As individuals, service-learning students scored higher on analytical and practical skills, but equal on creative skills. As a group, however, service-learning students scored higher in all three categories.

McCormick *et al. (*2008b) also performed a case study with engineering students on an EWB-USA service trip to Ecuador which involved pre-travel, post-travel and "post-post-travel" surveys as well as daily surveys and personal reflection journaling. The authors concluded that students developed "…a greater complexity in their thinking…" and gained valuable skills outlined as ABET competencies.

The National Science Foundation sponsored a 20-participant summit in 2009 on Project-Based Service Learning (PBSL) which included warnings against relying on the self-reporting metrics so commonly utilized to assess student outcomes (Bielefelt *et al.,* 2009). Nonetheless, much research continued to rely on self-reporting.

Mostafavi *et al. (*2013) conducted a case study of two of Purdue's Engineering Projects in Community Service (EPICS) curricular projects, one domestic and one

international. Qualitative data provided in student journals and the students' documentation of technical and non-technical skill acquisition was combined with the researchers' description of each project's details to draw the conclusion that students obtained relevant competencies outlined by ABET and ASCE (2008).

Litchfield *et al. (*2014: 7) assessed ABET-related outcomes for University of Colorado Boulder students involved in EWB-USA, other engineering LTS organizations, or neither via student surveys. Students' own perceptions revealed that those involved in EWB-USA or similar organizations believed they had "…greater broad and holistic skills…" than those who were not.

Songer and Breitkreuz (2014) investigated Boise State service-learning student outcomes from a 10-day trip to Belize in which the students created school ground paths. Combining students' perceptions (from surveys and journals) with the professors' description of the project, the authors concluded that students developed teamwork skills and increased global understanding and self-confidence.

A University of Michigan Service-Learning project, in partnership with Bridges to Prosperity, involved design and construction of a pedestrian bridge with local community members in Bolivia. Jeffers *et al. (*2015: 56) examined all five students' reflective journals which were guided by specific daily questions. Journal content from before, during, and after the four-week trip demonstrated that such projects help students learn adaptability and refine their technical skills while increasing global awareness and an "…understanding of the social context of engineering work."

Litchfield *et al. (*2016) included both students and professionals who were involved or not involved in engineering service in interviews, focus groups, and a large-scale survey to ascertain whether those involved in service would self-report higher levels of proficiency. No difference was reported in technical skills rankings, but students and professionals involved in service reported higher professional skills.

Leung (2016) conducted a three-year longitudinal study of 76 construction engineering students involved in service-learning at a Hong Kong university. Students completed pre- and post- program surveys and kept reflective journals, which together revealed an increase in "generic" skills. Their service involved no design or construction, but this does illustrate the global interest in assessing student outcomes.

This chronological review of literature highlights the lack of research which uses direct observation to assess student outcomes related to participation in international service learning and LTS experiences. While self-assessment and reflection are both valid assessment tools, according to Schuh *et al. (*2016), observation offers an opportunity to collect rich data that is not "…influenced by participant interpretation." Therefore, the researchers sought to contribute to the research of student outcomes related to participation in international LTS experiences through the unique perspective of field observation.

METHODOLOGY

Existing literature overwhelmingly concludes positive student outcomes from international LTS projects, but such conclusions are primarily dependent on self-perceptions of the students themselves. This study fills that gap by employing third-party observation via the collection of field data through ethnographic observation, focusing on veins of direct relevance to a wide range of stakeholders: employers seeking to hire entry-level professionals who excel in professional, technical and

social skills, MSOE's EWB-USA faculty advisors, the MSOE community at large (leadership, faculty, and students), and other universities with similar objectives.

