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A service learning project in Honduras as an enhancement to the undergraduate engineering design experience

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ABSTRACT: This article outlines a design engineering project involving the construction of a prototype home and other sustainable living components in Honduras as part of a long-term programme developed through the Alternative Village at the University of Manitoba. The programme is aimed at developing technical, social and professional skills in senior engineering students. During the 2012-2013 academic year, students designed and constructed design features of the home adapting to actual time, cost and resource constraints. Research was also conducted to evaluate how the students' in-country experience impacted them. As such, the project examined not only the factors involved in a technical assistance programme but the benefits of service learning for engineering students. Preliminary conclusions support research that service learning is a valuable tool that augments theoretical education students receive with practical experience prior to joining the workforce. This is accomplished in a context that expands their awareness, allowing them to see not only the technical problems, but the broader social effects of their work and the people impacted by their decisions.

Keywords: Experiential education, service learning, cultural competency, design education, sustainable housing

INTRODUCTION: LINKING SUSTAINABLE HOUSING IN DEVELOPING REGIONS WITH SERVICE LEARNING

Throughout the world, developing nations face many comparable economic challenges: unemployment, lack of housing, erratic or nonexistent utilities and a growing sanitation challenge. According to the UNDP 2006 Development Report, of people living in developing countries, nearly half or 2.6 billion lack basic sanitation, 1.1 billion do not have access to clean water and a quarter do not have adequate housing [1]. There is a requirement to provide suitable housing with access to power, clean water and proper sanitation for those who have none while reducing the negative environmental impacts occurring as a result of rapid development. Creative, sustainable solutions to housing issues that use alternative construction methods need to be implemented at a price point that even those living below the poverty line can afford.

Experiential education in the form of service learning provides engineering students the opportunity to contribute their emerging design skills to improve the lives of those in the developing world. Service learning experiences are now offered at numerous engineering institutions across North America, and in a variety of forms, ranging from extra-curricular programmes, such as Engineers without Borders (EWB) to full integration into capstone design courses. All variations provide students with multidisciplinary experiences, such as teamwork, communications, collaboration and knowledge of contemporary issues that enables them to build both process and awareness skills [2]. Such projects are particularly suited to increasing students' understanding of sustainability, cultural competency and sense of civic responsibility. Cultural competency in a global context requires that students have the ability to understand and communicate across sometimes vast cultural differences and is a skill particularly important for international projects where team members are likely composed of people from varying cultural backgrounds and projects may be conducted with communities possessing different cultural norms [3].

The project described here is part of an ongoing programme to improve the housing situation in Honduras, by studying the process of building and designing a sustainable home for a family living at or below the poverty line and to look for areas of improvement. The research had six objectives that would measure the success of the project. The first was for the building to be sustainable. This meant using alternative materials that were either naturally occurring or had less environmental or economic impact than traditional methods. The second objective was to create a home that was attainable. The price point of the home had to be appropriate for the income level of those it was built for. Beyond that, at the end of construction, the family needed the knowledge, skills and materials to be able to replicate the process.

Ensuring that the family and community were involved in the project and that their customs and culture were respected was the third aspect of measurement. The build aimed to invest in not only the infrastructure within Honduras, but the people as well, helping them to acquire new skills, as well as building their confidence and self-esteem. When houses are built without community involvement families may have a difficult time maintaining them afterwards, especially, if the materials are not easily sourced or repaired. When houses are given to communities by organisations, they may not meet the cultural needs of families and, as a result, they may be unwilling or refuse to use them [4]. The fifth objective was to open avenues for developmental research at the Alternative Village at the University of Manitoba in Winnipeg, Canada, potentially involving undergraduate and graduate students. Finally, the last objective was to create research that was ongoing, as it was understood that the real impacts of the work would not be immediate but revealed over time.

