Global Engineering Projects from the Young African Leaders Initiative

Keywords: global design project, domestic internationalization, humanitarian engineering

Abstract

In this paper several projects that integrate globalization issues into undergraduate engineering and technology coursework are discussed.

The Mandela Washington Fellowship for Young African Leaders brings African entrepreneurs to United States campuses for six weeks every summer, providing an excellent opportunity to identify potential clients for global engineering class projects. Many of the fellows could benefit from having access to engineering skills to grow their businesses. The university's engineering faculty partnered with fellows on projects in freshman Impacts of Engineering, junior Lean Manufacturing, and senior Capstone Design classes. Projects have included conceptual product design, detailed product design, process selection, manufacturing equipment design, and facilities design. Several engineering and technology majors have participated in the projects. The highlight is a micro-hydroelectric generator design project spanning several classes and semesters.

The projects are similar to traditional class projects and cover all existing course objectives. Students are also required to research and apply international standards, including product, safety and facility standards. Students also must consider the appropriate level of technology, humanitarian engineering aspects, and societal impact of the design. Assessment of the international component of one project allows programs to evaluate performance indicators on the global and societal impact of designs as part of ABET Outcome H assessment. The projects are also part of a larger humanitarian engineering initiative at the institution, and are assessed through surveys for that initiative.

Introduction

Initiated by President Obama in 2013, the Mandela Washington Fellowship for Young African Leaders brings 1000 leaders from Sub-Saharan Africa to United States campuses for six week long Academic and Leadership Institutes every summer.[1] The fellows are between 25 and 35 years old and have promoted innovation and positive change in their institutions, communities and countries. There are tracks in Business and Entrepreneurship, Civic Leadership, and Public Management. Fourteen campuses host leaders in the Business and Entrepreneurship track. Fellows in this track generally are running their own businesses. Fellows are expected to return to their home countries to continue to build their skills and implement what they have learned. Many of the fellows could benefit from having access to engineering skills to grow their businesses.

Our university ran Academic and Leadership Institutes in the Business and Entrepreneurship track for 25 YALI Fellows in the summers of 2014, 2015, and 2016. The institutes were run out of the College of Management, but engineering faculty led some training sessions and mentored fellows on individual bases. Out of these sessions, several engineering projects were identified which could be accomplished through various engineering classes. The projects had humanitarian engineering aspects to them, and provided international clients for student projects.

Literature Review

Recently, many engineering organizations have emphasized the importance of global engineering competence for engineering program graduates. A major impetus in the United States came from the National Academy of Engineers[2] highlighting the impact of globalization on the practice of engineering. An international summit hosted by ASME concluded that engineering grand challenges require engineering to evolve as a global profession. The profession will become more globally competitive[3]. Industry and academic leaders rated how importance it was for engineering graduates of today to be globally competent, averaging 3.8 on a 5.0 Likert scale[4]. A study on global engineering excellence by eight leading international universities recommended integrating experience-based programs into an international context. Our design projects use international experience-based projects to improve the global competence of our engineering students[5].

Several researchers have defined various descriptions of global competencies of engineers. Downey et al. identified 3 learning outcomes on cultural sensitivity.[6] Mazumder identified 5 skills in making a global engineer.[7] Warnick's extensive literature review identified eight global competencies for engineering success within a global environment.[8] Parkinson et al. identified 13 dimensions of global competencies.[9] Klein-Gardner and Walker surveyed 48 industry and academic leaders and found 6 of these dimensions as most important.[4] Of these, our projects directly address 3 of the most important dimensions:

- Ability to communicate across cultures
- Ability to appreciate other cultures
- Understand cultural differences relating to product design, manufacturing, and use.

