# Preparing 21st Century Engineering Students through a Student-Initiated Interdisciplinary Service-Learning Project

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## Introduction

As traditional demarcations between academic disciplines fade, and the virtual distance between Boston and Bangalore approaches zero, the engineering educator faces new challenges and unique opportunities. Preparing chemical engineering students to operate in international collaborative efforts is of critical importance in our global society. Engineering students should be equally conversant with anthropologists as their fellow chemical engineers, and as fluent in Spanish as in MatLab.

The Accreditation Board for Engineering and Technology (ABET) agrees. In their 2008-2009 Criteria for Accrediting Engineering Programs document, Criterion 3 "Educational Outcomes" specifically states the following as engineering program outcomes required for all engineering students [1]:

3 (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
3 (d) an ability to function on multidisciplinary teams
3 (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

The Engineers without Borders (EWB) program is devoted to improving the global quality of life with a bottom-up approach. Individual EWB chapters partner with developing communities and together design and implement sustainable engineering projects. In doing so students learn to design and implement resource efficient projects in an international context. EWB contributes to meeting the United Nations Millennium Development Goals through capacity building in local communities [2].

Here we discuss findings of a two year old interdisciplinary project in student initiated sustainable design education. First we present an overview of our project. We then briefly describe how our project benefits from commonly observed advantages of working in an interdisciplinary service learning framework. We then examine specific deviations from the usual model that we believe are particularly advantageous to our project and students. We conclude by discussing ongoing challenges posed by highly interdisciplinary projects.

## Harvard EWB Project Status

Under the suggestion of St. Jerome's Constanza Mission, a group of doctors from Boston Children's Hospital and South Shore Medical Center, we started a project to design a sustainable solution to a contaminated water supply in rural areas outside Constanza, Dominican Republic.

St Jerome's Mission first approached Harvard EWB because the members noticed that water-borne diseases are the cause for many of the illnesses they treat. They asked HCEWB to further investigate the situation to see where engineering design could help. Two trips were undertaken to Constanza in the 2007-2008 school year.

During the first trip in November, we spent most of our time visiting aqueducts, mapping the water cycle in the area, and building personal relationships with the community. Before returning to the US, we held a community meeting where we presented our findings.

In a second trip in May, eight members of our chapter, plus our professional mentor, traveled to Constanza. The community consists of about 1200 families. Coming into the trip, our primary contact in the village was the local nun, Sor Rosario. We were also in contact with Carlos Mena, the local INAPA representative, who is in charge of all the drinking water in the area. Before departure, we also made contact with two Peace Corps volunteers in the area who translated for us throughout the trip and who are willing to work with us remotely. We had knowledge coming in that there was a small-scale treatment facility not operating properly, and that there was not enough water supply. During the trip we split up into two groups. One group investigated the water treatment facility to obtain data and figure out why it was not functional, the other focused on ways to increase the water supply through either drilling wells or capturing more water at the source. We also did some health assessments on a house-by-house basis and water testing from the top of the system to the bottom.

During the second trip, we made many contacts in the area, including an engineer who helped build the treatment facility, local government officials, and a couple of families who had wells. We managed to obtain both topological maps of the area as well as plans of the treatment facility from INAPA Headquarters in Santo Domingo. We learned that water at the source of the system was already polluted with biological contaminants.

Additionally, the water treatment plant was not built correctly. In the facility, water first goes through a settling tank. However, there is a leak in the apparatus as the water enters the plant, and this allows some water to bypass the settling tanks. Following the settling tank, water passes through a sand filter. The filter has four layers: sand, gravel, stones, and large rocks. The total depth of the filter is 3.5 feet. However, the sand filter was built incorrectly and as a result gets clogged up very quickly, leading the locals to bypass it entirely. Following the sand filter, the plan calls for chlorination of the water, however this aspect of the design was never completed.

During the trip, we performed water tests at various points in the system, from the initial source to the homes at the end of the pipe. We tested for biological as well as chemical contaminants. Biological tests gave a count of Coliform and E.coli per 100 mL of water. Chemical tests gave values for nitrate and nitrite, chlorine, pH, hardness and alkalinity.

Water serving the community is taken from three sources in the mountains. We visited two of these sources. The first source is an open stream, the second flows under vegetation and is dammed for collection. These sources all come to the water treatment facility. The water then splits: part of it is stored in a holding tank and serves part of the community, the rest goes to another storage tank downstream and services the rest of the community. Because there is not enough water to go around, water supply in different parts of the community is intermittent.