From these objectives, the scope of this project was divided into two areas: technical development and service learning. Technical development encompassed the design work, option analysis and testing required for the actual construction of the house. Local resources of labour and materials were considered as part of the process to create a house that had a low environmental impact, was economical and one that could be replicated within the target community. The second portion of the project examined the social implications of the project. It studied the outcomes of the project on those involved including the family, the partner organisation and the participating students. The benefits of service learning were also examined by providing a group of engineering and architecture students from the University of Manitoba with the opportunity to apply their academic learning. Students designed and, then, constructed specific elements of the sustainable house. Through their involvement, they acquired an understanding of time, cost and resource constraints, as well as real world social challenges associated with designing and building in a developing nation.

BACKGROUND: EL PUEBLO CRECIENTE

This project involved not only the design and implementation of an adobe home in Honduras, but also the creation of the programme El Pueblo Creciente (EPC), *the growing village*, at the University of Manitoba. Through the programme, students learn about design and sustainable building, and utilise technical assistance to improve the state of impoverished Honduran communities. The aim of the EPC programme is to provide students with hands-on design experience requiring them to find sustainable solutions to housing challenges in low-income areas. These challenges include: constructing homes with local materials, rainwater harvesting and filtration, power generation, permaculture, health and waste management. The students create workable solutions to housing issues and, then, construct their designs in cooperation with a family in a partner community in Honduras. Over the course of the project, students gain an understanding of the daily obstacles developing nations face. At the same time, they aid a community to improve their economic status.

The programme is broken into developmental stages by year. Year one includes programme creation, analysing the process for creating low cost housing in Honduras and building an adobe home in a disadvantaged community. Years 2-5 are an expansion of the programme, which draws students from various engineering fields. During the fall term students who are selected to participate in the project, tackle design issues connected to low-income housing. Their designs are, then, incorporated into housing in Honduras during the winter semester. From years 6-10, the programme will potentially grow to include students from other faculties including: agriculture, education, nursing, business and medicine.

The phase of the project described here had its origins in the winter of 2012 with programme creation. The EPC programme was created by the first two authors in addition to a Honduran undergraduate student in biosystems engineering. This group formed the coordination team for the project. The work to be done included the construction of an adobe house for an impoverished family in the community of Consonlaca, Lempira, Honduras. The house was designed principally by the second author, in collaboration with the Honduran student and under the direction of her thesis advisor (first author) and director of the Alternative Village. For one week in February 2012, the coordination team traveled to Honduras on a site visit to gather information on the culture, local housing practices, availability of materials and plan logistics. The aim was to collect information on local building practices in underprivileged areas, as well as to determine which construction tools and materials were available for use both in the natural environment and from businesses in the area.

The design of the house included analysis of different materials based on cost, environmental impact and availability, as well as testing and prototyping of materials for non-conventional use. As part of the project, students from civil and biosystems engineering, and architecture competed in an application process. Ten students were selected to participate in the programme following an intensive interview process - nine from engineering and one from architecture. During the fall semester under the direction of the project coordinators, students participated in weekly meetings, which aimed to broaden both their theoretical knowledge and cultural experience. The students worked on design elements that were incorporated into the overall housing system with the goal of improving the current living conditions of the family. Over the fall of 2012, students designed and prototyped a latrine, an improved stove, a water collection and filtration system, and a sink and pump for the family with the guidance of the EPC coordinators. In January 2013, the second author commenced house construction, which continued for a period of seven weeks. The students arrived in Honduras in February 2013 and their designs were implemented during the final two weeks of the project. Planning of all logistical elements for the project coordinators and team members including transportation, accommodations, administration support, meal delivery, material acquisition and labour augmentation were strategised as part of the second author's thesis [5].

Honduras was selected as the location for operations related to the EPC programme, as well as for the construction of the sustainable home for this research. Honduras presented itself for many reasons, first and foremost being the need for housing aid throughout the country. The country has been hit by a series of disasters from which it has struggled to recover. In 1998, Hurricane Mitch caused a wave of destruction across Honduras destroying 70% of crops and transportation infrastructure, including nearly all of the bridges and secondary roads. Over 83,000 homes were either damaged or destroyed during the event. In 2009, the country was affected by floods, which damaged nearly 50% of its roads. In addition to these events, the country has suffered through many years of political unrest and corruption that has affected its ability to recover [6]. In spite of ongoing social unrest, rural Honduras is a relatively safe to travel in alone. Thus, research work could be carried out without too much risk of personal harm.