A component of engineering within a global context is the field of humanitarian engineering. While there is much alignment of the themes and considerations between global engineering and humanitarian engineering, there are also many differences that must be accounted for. Much of the traditional engineering practice is focused on solving the problems of the wealthiest individuals among the world's population.[10] However, if we are to create a just world where all individuals have access to the resources and opportunities to meet their basic human needs through economic and engineering development, then we must make this an integral focus of the engineering practice.[11] This can be best accomplished by communicating the importance of considering the effects of globalization from multiple perspectives and factoring in the ethical, environmental, and social aspects when delivering this content in the engineering curriculum.[12] Various models exist for the integration of these topics into the curriculum such as general education courses, specific engineering ethics courses, and various forms of service learning opportunities.[13] It is likely that a combination of these approaches will be necessary to really drive change in the engineering profession that starts within the university.[14] Additionally, however, it is also necessary to integrate these topics directly into the core technical content of an engineering program.[15] The challenge with this approach is to find the most effective pedagogical approaches to integrate these skills and produce a positive effect on student attitudes, behaviors, and performance while minimizing the risks to the clients, recipients of the service learning effort.[16, 17] An added benefit of humanitarian projects is that they attract a more diverse student population with wider interests.[18]

Freshman class projects

Impacts of Engineering is a 3-credit required course for all incoming engineering freshmen and is also available as a general education elective to all university students. Course objectives include several that are specifically directed at developing an understanding of engineering design from a global perspective.[19] These selected course objectives include:

- Demonstrate an understanding of the comprehensive nature of engineering design.
- Develop a systems perspective regarding the context of engineering design on a global scale.
- Evaluate the ethical, social, economic, and environmental impacts of engineering during the design, production, and end user phase of a product's life from multiple perspectives.
- Synthesize ethically, socially, and environmentally conscious design judgments and decisions.
- Evaluate trends and future impacts of environmental and social consciousness and globalization on engineering design and manufacturing from multiple perspectives.
- Demonstrate an experiential understanding of engineering design impacts relevant to the various engineering disciplines.

The engineering design process is taught through hands-on group projects. In fall 2015, the class worked with Fombah Kanneh, a product of the slums of Monrovia, Liberia. His Gift 2 Change company offers slum youth job opportunities in recycling and refurbishing clothing and furniture with the stated mission to, "help reduce poverty and build a middle class society through waste recycling."[20] The money raised through this process is used to provide employment for the men and women of Monrovia and to fund youth programs which provide clothing, books, educational materials, and training to the poorest children in Monrovia and the surrounding rural areas. Fombah wanted to add paper recycling to his business, so students created handmade and operated paper shredders and presses that could be duplicated in Liberia. They also identified possible products that could be made from their recycled paper.[19] Gift 2 Change has since added paper recycling to the business.

For some students who completed the course and this project, the role of comprehensive design became more apparent and the role of engineers in society more clear. Participating in the course project seems to communicate the desired message to students regarding our goals for the future of engineering development and the role they can play as engineers working on a global scale.[19]

Facility design projects

Lean Manufacturing is a required junior-level course for Manufacturing, Mechanical, and Plastics Engineering students. Students do an international facility design project as the major learning activity in the course. In spring 2015 students designed factory for the Sumi Kittony Apparel Company. This sole proprietorship designs and produces modern African wear. The factory will be built and operated in the slums of Kenya as a means for women to escape the poverty there. Some equipment has been purchased and construction began in spring 2017.

In fall 2015 students designed a guinea fowl processing factory in Bogatanga, Upper East, Ghana. The factory will use modern food safety practices and will eliminate the use of burned tires for processing the meat. This factory provides jobs for local workers, a market for local farmers, and local and healthy food options for local residents. The new facility construction began in spring 2017.

Course objectives require data analysis, facility designs, and alternative evaluation following lean manufacturing and facility design processes. For the global aspects, students conduct Internet research so that they are able to select equipment and design the facility according to appropriate national and international specifications, factory safety laws and quality standards. Students select manufacturing equipment while considering technical specifications, but also electrical requirements, equipment safety certifications, utility systems, import costs and restrictions, maintainability, language issues, and cultural acceptance. Projects are evaluated more on the students' ability to identify critical issues, select or design a feasible alternative, and defend their selection than the specific designs and selections made.

Capstone I projects

Capstone One Design Practicum is the capstone course for Engineering Technology students and the first of a two semester sequence for all engineering students. Student teams create computer designs of a machine, system, or product. Additionally the course requirements include manufacturing process planning, economic justification, and design for manufacturing rationale. Many YALI Fellows need improved manufacturing processes to increase production and quality in their companies, all within tight budget and technology constraints. These make natural projects for the Capstone One courses.

