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Teaching Design for Constrained Environments: A Partnership with Non-Governmental Organizations

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Background

Senior capstone design is an essential element of most undergraduate engineering curricula. It provides an important opportunity for faculty to assess the ability of students to apply their acquired technical knowledge to the solution of real engineering problems before they enter professional practice.

A rich source of real, challenging engineering problems, including those described by the National Academy of Engineering as "Grand Challenges," resides in the developing world. Such problems are frequently notable for the constraints they embody – including cost, durability, maintainability, simplicity, and cultural fit. Students presented with problems of this type must empathize with a consumer and an environment about which they typically have no firsthand knowledge. This is the essence of design for the real world.

Objective

The objective of this project is to develop a sustainable mechanism by which engineering sophomore and junior students can be engaged in a modified study abroad experience. In this model "study" becomes "work-study" and "abroad" becomes "developing countries." By partnering with Non-Governmental Organizations (NGO's), the project exposes students to environments of significant constraint in the developing world. Such an experience can provide students a global framework for design thinking – a potentially useful skill as preparation for professional practice in the global economy of the 21st century.

Pilot Study

In the summer of 2014, three undergraduate biomedical engineering students from Virginia Commonwealth University (VCU) spent two months at urban and provincial clinics and hospitals in Nicaragua (two students) and Tanzania (one student). They were part of a cohort of students selected by Engineering World Health (EWH), an international NGO headquartered in Washington, DC, to participate in their Summer Institute Program.

The students spent their first month in an orientation program, conducted by EWH staff. This in-country program provided language and culture immersion, along with instruction in repair of the types of medical equipment students would encounter in the field. Students spent the second month working in small teams at partner clinics and hospitals where they repaired broken equipment. Much of this equipment had been donated by western NGO's and medical device companies. Eighty percent of such donated equipment is typically inoperable within one year of donation, according to EWH.

VCU students were further tasked by their advisor to engage in "needs finding" by engaging doctors, nurse and technicians in the host clinics.

Results

Each student was interviewed prior to departure for the summer program and immediately after returning. In the pre-visit interviews, students expressed a strong desire to apply their engineering education to "do good in the world," a sentiment frequently expressed by students generally. They also expressed a desire to have a "real experience," which by their definition meant full immersion, not an insulated, isolated living or working arrangement.

Students also expressed some anxiety about their ability to translate their engineering knowledge into actual practice. They remarked on their perceived inadequacy and inexperience in "fixing" things. And finally, although several had completed Spanish language course in high school, they expected their modest language skills to be a handicap. The student traveling to Tanzania had no familiarity at all with Swahili, the national language and was therefore perhaps the most anxious.

Upon their return, the students were interviewed again. In these interviews students said that some of their preconceptions were correct but many were not. The living arrangements for example were in fact more basic than they anticipated. But because most accommodations were provided by host families, students experienced continuous exposure to both the language and the culture. In several cases, students were included in family events and developed friendships with family members that have persisted.

The workplace was unique to each student but had some characteristics that were common. In some cases the daily contact was primarily with technical staff and less often with clinicians and nurses. In these setting the engineering departments did many jobs unrelated to medical equipment maintenance. The biomedical staff served as plumbers, carpenters, and electricians for the clinic or hospital. Students who expected to be intensively engaged in repairing medical equipment, found themselves engaged in a scope of work that included many other things. They encountered, and adjusted to, a pace of work that was different than they anticipated.

Students also reflected on the difficulty of maintaining, or even using, some of the medical equipment donated by NGO's and medical device companies. User training was typically not provided by the donor. The equipment was often inoperable because parts were no longer available from the manufacturer or too difficult to procure from foreign suppliers. Maintenance and user's manuals were in languages different than that of the country to which the equipment was provided.

Students' anxiety about language proficiency proved to be largely unfounded. They attribute this primarily to the intensive and immersive language preparation they received in-country for the month preceding their assignment to hospitals and clinics. Even the student working in Tanzania found that his basic training in Swahili enabled him to be sufficiently conversant to both do his job and function in the culture. Students also reported that the EWH model of assigning teams of students rather than individual students to hospitals provided both a language and acculturation support system.