The second reason for selecting Honduras is the number of people living in poverty within the country who are unable to attain a more secure socio-economic standing. Despite some economic growth, the distribution of wealth remains very polarised, with nearly 60% of the population living in poverty and 36% living in extreme poverty. These numbers increase to 63% and 50%, respectively, in rural areas [7]. Honduras allowed the opportunity for long-term planning as it is not just scattered families living in poverty but rather whole communities. Meaning that over time, data could be collected from many families within one community and improvements to their economic situation could be more easily observed. As Hondurans speak Spanish, this added to its characteristic as a location that would present many of the challenges individuals would face when trying to carry out alternative construction in various parts of the world, including language barriers. Given that the construction timeframe for this project was limited to the academic school year, Central America presented itself as a viable destination. This is because their construction season of January to May aligns with the winter school season in North America. The proximity for travel and relative affordability, with respect to logistical costs, all added to make this area ideal.

The final reason for selecting Honduras, was availability of contacts on the ground. A senior biosystems undergraduate student at the University of Manitoba from Honduras, offered to help with the programme. He also provided contacts from within World Vision Honduras, who had experience constructing housing with impoverished individuals in the country. Both the student and World Vision were more than willing to partner in the programme supplying the group with strong local contacts who could provide insight into local customs, serve as guides and help them to quickly adapt to the area. These contacts would provide awareness into the undercurrents of the community and advise the group of their feelings towards them, which as outsiders, they could easily overlook or misinterpret.

The intent of the EPC programme is to return annually to the community of Consonlaca to conduct projects. By returning each year to the same location, the development changes both in terms of construction and the community members themselves will be easier to observe and monitor. As a result, the programme will have maximum impact as families within the community will have access to the designs that are implemented each year, and the University of Manitoba will maximise the research potential in the area, building upon ideas from year to year.

STUDENT DESIGNS

It was important that students involved in the service-learning component were able to contribute to the programme in a meaningful way. To that end, the coordinators identified a set of projects during their field trip in February 2012 that would add sustainable infrastructure to the home. These included rainwater harvesting, water filtration, latrine, stove and a water use appliance known locally as a pila.

All of the students were able to gain hands-on experience with engineering design in the 2012-2013 academic year with the knowledge that they were going to have to make these components work in the field. This was not an academic exercise. Students were able to use their knowledge gained from course work, but soon realised that more substantial research was required for application. It also became apparent that social aspects and material availability had to be incorporated into their design. While engineering educators talk about the iterative nature of engineering design in courses, the teams learned this first-hand as they refined their components. Student survey responses clearly indicated that having responsibility for their design projects was not only considered valuable, but also reinforced their ownership of the results. The lessons they learned from the prototyping experience were the same regardless of the component. During the prototyping phase some students expressed frustration when their designs did not work as anticipated; however, they learned from the experience. This would prove to be valuable background for the in-country experience. Based on both the survey results and observations by the coordinators, the prototyping phase was not only valuable to refine designs, but was critical preparedness for on-site work.

Rainwater Collection and Filtration System

The primary source of water for all aspects of living in the community comes from a piping system that brings water from the mountain areas of Honduras. A limited supply of water is available from streams as no wells were found in the programme area. Homeowners pay a fee for installation and access to the piping system with service that can be interrupted at any time. The water is not treated. During the field study, there was no evidence that rainwater was collected. To supplement water demand and provide an alternative, a rainwater harvesting and slow sand gravel filtration system was designed by the students. During the fall 2012 term, a team of three students conducted research

and built a prototype. Students were able to use their knowledge from courses such as fluids, water treatment, biology and structures; however, this only gave them the foundation for the work they would have to do.