Jocylene Agbo of Abidjan, Nigeria invented and patented Jo-Jo laundry detergent, designed to work well hand washing in northern Nigeria. Production requires measuring and mixing wet and dry ingredients, drying the mixture, and packing and sealing in bags. Current production is labor intensive and inefficient, done by hand in 100kg batches. One student team designed a filling, mixing, and drying system that could produce 500kg batches with less cost and more consistent quality. Abidjan has sufficient manufacturing capability to build the machine to the given design. A scale model of the students proposed design, based on a cattle feed mixer that mixes in both axial directions is shown in Figure 1. Preliminary testing of the model demonstrated excellent mixing efficiency.

Figure 1. Prototype laundry detergent mixer

Avomeru Company produces avocado oil in Arusha, Tanzania.[21] However, most avocados in the region spoil because they cannot be safely transported from the orchards to Arusha for processing. Portable presses that reduce the avocado produce to oil in the field can help more full utilization of the crop. Two student teams designed portable cold presses which can be taken to orchards on a truck. There they press avocados into crude oil which is more easily transportable and has a longer shelf life. With several presses, over 250 farm co-ops in the region could generate a steady demand for their produce in the form of avocado oil. An MIT founded innovation center in the region contains necessary production equipment to manufacture the presses according to the student proposed designs. Both designs allow for easy disassembly for transport and are powered by gas engines. On campus experiments were performed by the student design teams to verify that the proposed screw compressor design concept would effectively extract avocado oil utilizing one of our plastic injection molding machines retrofitted with extraction hardware of the proposed design shown in Figure 2.

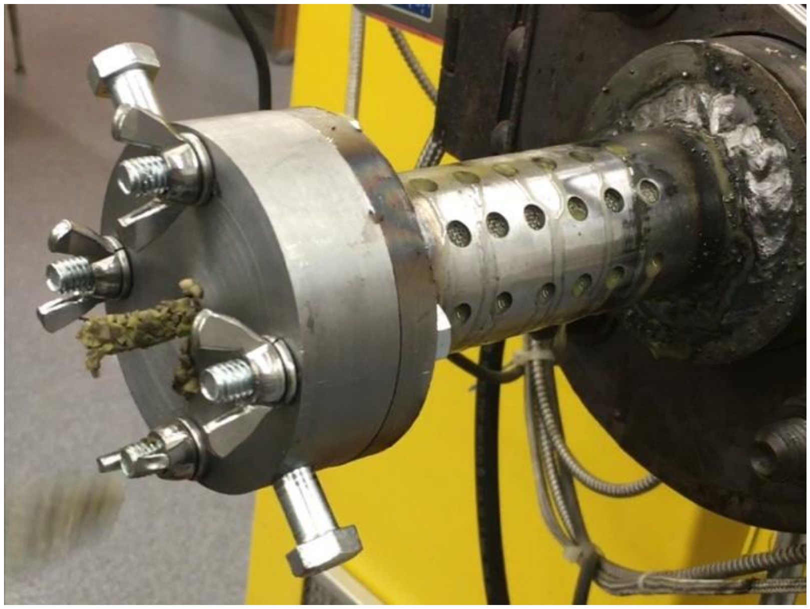

Figure 2. Avocado press oil extraction hardware

The Capstone One course objectives include: (i) To foster individual achievement through team success (ii) Utilize independent research for design, (iii) Application of prior course material and experience to practical industrial design, and (iiii) To gain appreciation for the structure format and process used in industrial design projects. Creativity, industrial documentation standards, design for manufacturability, solid modeling, design analysis, finite element analysis, team dynamics, economic justification, project management, ethical standards, and communication skills are further developed within the course. In addition to these, utility requirements, material specs, material availability, and production capabilities for the region are issues that must be addressed in the global engineering projects.

Generator project covering several courses

One project has covered several classes and semesters. Hastings Mkwandwire of Mzuzu, Malawi builds mini-hydroelectric generators from scrap materials. Generators are installed in remote mountain locations far from the electric grid to power small clusters of homes. Currently, less than 10% of these homes have access to electricity.[22] The overall goal of the project was to create a low-cost generator design that could be mass produced.