Our water tests showed that water in homes further downstream from the treatment facility was had more biological contaminants than those closer to the treatment facility, suggesting that there is either sedimentation or leaks causing contamination in the pipes. In homes, people store water due to its intermittent supply. Some people treat their water with chlorine, which reduces the amount of contamination. Some families purchase bottled water, which we found to be free of any contamination. We also tested a couple of local wells, and found that some were significantly contaminated as well. The few wells we found in the area were drilled by hiring outsiders to come in for a costly fee.

During the trip, we obtained topographical maps as well as the original plans for the treatment facility. These maps also include the pipes that distribute water to the homes. We also took measurements of the entire treatment facility so we can compare it to the original drawings. We will use this information to make calculations about the water flowing through the facility and in the pipes. These next steps will be part of the work of our project teams this year. We also took some samples of the local soil back with us for analysis, as well as samples of the sand from the filter; these will be analyzed during the year.

We found that we could obtain many materials that we believe will be necessary for drilling wells and improving the treatment facility either in Constanza or at the capital on Santo Domingo, including piping, metal washers, etc. The local people were also very creative when it came to suggesting alternatives. Due to curiosity and desire for change, it was very easy to find volunteers to help us out, including people with engineering experience.

This year, our project will focus on two areas. The first is fixing the water treatment facility, since the infrastructure is already present. We want to 1) fix the sand filtration system, 2) install a chlorination system, and 3) create a flushing mechanism for the pipes. All of these initiatives will require community support and maintenance.

Secondly, even if we fix the water treatment facility, there will still not be enough water to supply the area. We are working on designing a method to drill wells at a low cost for families or groups of families. This task will increase the water supply and also ensure that the wells are maintained by the families we drill them for. Some families already have wells, so we know it is possible to reach the water table, and over the year we will be investigating 1) exploration techniques, soil analysis, and finding water; 2) perfecting the design of our drilling technique, and 3) filtration and storage of water for use.

The community reaction was varied. There is a group of people who are very concerned about the situation and are glad we came to help. These people are aware that their drinking water is unclean and want to do something about it. They are excited about our project and were very helpful during the trip. Some others were complacent or apathetic about their situation, but there is enough community interest such that when we return we will have the resources we need.

We are working with the local community in everything we do. With whatever we build, the local community will help us at every step and will be responsible for maintaining it after we leave. We will work through the Peace Corps volunteers, as well as Sor Rosario to coordinate our planning efforts with the people on the ground, so that they know what we are planning in every step of the process. We found a higher level of knowledge and innovation than we expected among the people, and expect that, when we return for implementation, they will be very helpful in obtaining materials and figuring out alternatives. We expect the members of the community to provide labor to help us with building.

**EWB: Highly Interdisciplinary**

EWB is a well received program as evidenced by its pervasiveness on engineering campuses with 153 established chapters out of 600 schools with ABET accredited engineering programs. [2] In fact EWB projects can be seen as meeting all 12 of the program objects listed in ABET requirement 3. [1] EWB programs often have three interdisciplinary aspects: the projects themselves, sustainable design, and the participants. [3] We will discuss briefly how this occurs using our project as an example.

The projects of EWB rarely fall within a single traditional engineering discipline. [4] A majority of EWB projects deal with water as, despite significant progress, access to clean drinking water remains one of the single largest health challenges in the developing world. [5] Water related projects commonly deal with increasing access to water supplies—where the quantity of water is insufficient to meet the needs of the local peoples or water purification projects where the water supplies are not fit for human consumption. To find water supplies; drill wells or build pipes to access water sources; pump the water from the ground and purify it to the point where it is fit for human consumption; test the water for biological contaminants involves a whole range of skills that cross traditional disciplines. Our project thus relies on the input and individual knowledge of a team of individuals with a variety of skills and classroom knowledge, making the activity highly interdisciplinary.

Sustainable engineering – a cornerstone of the EWB philosophy in general and our project in particular – requires an interdisciplinary approach. In brief, sustainable design charges engineers to create a solution that can be wholly created and maintained by local individuals with locally available materials using locally available tools and manpower. [6] This charge demands an interdisciplinary response. Although a mechanical engineer in our group designed a system for drilling based on tools, machines and techniques available in a university lab environment, he then looked for help from a material scientist to see whether the same drill bit could be produced from materials available in a local plumbing store.