While students expressed a heightened appreciation for the need for simple, environment-appropriate design, they did not return from their experience with clear concepts for better designs in mind. Their focus on repairing existing equipment perhaps obscured conscious awareness of opportunities for designs that were less likely to fail or easier to maintain and repair. This awareness began to crystallize only after their return.

Discussion

The teaching of engineering design has evolved as the practice of engineering design has evolved. It has moved from a focus on individual technical competency to team competency to interdisciplinary team competency.

For companies and other organizations that function in a global economy, we often hear about the need for engineers who can "innovate." Indeed the imperative of innovation has transformed views on how companies use their engineering design resources to apply innovation principles to achieve competitive advantage.

But innovation as currently practiced in corporate settings is viewed by some managers to be inadequate. The environment that encourages "outside the box" thinking is the same environment that may lack resources or will to execute the product of the innovation process. Those who participate in innovation team assignments often comment on the disconnection between the apparent absence of constraints in project initiation and the suffocating presence of constraints in project execution.

There is evidence in fact that the highest forms of creativity may be derived from designing within an envelope of significant constraint, i.e. thinking "inside the box" [1]. There is also an emerging view of "reverse innovation" that suggests that good design for the constraints of the developing world informs and improves design for the developed world [2-5].

The current study exposed students to environments significantly different from their own, perhaps a worthwhile objective in itself. But the core objective of the study was to expose students to environments of high constraint. The countries selected were among the 138 countries designated by the World Bank as "developing countries." While this designation is based on per capita Gross National Income (GNI) data (threshold $11,905 in 2014), the relationship between constraints of many types (e.g. power, sanitation, education, health) and national wealth is well-established and the consequences for product design are clear.

In the pilot study, the major awareness growth of the students involved was less about cultural differences and more about the ubiquity and pervasiveness of constraints. The most basic repairs could sometimes not be made because simple parts or materials were not locally available. If parts were available from foreign suppliers, the cost and complexity of ordering, shipping, and receiving the parts made the task difficult or impossible.

Two of the three students who participated in the pilot study are now completing their senior design projects. They are members of teams in which others students have not been exposed to the "constrained design" model. Those teams are engaged in more conventional projects in which the focus is on technical mastery and customer requirements that are more typical of western countries. On those teams the students from the pilot project are more likely to introduce concepts of constraint and customer empathy during design conceptualization and preliminary design.

The third student will begin her senior design project next year. She will be part of part of a team that will develop a simple, low cost device to reduce the incidence of urinary tract infections in bedridden females that result from fecal bacteria migration around in-dwelling urinary catheters. This project, if successful, will have significance for hospitals in both the developed and developing world.

Conclusions

Based on the results of the pilot study, some preliminary conclusions and observations can be made. First, many students are motivated to work for extended periods in developing countries and are capable of doing so successfully. Second, students require time to acclimate to both the culture and the constraint environment they encounter. Third, NGO's provide a valuable resource for identification of opportunities and in-country support. Such support makes it easier for academic departments to engage their students in this type of experience in developing countries where they themselves may not have established relationships. Finally, a focus on "designing for constraint" in these experiences must be more carefully framed for the students than was done in the pilot study. Students must recognize this as a specific task and be provided the tools and practice to engage the task before they depart.

Going forward, five VCU engineering students will work in Rwanda and Nicaragua in the summer of 2015. Two additional students will work concurrently in St. Vincent and the Grenadines in partnership with the World Pediatric Project (WPP), a U.S.-based NGO that supports pediatric medical teams working in the Caribbean.

Based on lessons learned in the pilot, these seven students will be tasked to return with topics for senior design projects. They will meet as a cohort before departure to prepare for this task. They will study topics on reverse innovation and constrained design facilitated by design faculty in the Biomedical Engineering Department.

Upon their return from the summer experience, they will also serve as mentors for teams of junior level design students who will develop the project ideas into topics available for selection by senior students the following year.

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