Ethnographic field data was gathered by a qualitative researcher during a spring 2017 construction trip to Joyabaj, Guatemala to assess student outcomes in areas of technical, social, and professional skill application and development. The research team included the following:

- Civil and Architectural Engineering and Construction Management (CAECM) Department faculty member, who is also a faculty advisor for MSOE's EWB-USA chapter. This faculty member led the construction trip being studied, and as such, might be less objective.
- CAECM faculty member who was also the Chair of Servant-Leadership at the time of the study and is now the Director of the CREATE Institute focused on real-world engagement in experiential-learning. This faculty member has had no involvement with MSOE's EWB-USA chapter.
- Faculty member from Humanities, Social Science, and Communication (HSC) Department who has had no involvement with the MSOE chapter of EWB-USA.
- Data collector with a Bachelor of Civil Engineering and MA in International Development (which included coursework on ethnographic research) who lived in Central America for eight years working with an engineering NGO who did not, and does not, serve in any formal capacity at MSOE and was chosen to heighten objectivity.

Upon obtaining project approval from MSOE's Institutional Review Board, a research team member introduced the project to the ten student trip participants and gathered signed consent forms. Nine travellers consented to participate. The same team member then chose four students to ensure a diverse representation: two female and two male students, two junior/senior and two freshman/sophomore students, and students with and without defined leadership roles. The four students' names were provided to the field observer who developed pseudonyms. The other two research team members did not know which four students were selected, and only the field observer knew the identity of the pseudonyms.

Ethnographic field data was gathered by the data collector over the ten-day construction trip and the notes were passed on to the research team for coding and analysis. This study was limited to observing the participants during the construction trip. Therefore, a baseline of skills prior to trip was not possible to establish. Future longitudinal studies could address this limitation.

Project Context

The MSOE chapter of EWB-USA has been partnering with the Municipality of Joyabaj in the western highlands of Guatemala on civil infrastructure projects since 2008. The chapter is heavily student-led by upperclassmen student officers in addition to project managers for each project. Two CAECM professors serve as faculty advisors. Engineers, construction managers, and architects from the Wisconsin Professional Partners chapter of EWB-USA provide additional student mentorship.

The chapter holds weekly meetings with an attendance level of approximately 25 committed members. Each project is subdivided into teams often led by upper-class

students who then mentor younger students, although occasionally first-year students have leadership roles. Student officers select the most involved and committed chapter members as project managers and travel team participants. Travel teams include 8-10 students of various academic years, gender, and major. The typical project follows a yearly schedule which begins with site assessment in the spring. Students meet with the municipality and local community leaders to learn about the community's assets and resources as well as the project specifics, and then conduct the necessary site investigations (e.g. topographic surveys, soil studies, etc). By summer, the students are working on the engineering design (e.g. structural, geotechnical, hydrology) in close communication with faculty advisors, professional mentors, community leaders, and EWB-USA staff. Students draft the final construction drawings by late fall, and winter months are dedicated to construction planning (e.g. estimating, scheduling, skills training). A team of students, faculty, and professional mentors travel in the spring and (1) work alongside the community to construct the project and (2) assess the next year's project.

This study's project was a 165-foot cable suspended bridge in the village of El Temal as shown in Figure 1. The bridge is unique in that it was built to sustain the traffic of three-wheeled motorized taxis known as "tuk-tuks." It has a wooden deck on top of steel cables which are anchored into large masonry towers on each side of the 60 ft deep gorge. The bridge provides a critical transportation link for the community to local markets, schools, and healthcare.