Figure 1 shows the installation of the system that includes an eavestrough to collect rainwater and direct it into an 1100 litre storage tank. The community water supply is connected to the tank and is allowed to fill to half the depth using a float valve, leaving a minimum of 550 litres for rainwater. The rationale for connecting the community water was to provide some storage for those times when the water supply is interrupted and ensuring all water consumed is first filtered. The water tank is connected to a slow sand filtration system. Layers of stone, gravel and fine sand create a filter in a 180 litre plastic barrel. Once filtered, the water is stored in a reinforced concrete tank. The students formed and poured the tank on site. The filtered water is pumped up for use in the washbasin or pila.

Figure 1: Rainwater tank and hookup.

Figure 2: Latrine.

Latrine

While the use of latrines is reasonably commonplace in rural communities, there is a wide range of style and construction quality. Figure 2 illustrates the completed latrine at the project site. The students incorporated local materials, such as cana brava, a bamboo-like plant, to clad the outside of the structure for cooling and aesthetics. Reinforced concrete was used for the base and corrugated metal sheeting for the enclosure. The toilet seat was cast using a clay mould covered with concrete. A concrete-lined pit was constructed with a soak-away trench similar to a septic field. The students used courses in structures and hydraulics combined with research for the design. There were some design modifications on the site due to ground conditions and material quality. While disappointing on some levels, this turned out to be an excellent experience for the students to problem solve in real time to create a workable solution.

Stove

In rural Honduras most cooking is done using wood as a fuel source. The students worked on a stove design intended to improve draft control to increase efficiency; thereby, reducing wood use. The stove was constructed using adobe blocks covered with a cement-based plaster. The students worked on various prototypes to investigate chimney design.

Pila

Washing dishes, clothes and bathing, as well as water storage is all done using one appliance known as a pila. A new design was conceived that would provide for a double sink, one with a washboard and one for dishwashing. Typically, the water from the pila is drained onto the ground. The student design incorporated a greywater storage tank to be used for watering plants. Clay moulds were made to form the basins' shapes onto which concrete was poured. Concrete legs were cast in polyvinyl chloride (PVC) tubing to reduce the overall weight of the appliance. While the function of the pila remained the same as the traditional one, the two sinks lessened cross contamination and provided a convenient way to store spent water.

EXPLORING THE SERVICE LEARNING EXPERIENCE

A major objective of the El Pueblo Creciente project was not only to give students hands-on experience, but also to allow them to work through the entire process of construction, from conception to design to execution, performing the work. Each group was responsible for the success of their own design. In this way, they would acquire an understanding of rework, schedule changes, resource shortages and the many other challenges that come with a project. In addition, the students were exposed to another culture through interaction with those affected by their work. This approach was to give students a greater awareness about how their work may impact others in their future careers. In this way, students would develop a broader perspective towards not only the technical, but also the social aspects of their work.

Research derived from Kolb's learning cycle, the Lewinian experiential learning model and Piaget's model of learning all reinforce the value of reflection in advancing learning [3]. Service learning emphasises the importance of self-

reflection in order for students to get the most out of their experience. Typically, students through their coursework are required to complete reflective essays and/or journaling and these artifacts are graded [8]. In this case, findings from the students' experience in Honduras were gathered through discussions, as well as pre- and post-construction questionnaires. While students were in-country, discussions took place on a daily basis with the coordination team and each other. At the end of the work day, a time was set aside for reflections on the day's events. Students were encouraged to share their experiences, ranging from technical to personal aspects. Discussions included lessons learned, critiques and observations or what students would like to see as part of the project. Several themes emerged from these group activities that provided insight as to how service learning is beneficial to the engineering experience and augments the technical education students received.

To gather more data on the impact of service learning, and to observe the social effects of the El Pueblo Creciente programme over time, open-ended questionnaires were designed as a means of monitoring these changes. The questionnaires collected data from three different groups: the students from the University of Manitoba participating in the programme, members of World Vision directly involved in the project and members of the community in Honduras who were involved or affected by the project. The questionnaires aimed to gather data on the success of the project in meeting schedule, cost and resource goals, as well as efficiency of project management. They also offered information on the changes in perspective of those involved in the project before and after construction. This component complied with the University's ethics review process ensuring, anonymity, confidentiality and opportunity to withdraw without penalty and was approved by the University's human ethics committee. The third author and design course co-instructor provided guidance on the ethics submission and protection of confidentiality of participants, as well as question content and wording. A translator confidentiality agreement was also distributed for those who assisted in translating the surveys between English and Spanish. For the purposes of this article, only findings that relate to the participating students will be discussed.

