Encouraging Innovation through Design in Resource Constrained Environments

Ian Davis, Jeffery M. Plumblee, Autumn Brown, and David Vaughn
Clemson University/The Citadel/Clemson University/Clemson University

Abstract

As technical fields continue to globalize and the skills required of future engineers evolve, traditional engineering programs are often falling short of meeting the needs of the 21st century engineering student. Specifically, graduates are lacking an ability to innovate and design in real-world scenarios. CEDC is a student-led, service-learning organization at Clemson University whose mission is to improve the quality of life in the Central Plateau of Haiti while simultaneously developing well rounded, capable engineers. The program utilizes student-designed technological and health interventions to improve health metrics and daily life in Haiti. Students design and implement these projects in a resource constrained environment, focusing on functionality, feasibility, and sustainability. The resource constrained nature of the projects requires students to produce innovative and non-traditional solutions to pressing, real-world issues. This paper examines two CEDC projects, Do-It-Yourself Water Filter and Solar Powered Refrigeration, and analyzes the program's ability to bolster innovation through design of projects for developing regions.

Keywords

Innovation, design, humanitarian engineering, service-learning, resource constraints

Introduction

Engineers of the 21st century are facing rapidly evolving, globalized fields in which technology changes at a frenetic pace. While traditional engineering programs provide students the technical skills needed to address problems and the structured engineer's mindset to design solutions, these programs are not equipping students with the abilities needed to achieve long term success[1]. Specifically, many students are not prepared to function in and engage with an interconnected and global environment[2]. This hinders the students' likelihood of prosperity in the professional world.

The core purpose of an engineer is to design, develop, and implement solutions to problems. To do so, engineers must be able to innovate, or use creativity, the thought process behind innovation, to "make something that is new or better"[3]. It is imperative for an engineer to be able to work in teams, learn from design flaws, and understand the social implications of project execution[4]. For this reason, additional considerations should be made to incorporate the broader impacts of engineering design further than what is typically examined in a classroom setting. To thrive in the 21st century, engineers must be competent in creativity and entrepreneurship[5].

There are many suggestions for supplementation of traditional engineering curricula to develop creativity in engineers. The proposed solutions vary widely, and the benefits of service-learning and humanitarian engineering projects have been extensively noted[6]. One of the principle benefits of participating in humanitarian engineering is the opportunity to partake in interdisciplinary, project-based learning. This style of learning allows students to see designs from inception to implementation, and to enhance classic design thinking. The complexity of international development projects also forces students to think far beyond their own discipline to consider the social and cultural ramifications of project[7]. In comparison to capstone design courses, which have been implemented across engineering disciplines but rarely culminate in much more than an on-paper design with no societal considerations[8], development project-based learning has students take designs through prototyping, appropriation of funds, and implementation. Furthermore, the classically taught design thinking is amplified through the use of resource constraints, development goals, observable outcomes, and considerations for scaling[9].

Clemson Engineers for Developing Countries

One organization where the benefits of project-based learning within the context of international development are apparent is Clemson Engineers for Developing Countries (CEDC). CEDC is a student-led, service-learning organization at Clemson University whose mission is to improve the quality of life in the Central Plateau of Haiti while simultaneously developing well rounded, capable engineers. The former outcome is achieved through field implementation of a myriad of humanitarian engineering projects. These have included the construction of the first chlorinated municipal water system in Haiti[10], installing solar powered LEDs to illuminate classrooms in the village of Morne Michel[11], and expanding the capacity of rural aquaculture and fish farms through an improved water transportation system[12].

The latter outcome, developing well rounded, capable engineers, stems from the program's multilevel engagement platform and innovative project model[11]. Students are able to enroll in the course for a one-hour elective credit. Participation is on a semester basis and students of all disciplines and year standings are eligible to participate. Students begin their projects by developing a project charter, and then move on to performing a literature review to explore the context of the problem in more detail. It is only after completion of these deliverables that students may continue their research and design. The next steps include constructing and testing prototypes, defining a product development methodology, and eventually developing a delivery plan. The next levels of engagement come from fall and spring break trips where students perform data collection and the opportunity to intern in country for 7-12 months.

Case Studies

As of Fall 2017, there are 16 project groups within CEDC spanning a wide range of disciplines and skillsets. Some of the work currently underway includes reverse engineering commercially available water testing systems, researching methods of waste management in developing countries, and determining the structural properties of bamboo reinforced concrete in comparison to traditional steel reinforced concrete. The following sections provide discussions of two project groups: The Do-It-Yourself (DIY) Water Filter group and Solar Powered Refrigeration group. Both projects are still in the research and development phase and exemplify the multifaceted approaches needed to engineer solutions in the developing world.

DIY Water Filter

The DIY Water Filter group began in Fall 2016 with a broad project scope. According to the group's original project statement, the principal goal of the group is "to build a set of renewable water filters that are sustainable, using basic components" and allow for the technology to be scalable to the personal, home, and municipal level. For the technology to be truly "Do-It-Yourself," it is imperative for the filters be constructed with materials available in the communities where the technology will be used. Due to the current organizational scope of CEDC, this means all materials must be available to individuals within the Central Plateau of Haiti. This restriction has been the primary driver of the research and design.

Due to the potential large scale of the project, students found it necessary to focus on the lowest level of the project's intended implementation, the personal level, and would later use the lessons learned to expand into the others. Students began by researching existing designs from both the developed and developing world. The former includes the designs of many popular, commercially-available personal water filters. Additionally, students aimed to connect the concepts found in commercially-available products to current small-scale technologies being used to filter water in developing regions. The chosen filter design uses a PVC bucket and interwoven yarn through a porous PVC pipe to filter particulate from the water. This design, illustrated in Figure 1, allows for an optimum amalgam of efficacy and feasibility.