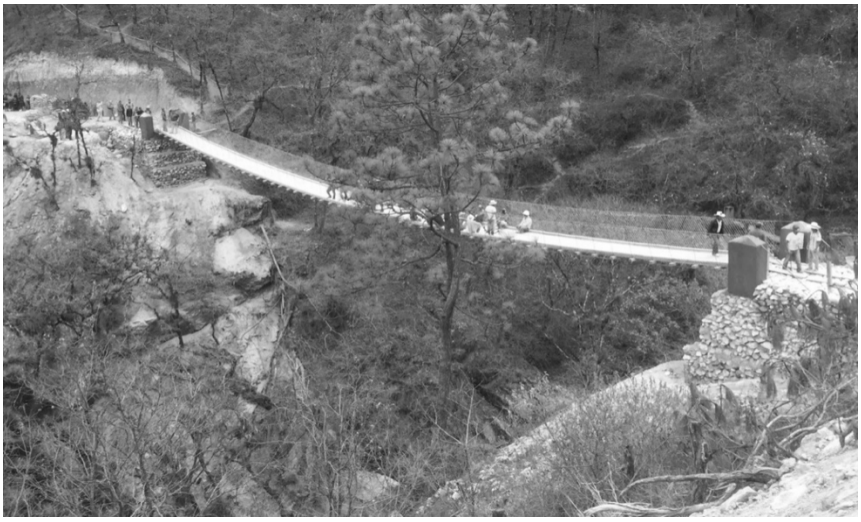

Figure 1: El Temal "Tuk-Tuk" Bridge under Construction

Before one can even assess student outcomes the very nature of the project itself must be scrutinized. In this case, the project fosters community empowerment, involves mutual learning, and builds upon the creative and collective capacity of the host community such that their own confidence and ability to set goals and accomplish them is reinforced.

Field Observations

The interconnected nature of the students' technical, social, and professional skill development was evident throughout the field data. Watching the accrual and application of technical skills was in fact an observation in human communication, as the social-professional skill of communication was crucial through the entire project. Without proper and effective communication in engineering and construction, unsafe conditions, delays, waste, and other problems can emerge.

The blend of technical and communication skills was observed in the reading and interpreting of construction drawings and in explaining them to team members. Students gained experience in explaining technical topics and processes to other team members, and in one instance to clarify something a professional did not explain well. The pseudonyms for the four students who were observed are as follows:

- Jonathan, student with a defined leadership position;
- Ashley, student with a defined leadership position;
- Allison, student without a defined leadership position; and
- Benjamin, student without a defined leadership position

Field observations noted both verbal and nonverbal communication, nonverbal being used when hearing was difficult or to overcome language barriers in a tri-lingual context. Students proficient in Spanish communicated directly with Spanish-speaking community members, and hand signals or a translator served to communicate with monolingual K'iche' speakers. Students who only spoke English relied on a variety of non-verbal cues and/or others to translate for them. This web of communication required a great deal of teamwork as well as cultural sensitivity.

For example, Allison and Ashley practiced verbal and non-verbal communication to explain to other students the process of mixing concrete and mortar, as well as to communicate with local volunteers. At one point, Ashley said in Spanish, "¿Necesita piedrin?" [do you need gravel]? Sometimes non-verbal cues were used even by Spanish-speaking students as not all Guatemalans spoke Spanish. Ashley, when asking a local volunteer about mixing another pile of mortar, used eye contact with the local volunteers to enact the work.

Both communication and problem-solving skills were key when students had to adjust their plans and estimates. Before the construction trip, the students had calculated materials estimates and established a step-by-step construction process. Upon arrival, however, they realized the excavation was not done correctly, resulting in the need for a longer span and different tower elevations. This required the students to rerun design calculations and material estimates based on the new dimensions to ensure the cable forces were not too large, bridge deck was not too steep, and materials on site were sufficient.

As is often the case in the developing world, there were multiple delays in deliveries. The students were constantly updating the estimates to ensure there were enough materials on hand when needed. Evening planning sessions recapped the day's events, sessions in which the professional skill of foresight was essential as they made necessary adjustments for the next day's plan. Jonathan demonstrated his communication skills—and leadership ability—one evening when the team was discussing the day's work, specifically regarding his approach which involved asking more questions than making statements:

- "The large rock and sand… split between us?"
- "How are we on rock, sand, and gravel everywhere?"
- "We got enough sand for the tower part?"

By asking questions of his fellow students instead of simply providing direction, Jonathan included the other students in the conversation (Benjamin and Allison among them) and helped develop their own skills of planning and foresight.