The 10 students who participated in the project, were given their pre-construction questionnaires prior to leaving Canada in February. Questions asked of the students tried to capture their thoughts on the project planning process, what they thought were important consideration factors and what they hoped to learn from the project. Students were then given post-construction questionnaires upon project completion at the end of February. The latter questionnaires gathered information on the performance of the execution phase and what was learned in the process. Students were asked questions on whether the project contributed to their overall education, what impact it had on their view of engineering as a field and their levels of confidence.

Prior to the project, students identified areas they would like to improve, as well as what they hoped to learn from their involvement. Technically, they hoped to learn more about construction management and the design process by gaining exposure to scheduling, budgeting and resource control. Moreover, they wanted more hands-on skills using tools and working with alternative materials. Of the 10 students who participated in the project, very few had practical construction experience and only one had participated in a development project previously.

Questionnaires revealed that all were interested in learning about a new culture, to see how it varied from and was parallel to life in Canada. They wanted this experience to change them, to bring them more perspective and awareness as to how they view their daily responsibilities and the type of professionals they would become. One student said: *I want to be able to take my experience at my first development project to how I act in everyday life, the decisions I'll make as an engineer*. They sought to gain insight into their skills and qualities and how they could be improved.

Though eager to participate in the project, students were hesitant with regards to the design process. All did not feel confident in their abilities, based on their university experience working on small team projects with little opportunity to apply theoretical knowledge. One student pointed out: *I felt intimidated by the fact we were building/designing something new that hadn't been done before. There was no particular design we had to go off of, which was scary. As a student who has little experience, I am scared to do something I have no experience with*. Much of their knowledge was based on classroom scenarios with defined parameters and known solutions as opposed to the project where there was limited information available about material availability and site conditions. This was partially due to the fact that a family was not selected by World Vision until approximately one month prior to project execution. With so many unknown variables, students worried whether they would be able to build their designs. One student remarked: *Sometimes I felt that more assistance or support was needed throughout our design process or that I was ill-equipped to design what was asked of me. In hindsight though, I feel that it was an amazing learning experience being put in that position.* Students had to take what information they were given and come up with designs that were flexible enough to adapt to a changing situation.

In the execution and planning of the project, students felt it was important to always consider the needs and opinions of those for whom they are building. They felt local building practices needed to be respected and those affected by the project needed to be involved as much as possible. It was essential that the family in Honduras be taught all parts of the building process so they could maintain and replicate it afterwards. Highlighting this point, one student said: *It is imperative to account for the social component of the equation because life and engineering [are] not just black and white. I need to understand the repercussions of my engineering or life decisions...*

After the completion of construction, the second questionnaire was administered. Students were also able to exchange impressions and opinions during the project debriefing. In general, the students learned a great deal about scheduling, project management, how to make up lost time on a project, and how to manage multiple activities at once. *I think the project was very successful. I learned a lot about design, construction and most of all on site changes*, said one student. Another expressed that: *…allowing the students to design aspects of the house was a very important part of the project and was done well.*

They gained confidence in themselves and their ability to work through a problem. One student remarked: *I learned that sometimes you need to stop stressing and go with the flow, let the changes happen. …I learned that I need to be more confident and vocal in my thoughts and opinions and not constantly worry about sounding stupid. But I feel my confidence will only go up by getting more practical/hands on experience*.

Working within a limited budget, with poor quality materials, limited resources and not much time taught students how to think quickly. They came to realise they had to use their design as a guideline for what they were building, adapting it as the situation changed. They learned how to deal with trade-offs when what one is building is not necessarily the ideal solution, but it is the solution that works. *Your designs on paper will never exactly match your finished product. Re-designs will have to be done and you will have to think on your feet and make quick decisions*, wrote one of the students.