In a looser sense of interdisciplinary—the integration of students and mentors of different years and stages of their careers adds to the interdisciplinary nature of the undertaking. Although an undergraduate student, graduate student and professional engineering mentor all thought of themselves as mechanical engineers, when it came to actually fixing the water filtration system, each had very different expertise and experience within mechanical engineering and consequently had different contributions to make. Thus the integration of multiple kinds of thinking that resulted from a number of years of experience was yet another interdisciplinary aspect of the project—commonly found in EWB projects.

**Harvard EWB: Uniquely Interdisciplinary Aspects**

In addition to the wonderfully interdisciplinary nature of the generic EWB experience, our EWB chapter has further benefited from further interdisciplinary interaction in two ways. First a large proportion of EWB undergraduates are non-engineers. Second we have had the unique opportunity of interfacing with non-engineer professional mentors.

The interdisciplinary environment created with the inclusion of non-engineering undergraduate students has uniquely benefited both engineering and non-engineering students alike. Approximately half of the Harvard EWB club is composed of engineering students, a third come from the natural science ranks and the remaining sixth are social science and humanities students. While engineering students are primarily drawn to EWB as an opportunity to apply what they learn in the classroom, students from non-engineering disciplines are drawn to EWB to experience what they do not learn in the classroom—namely design. Both groups are drawn to the idea of helping those in the developing world and the bottom up philosophy of change championed by EWB.

Engineers truly benefit from having natural scientists challenge them to develop an idea more mathematically before just hacking together a design—which is perhaps an engineer’s first instinct. Natural science students benefit from actually building something that works—rare in the physics or biology classroom. Both groups of scientists benefit greatly in terms of communication. Explaining how to improve water flow rates through a sand filter to a History student is not easy, however in having to do so they better articulate their own ideas leading to overall better communication. Similarly, science and engineering students learn much when their grant proposals and write-ups are marked up by those with better verbal skills. The humanities students learn much about what engineering is all about and specifically how an engineer approaches a problem. These students describe how they are then able to incorporate their experience with EWB into their coursework. The uniquely interdisciplinary composition of the Harvard EWB project benefits all students concerned.

A second uniquely interdisciplinary aspect of EWB is cooperation with the medical doctors of the St. Jerome’s Parish Constanza Mission. While an engineer might describe the heart as an electrically activated, two stroke pump with mean time to failure of two billion cycles, a doctor would describe the heart in terms of its structure and function in the cardiovascular system. As previously described, this group of doctors has been traveling to the community of Constanza twice a year for the past five years. Although they had made a significant contribution to the health of the local community, their efforts to prevent waterborne illness was not sustainable. They would distribute the appropriate medication and then returning six months later find that the same individuals needed the same medicine again. The doctors realized that in order to get to the root of the problem, they would have to improve the water quality of the community. Like working with humanities majors, interacting with the Doctors forced engineers in Harvard EWB to communicate without jargon or technical terms and to be very specific in our future request for information for as we learned quickly the way that doctors think about a problem and engineers is very different. This interdisciplinary interaction with highly educated experts in a different field was very informative.

**Challenges Posed by Interdisciplinary Activities**

Creating a functional interdisciplinary learning environment where all participants benefit is no easy feat. Although all participants outwardly appear to speak the same English language, in fact each group of participants speaks in a discipline specific tongue and is armed with discipline specific knowledge. [7] Although a student pursuing engineering, a natural science or a domain within the humanities approach problems differently, all are bound together with an overriding enthusiasm for the end result—helping those without access to clean drinking water. The project would likely fall apart without this strong individual motivation, which causes all participants to teach and all to learn. Since the project is student initiated and students run, all students are there because they want to be. The desire to succeed is far higher than for any engineering class problem set. A strong sense of camaraderie develops and slowly these challenges can be overcome.

**Conclusion**

Although the traditional engineering student course in design remains at the capstone of most engineering curriculums, interdisciplinary student-initiated service-learning programs like EWB can provide an alternative and less formal introduction to the world of engineering design. [8, 9] Students involved are highly motivated as they set their own objectives for themselves and their team. Additionally, there is a strong sense of helping others that drives the process forwards. Working in highly interdisciplinary groups on long term projects is highly advantageous to 21st century engineers as projects like EWB will likely define much of their future work experience. [4] Improving how engineers are able to relate and communicate with non-engineers is of upmost importance as well. [10] While a head-to-head comparison of the EWB approach to learn design in comparison to a more traditional engineering design course has not been undertaken and would be difficult to conduct due to significant variation between programs at different schools, it would be very interesting to qualitatively asses differences in student readiness for the capstone design course between those who participated in an EWB experience and those who had not. [11] We anticipate as the EWB students go on to careers in industry and academia, that they will report EWB as one of the more formative components of their engineering education.

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