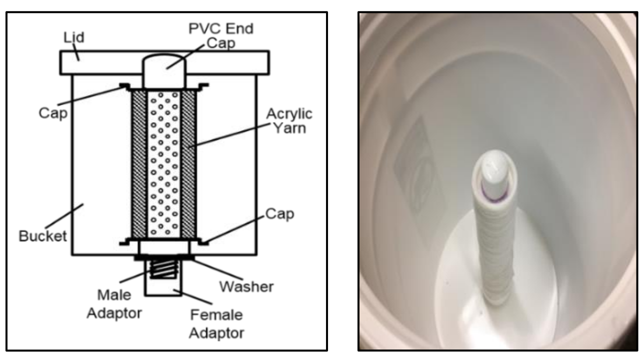

Figure 1. DIY Filter Design and Prototype

The filter's design has been iteratively refined in order to ensure the technology's sustainability and propriety within the target setting in Haiti. The group has taken actions to simplify the design by reducing the layers of yarn from 35 to 5, making the filter more user friendly, and is currently building new prototypes to compare efficacy between the two designs.

Students working within this group must regularly asses the tradeoffs inherent between efficacy and end-user interaction. Knowing that the project is currently meant to be "DIY" for rural

Haitians has directed their design process by forcing the group to continually ask themselves questions regarding material availability, simplicity of design, and effectiveness of the device. Any one of these three aspects not meeting minimum criteria represents failure for the entire project. In addition to these larger concepts, students still gain technical skills, including prototyping, water quality testing, and experimental design and data collection, which allow for a holistic learning experience for the students.

Solar Powered Refrigeration

The Solar Powered Refrigeration group is a response to the pervasive issue of vaccine spoilage in developing regions[13]. In many developing communities, electricity is non-existent or unreliable. One of the most threatening ramifications from this lack of reliable power is the spoilage of life saving vaccines. Because of the unreliable power, many clinics do not have the capability to store the vaccines within the allowable temperature range of 2-8° C[14]. This issue of proper vaccine storage can inhibit vaccination programs that contribute to general health of the target population. To help overcome this challenge, the Solar Powered Refrigeration group is working on a solar powered refrigerator that could be used in these clinics. This device is designed to collect the energy needed for cooling from focused solar energy and will not be connected to a grid-based energy source.

The group's project charter requires that the system be:

- Able to maintain temperatures of 2-8° in inclement weather and through the night;
- More cost effective than traditional refrigerators;
- And able to be manufactured or assembled in the resource constrained environment the device is meant to serve.

As with the DIY Water Filter group, this team is focusing their efforts for implementation within the Central Plateau of Haiti.

To meet these design criteria, the group is using an absorption refrigerator, operated by heat from focused sunlight. The design includes a heat storage system to power the unit when it is not in direct sunlight and a solar tracking system that maximizes the energy collected. This design and it's physical prototype can be seen in Figure 2.

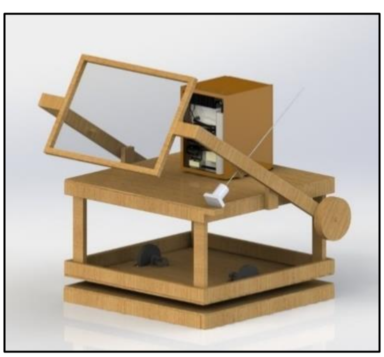

Figure 2. Solar Refrigerator Design and Prototype

This solar tracking system uses a Fresnel lens, an array of photo sensors, and a DC motor to follow the sun as the Earth rotates, allowing for the optimum amount of sunlight to be focused by the lens.

Throughout the timeline of this project, the student's self-imposed constraints have given them direction and purpose for their work. Additionally, students have had to continually weigh tradeoffs between cost, constructability, reliability and maintenance, and resource availability during the project. These considerations have encouraged innovation rather than limiting it; students must choose to be innovative within the current design boundaries.

Conclusion

Project-based learning has begun to complement the traditional lecture based classroom. Teaching methods involving humanitarian engineering have the ability to further augment the classroom experience. Designing for development allows students to work for a greater purpose and under unique constraints that may be unaddressed in theoretical design problems. When exposed to these unique constraints and motivations, students innovate out of necessity and push themselves beyond customary thinking and design. This drives student creativity and refines their ability to innovate, see broader project implications, and be better prepared for the challenges of the 21st century.

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Ian Davis

Ian Davis is an undergraduate student at Clemson University pursuing a B.A. in Economics. His areas of research include engineering educational outcomes, foreign infrastructure investment in developing countries, and the societal implications of humanitarian engineering initiatives. Davis is also the Director of Program Advancement for Clemson Engineers for Developing Countries.

Jeffery Plumblee II, Ph.D., M.B.A.

Dr. Jeffery Plumblee is an Assistant Professor in the Department of Engineering Leadership and Program Management at The Citadel. Plumblee's research interests focus on building a more resilient society. Plumblee has a passion for providing opportunities for students to work within resource constrained settings (primarily humanitarian technology and delivery), and he enjoys understanding how these activities uniquely develop students.

Autumn Brown

Autumn Brown is an undergraduate student at Clemson University pursuing a B.S. in Environmental Engineering and Science. Brown's research interests focus on capacity building of developing communities through applications of engineering and science. Brown is committed to empowering others through education and experiential learning. Brown serves as the Assistant Program Director for Clemson Engineers for Developing Countries.

David Vaughn

David is a Professor of Practice with Clemson University's Glenn Department of Civil Engineering. His research interests focus on developing the means and methods to create resilience in underserved and resource constrained environments both domestically and internationally. Vaughn's passion has been demonstrated by his commitment to humanitarian projects and the development of students through service projects.