Collaborating with the family to construct the house showed students how their designs affect other people, how they need input from those using the end product in order to develop a workable solution and what they need to consider in planning. This was captured best in one student's statement: *I think the trip helped me to see the good that can come from design. Designing a house on paper used to feel like a task that wouldn't* change the world *in any noticeable way but this trip showed me that even a simple design can change the life of someone for the better. I also found that I have a much better understanding and appreciation for the people who have to read my designs and produce them (it is a lot harder than it looks!). I also learned that the person [client] you are designing for is more important than how* clever *your design may be. That it can be used and built by the person it is designed for is the most important thing*.

Experience using tools and materials gave them an understanding and respect for the people who will be putting their plans into action. Interacting with another culture, students learned that even though people come from different places, they also have similarities. It is important to respect another culture's way of life and beliefs. *I learned that I can still relate to people and have a genuine connection with them without being able to speak the same language, which was very powerful*, said a student. Another wrote: *To stay with a local family and to work in a small village really made a big impact of showing the differences and similarities between life in Canada and Honduras*.

Students found service learning to be an important part of their education as engineers and university students in general. They felt that there should be more opportunities for challenges like this one. When working with people one-on-one, an immense amount of learning takes place that cannot be passed on from a textbook including, humility, confidence and a willingness to learn from mistakes. One student summarised their experience as follows: *I think this project has allowed me to view engineering as a more complete process than I had previously imagined. Seeing how things needed to be constructed (what tools and materials were available along with the actual chronology of the process) made me consider different parts in the design process. I also got to experience for the first time, engineering as a means to development. Experiencing using technical knowledge to help others and building purposeful things let me get a bigger picture of the importance of the technical skills we learn in school. It has helped me to see my coursework as more important because I have seen how engineering can be purposeful and that is very motivating.*

Service learning shows the human side of engineering. Through their experience, students can grasp the amount of trust that is given to them by others. As an engineering professional, they have a responsibility to build and design for those who do not have the technical knowledge to do so. Students revealed that this project had broadened their perspective, and is an experience they will carry with them their entire lives. As one student put it: *When I interviewed to go on the trip, I said I wanted to be able to connect my design to the people it was designed for. I feel like this was such a good opportunity to do just that. To see the end result, the happiness on their faces was amazing, so now if I become a structural engineer, not only will I just see the structure but the people in it.*

In summary, the discussions and post-construction questionnaires reveal significant insight into students' understanding not only of the design process and its capacity to improve lives, but also a newly acquired respect for ways of life profoundly different from their own.

CONCLUSIONS

Experiential education through service learning holds great potential for engineering students to not only gain technical skills through practical experience, but also the opportunity to see the social effects of their work. When completed in an international context, students also develop a cultural competency that serves them well for future cross-cultural design experiences and their postgraduate career. The first phase of the El Pueblo Creciente programme described here provided engineering and architecture students with an opportunity to use their emerging skills to design various components for a sustainable living project in rural Honduras. Based on discussions and questionnaires conducted prior

to, and at project completion, all participants expressed the value of this type of hands-on design experience. This project enhanced their academic experience by challenging them to design and implement with limited resources within a cultural context far removed from their own. Not the least important of the outcomes was the overall feeling that this experience had a profound impact on their life journey.

From an instructional standpoint, the opportunity to provide students with a service learning component is one that should be embraced whenever practicable. In a design course, participating students have an enhanced sense of ownership towards their work that is unique, whether this takes place as part of a course or within the context of the broader programme. It is clear from student surveys and the instructor's first hand interaction with the participants, there is essentially nothing comparable that can provide students with the challenging and rewarding experience this approach to learning provides. This was not an academic exercise. It was a real project that carried with it the reward of completion and the responsibility if things did not work - the same conditions the students will face once they graduate and enter professional practice. In our opinion this opportunity gave the students insight into how to connect what they are learning in the classroom and apply it; a critical skill for any design professional.

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BIOGRAPHIES

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