Product design migrated through one semester project in the freshmen engineering course, two rounds of the Capstone One Practicum, a Prototyping course, and one Independent Study course. The freshmen engineering design project involved a redesign of the hydroelectric generator's turbine . Students were tasked with finding the appropriate geometry, materials, and construction techniques to produce a turbine that would maximize electricity production in response to a flow of water. Examples of the students' designs can be seen in Figure 3.

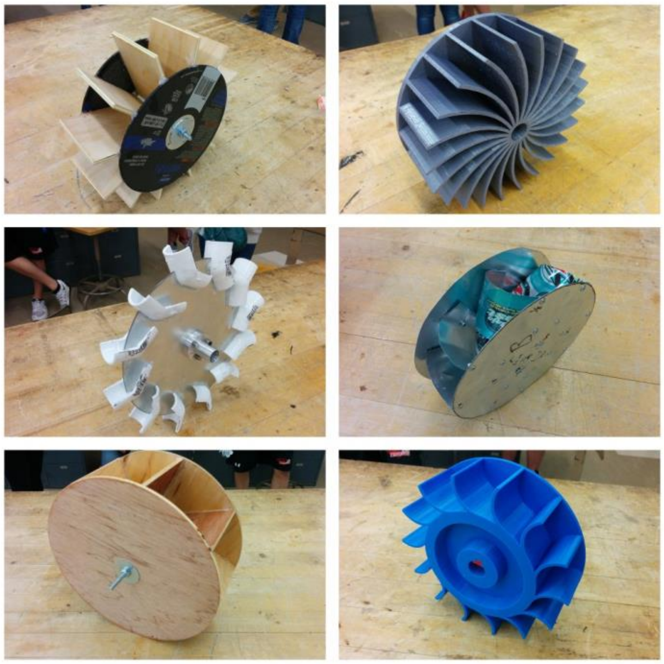

Figure 3. Student designed rotor prototypes. Figure files available under CC-BY.[23]

The first capstone group designed an axial flux disc generator using molded epoxy for the rotor and stator material. In the independent study project, the student and professor visited Malawi to validate the feasibility of the design. It was discovered that epoxy molding was difficult due to unavailable epoxy materials and mold making and mold repairing facilities. A cage-style radial flux generator was built in Malawi, but it was also determined that mass production would take too long and could not sustain the necessary tolerances. Finally, an axial flux design with sand casting production and aluminum material were settled on. A second Capstone One team refined, built and tested the current design. The design only requires copper wire coils, bearings, and permanent magnets as purchased materials, while the remaining components may be fabricated from locally available scrap and recycled materials. The generator produces 63 watts at 1000 rpm for about 82 USD purchased materials. A functional prototype of this design is shown in Figure 4. Finally, a Prototyping course group will make and test the final design, with casting assistance from the American Foundry Society student organization.