Students also noticed opportunities to learn from their Guatemalan counterparts who had more hands-on construction experience. As all the mortar and some of the concrete mixes were mixed on the ground without a mechanical mixer, it was a process which Guatemalan volunteers had already refined from much practice. Initially, the students mixed differently than the local volunteers. As the week progressed, the students adapted the local method which produced a quality mix but required less physical exertion. The adjustments included how the ingredients were mixed, order of steps, the tools used, and even how the bags of cement were opened. The students thus discovered the skills and talents of the host community and recognized that learning was two-directional.

Learning and problem-solving continued as the students adjusted to work-related variables. The students gained invaluable technical insights regarding how one must think of construction feasibility when drawing up plans. There were construction tasks that the students planned very well and some in which the fine details were unplanned and left for later. The students were at times quick to solve or prone to delay and observed how the process can grind to halt when decisions were not made. Occasionally they exhibited astute foresight in considering possible problems. During the cable tightening phase, for example, the students gained technical experience with a builder's level and in conducting calculations necessary to ensure the cables were pulled to the correct sag.

The ability to combine technical and professional skills to communicate and engage in problem-solving strategies had great impact on the project's overall quality control. Each student was tasked with quality control to ensure that the bridge was built according to the drawings and specifications. This included (1) inspecting excavation for dimensions and elevations; (2) monitoring the concrete and mortar mixing process for strength and workability; and (3) inspecting the work of local volunteer masons for conformance to drawings and specifications, both for quality control and to minimize waste.

Just as the students were expected not to compromise the quality of the project, they were similarly expected not to compromise safety. The team brought the proper personal protective equipment (PPE) for both EWB-USA team members and community members. Daily safety briefings were held in English, Spanish, and K'iche' to cover potential dangers and risks. When the students observed potentially unsafe situations, they were able, and empowered, to intervene and enforce safety measures in a cross-cultural, tri-lingual context. Ashley served as one of the project's Safety Officers. She was continually active in this role as illustrated in the following actions: ensuring the mixing pile was located away from where rocks were being transported, advising team-members when they needed to wear safety glasses, suggesting that Ben wear a hardhat when rocks were being transported, and then later requiring everyone on the job site to wear hardhats.

FINDINGS

After analysing and synthesizing the literature with the field data, the research team discovered the following:

- Students benefit from participating in a coordinated effort to blend their technical, professional, and social skills. For this project, it occurred all year, although observations were drawn specifically from the 10-day project trip.

- The construction project provided students with a context to utilize terminology and concepts discussed in the classroom as they learned to communicate concepts, tasks, and processes in a real-world project.
- Although the nature of the project required leadership skills from every participant, the professional skill of leadership was developed most in students with defined leadership roles.
- The greater the student investment - both technically and socially - the more likely they exercise leadership. Enacting engineering skills in a cross-cultural, developing world environment forces student investment, especially given the need to continually adapt to variables and unforeseen conditions. Therefore, the transferability of these findings would not include projects for which the students do not have a year-long team-based commitment involving design, planning, and ultimately construction done in partnership with local community volunteers in an international setting.

CONCLUSION

The study's goal was to discover what professional, technical, and social skills are engendered by students who participated in an MSOE EWB-USA international construction trip. Gathering field data as a method to observe students proved useful. As was demonstrated in the team's cohesion, the development of technical and non-technical skills did not solely take place during the 10-day trip in Guatemala but rather over the course of the academic year. This was evidenced in the quality of verbal and nonverbal discourse while working together in-country, and their focus on exercising engineering and construction skills through constant social interaction.

The researchers see value in long-term, real-world, community-based, problem solving projects such as those with EWB-USA where students are working alongside community volunteers in an international setting. Working with other student groups which share similar purpose and philosophy of community engagement may prove useful for growing students with strong professional, technical, and social skills.

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