International, Low-Resource Design Projects: Building Capacity Abroad

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The Mechanical Engineering program at Virginia Tech is large and continues to grow, with a current class size of about 400 expected to grow to 500 in the next four years. As a result, there has been a need to add design project options in two categories: industrially sponsored and internationally focused humanitarian projects. The international project option has been popular since 2013, with 131 students participating in 21 projects in four countries. Design data from the projects is archived and available to anyone interested in adopting the design for use. The projects have historically been structured so that there is an in-country contact who provides customer needs information for the team during the formative stage. A trip with a subset of the team to the country happens either during fall semester to trial a prototype design, or at the end of the spring to deliver the finished product. This paper presents an overview of the project type that is suitable for international humanitarian capstone design, and it addresses the challenges and rewards of traveling with senior engineering students to resource-limited countries.

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Introduction

Capstone design gives students an opportunity to apply technical knowledge in solving open-ended problems, but it also provides a foundation for integrating social and cultural influences into novel solutions. The simplest design projects are an extension of class homework, usually with a customer who is internal and has narrowly defined what the product should do. An example of this would be found in an improved fastener design, which should be corrosion resistant and operated with a screw driver. More interesting designs would require a student team to consider how a product integrates into society. Is the product shared? Will the product pose a danger to bystanders? Will the product fail because the infrastructure is inadequate? Does the product have a meaningful value proposition when the consumer is brought in?

International humanitarian projects provide students with complexity that is rarely found in typical capstone experiences. The motivation for such programs is outlined in Dym[1] which stresses the importance of global, technical, cultural and business constraints that provide the context for successful design. Downey et al.[2] ties engineering success to exposure to new cultures that define and solve problems differently. Warnick[3] has shown that international capstone projects benefit student global awareness through an the opportunity to investigate, assess, coordinate, design, communicate and witness a design implementation of an engineered solution in an international setting.

Students working international projects find a need for flexible thinking given the unfamiliar culture, forcing a thorough examination of how a product will integrate throughout its life cycle. Does the required manufacturing technology exist to produce and maintain the product? Is there a favorable business climate for the entrepreneurs who will produce and sell the system? Does the product serve more than one purpose which will make it more appealing both to the new businesses and consumers?

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The projects have historically been structured so that there is an in-country contact (or contacts) who provides customer needs information for the team during the information gathering phase of the project. A trip with a subset of the team's members to the country occurs either during fall semester to trial a prototype design, or at the end of the spring to deliver the finished product. These trips present challenges which, over several years, have been addressed to increase efficiency and give the students an experience that supersedes any domestic equivalent.

What makes a good project?

The success of an international project is dependent on many factors that need to be addressed early in the project definition. Foremost is a desire to design the final deliverable with local sustainability in mind[4-5], and successful technologies should meet at least two supportive roles in society:

- Replace existing technology with a better system. "Better" is defined as cheaper, easier to use, or more efficient than an existing technology.
- The new technology is designed to solve a problem but it should also solve another problem as a bonus. For instance, a new seeder design should plant seeds effectively, but it might also be modular with other attachments or it might be designed to distribute fertilizer. And knowing that the seeder will be used in a community, a cellular data modem can be attached to report its location and what is being planted.
- There is a strong value proposition in the device to encourage an entrepreneur to adopt the design with production, operation and maintenance contracts. Some initial exploration into funding streams can support the case for business development.
- Technology education is frequently a bi-product of new device introduction, and this should be considered in the overall product design and use. As an example, aerial imagery from a drone provides many opportunities to teach remote sensing and how those data products are applied. Teachers can be provided local community aerial imagery, and lessons in data analysis can be taught with the product.
- Case studies of products that failed should be explored by the design team; this is helpful in giving a new perspective to technology introduction and how not to repeat a failed technology introduction.

A visit to the targeted community is important to collect customer needs through interviews and focus group sessions. Focus group meetings are particularly useful as they tend to formalize needs that are collectively expressed by users. Figure 1 shows an interactive session with farmers from Senegal expressing a need for an improved seeder.

From an educational standpoint these projects give students exposure to business and global dynamics not experienced in traditional design, so if failure occurs it can have many root causes. Material sourcing, safety, manufacturing and operational standards need to be considered to be successful, competing with the obvious challenges known from engineering design. There is security in the engineering, but neglecting the environment where the system is operated or not considering who will maintain it can guarantee failure.

Course structure

Similar to all other senior design capstone projects, teams of five to eight students are formed in the first week of class from the students' ranked selections of their project preferences. The team size is determined by the project complexity, with students chosen based on their technical qualifications or their international travel experience and desire to work in developing nations. Other projects have originated from the students themselves who have taken a prior trip and made connections with a community.

Figure 1. Meeting with farmers to discuss seeder design

A few select faculty with international experience advise the projects and commit to leading the students on their trips. In the course design, a common lecture is given once per week during the fall semester to pace the student teams through the design process, including customer needs, specifications, concept generation and selection, preliminary design and detailed design. In the spring, the course continues without the lectures however the student teams work closely with the advisors to refine the design and "roll out" their final product by mid-semester.

Testing and evaluation occurs in the second half of the spring semester. Ideally the product would be evaluated in-country and any required redesign would happen prior to the end of the semester. In reality, travel during the second half of the spring semester is nearly impossible due to the students' schedules. Testing is performed near Blacksburg in as close to actual conditions as possible.

Project examples

Virginia Tech provides about five international project options per year to its seniors, with ideas originating from VT faculty in engineering, agronomy, or other outreach personnel supporting study abroad programs. The projects are selected based on an appropriate scope for a design team and to have support both domestically and internationally.

Latrine pit desludger

Shown in Figure 2, this device was designed based on a suggestion from a water and sanitation expert affiliated with the CCAP SMART Centre in Mzuzu, Malawi. In addition to providing bore hole drilling and pumping technologies, the SMART Centre also participates in waste management projects such as affordable latrine pumping.

Figure 2. A desludging team using the Virginia Tech designed pumper

This device was prototyped in Blacksburg and tested by SMART Centre personnel with success. For testing in Malawi, the internal valve components were fabricated in Blacksburg and carried on the trip while the wooden structure was fabricated locally in Malawi. Cost for entire fabrication in Malawi would be less than $100, and the interest from the SMART Centre proved this design to be a success. This low-cost design represents a sustainable business opportunity for entrepreneurs; all components of the system can be locally sourced.

Portable exam table

Sponsored by CerviCusco, a women's health NGO located in Cusco, Peru, this project aimed to design an exam table that could be backpacked into remote villages where healthcare facilities are limited. The table is used not only at outside venues (temporary tented facilities), but also at existing healthcare clinics that do not have functioning exam tables. Figure 3 shows the final table design.

A doctor from Augusta, GA who founded the NGO was available for feedback during the design cycle. Having this U.S. contact was an invaluable resource for the team since the students were able to demonstrate concepts in person and receive valuable feedback prior to final design. In a two-day cervical cancer screening campaign, the table showed superior performance over existing equipment that was broken or lacking critical components.

Figure 3. Portable exam table set up in clinic in Tinta, Peru

Manually powered washing machine

Domasi rural health clinic in Domasi, Malawi does not have a functioning washing machine to clean bedsheets, and so the task of designing a manually powered washing machine was undertaken. With visits to the clinic (Figure 4), the needs of the staff were realized and a prototype was constructed for single person operation to meet the needs of a 40-bed hospital. Figure 5 shows the prototype designed last year which is used as a starting point for the current year in this two-year project.

Working with a fabricator in Malawi, this design was built around simple fabrication techniques using bent sheet metal and welded components. One of the challenges in countries such as Malawi is the availability of raw materials, where the cost of importing materials can be much higher than the material cost itself. There are plastics companies in country and so plastics are fairly reasonable, but steel and aluminum prices are high. Material sourcing is an important part of the design refinement.

Figure 4. Taking measurements at the laundry facility in Domasi

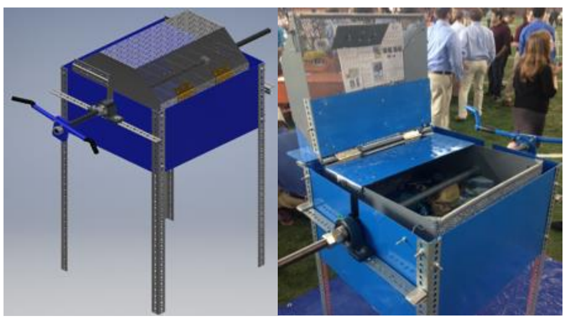

Figure 5. The prototype design finished last year

Travel considerations

A major challenge of running an international project is not technical but logistic; pulling off international travel with students is always an adventure! It is helpful to have some students who are from developing nations, or have traveled to less developed areas participating in service-related work. It does not have to be everyone; if half of the team has travel experience the other half will survive quite well.

Virginia Tech requires a lab fee for engineering students which is used for laboratory and curriculum development. One of the visible benefits of this fund is a 3,100 sq. ft. student machine shop that opened in 2016. We have also used the funds for international travel. In some cases, students will contribute to the cost of travel, but generally funds are available through the department for these trips. A crowdfunding campaign was initiated this year to support travel but only raised 10% of the desired $10,000. Other sources of funding can be obtained from student organizations (Student Engineer's Council), college support, and corporate sponsorship.

Transportation arrangements always come with some safety risk and it is advised to dedicate time to research options. In Peru, a driver who was recommended by the hotel was unable to find the hotel. In Malawi, a driver drove over a farmer's goat (and avoided an even more stressful outcome by not slowing down).

The rule that frequently gets broken is to never drive at night due to the poor condition of vehicles and the heterogeneous mix of traffic on the roads, from pedestrians to donkey carts. It is difficult and nearly impossible to impose hard rules on schedule when traveling to remote locations, but every attempt should be made to end the workday with enough daylight to complete travel back to the hotel.

Conclusion

The opportunity for mechanical engineers to design products for use in a new location in a different culture can be a life-changing, empowering experience. For those students selecting an international humanitarian project, new barriers and challenges are added in the design process resulting in an added complexity problem. Navigating through to a successful solution proves these students to be leaders, wherever their future design challenges take them.

References

1. Dym, C.L., et al., "Engineering Design Thinking, Teaching, and Learning", Journal of Engineering Education , 94 (1), 2005.
2. Downey, G.L., et al., "The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently", Journal of Engineering Education , 95 (3), 2006.
3. Warnick, G., Magleby, S., and Todd, R., Parkinson, A., "Globalization: A New Frontier for Capstone Courses," AC 2008-1230, 2008 Annual Conference and Exposition, 2008.
4. Taylor, A., Turovskiy, J., Drew, B., Muelenaer, A., Redican, K., Kochersberger, K. and Bickford, L., "A Sustainable Engineering Solution for Pediatric Dehydration in Low-Resource Clinical Environments," J. Human. Eng., Vol. 4, No. 2, 2016.
5. Standridge, Z., Kochersberger, K., and Donnelly, J., "Design and Development of a Low-cost Delivery and Mapping UAV Suitable for Production and Operation in Low Resource Environments," AIAA SciTech, Kissimmee, FL, Jan 8 – 11, 2018.