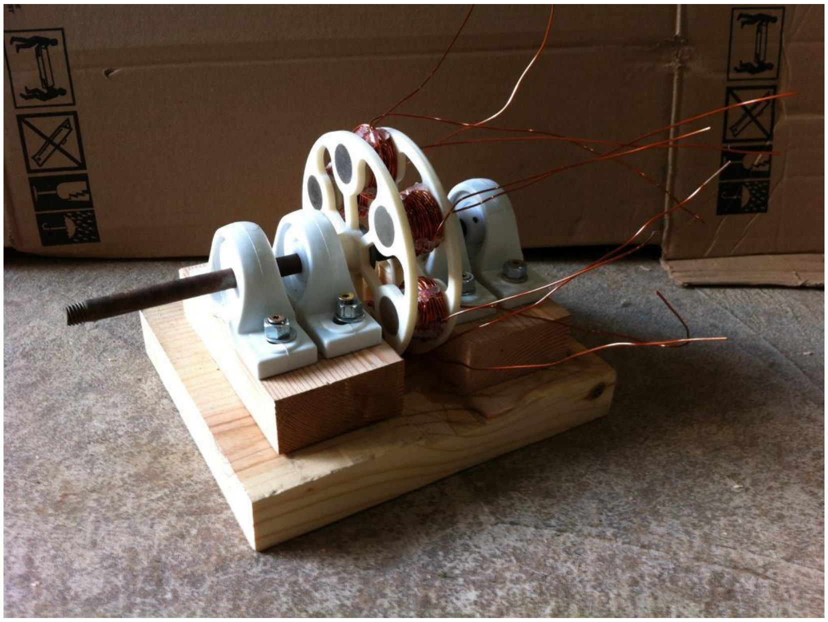

Figure 4. Functional prototype of generator design

Simultaneously, the Lean Manufacturing classes designed two iterations of the factory, considering equipment selection, capacity, manpower, and safety requirements. A standard product and process is expected to increase production from one to 20 generators per week. Also, one Impacts of Engineering class conceptually designed turbines that could later be cast. Crude prototypes were made out of aluminum cans and other scrap materials and tested, with the winning design ideas forwarded to the Capstone One team for final aluminum casting design.

Social and technical advantages of local production were evaluated during the independent study and communicated to other design teams. Local manufacturing provided needed employment and skills training. Product maintainability was enhanced when spare parts could be made and installed by local workers. A local church synod’s offer to distribute and install generators guarantees product acceptance by the end users.

ABET assessment

Currently, ABET Engineering Outcome H is a challenge for many programs to evaluate. It requires “broad education necessary to understand the impact of engineering solutions in a global and societal context.” The YALI Fellows’ projects provide performance indicators for Outcome H. Our university evaluates this outcome in the Lean Manufacturing class, because all students in that class directly work on the same international project. Each student on a team must research and design a solution to a different issue related to the global aspects of the project. Issues vary by project, but have included equipment sourcing and selection, material sourcing and selection, material/equipment import process and tariffs, factory safety standards, quality systems, training and maintenance plans, and cost justifications.

The individual problem responses provide artifacts for Outcome H evaluation. Our assessment evaluates each student from 1 (unsatisfactory) to 4 (exemplary). In Fall 2013 Outcome H was assessed based on a fictional global case study problem. With our scale, 24 students scored an average of 2.93. In Spring 2016 the outcome was evaluated again, based on a YALI Fellows project. This time, 29 students scored 2.85 with our scale. There was no statistically significant difference between the outcomes, and both scores are considered good.

Humanitarian Engineering assessment

A quantitative survey instrument was developed[13] as an adaptation of the Sustainability Skills and Dispositions Scale[24] in order to assess the impact of humanitarian engineering content on student learning outcomes. This instrument asks students to rate themselves in terms of their confidence in technical design and in working with communities and measures their sense of their responsibilities as professionals in global, social, and environmental contexts. Also included are some items from the Engineering Professional Responsibility Assessment[25]. This survey asks students to rate to what degree their professional responsibilities include such things as volunteering, doing pro bono work, changing designs with input from communities, etc. Finally, some questions from the ethnocentrism scale developed by Neuliep and McCroskey[26] were included. This survey measures attitudes towards cultural differences and will be useful in seeing if students grow in their knowledge of and attitude towards the differences they encounter when designing engineering solutions in a different culture. Finally, basic demographic information (race/ethnicity, gender, etc.) was collected.

Through the administration of the survey, students submitted responses to a set of prompts asking them to reflect on the curriculum and their perceptions of humanitarian engineering and how those perceptions changed as a result of the curriculum. A total of 69 students provided comments. Of those, 14 students said that the curriculum didn't change their thinking as a result of the course with three of them explicitly mentioning that they did not agree with the message of engineers helping others or did not see themselves participating in "that kind of work". Three of the students mentioned that they already held the views presented. For the remaining students who claimed to have changed their views as a result of the curriculum, comments were qualitatively coded and sorted into broad themes outlined below. The parenthetical numbers indicate how often the theme was found in the comments. Some student comments contained more than one theme and responses of simply "yes" or otherwise lacking details were excluded.

Of those who said the curriculum did change their minds there were several themes:

- I have more knowledge about the impacts that can be made by engineers and/or how they can help (20)
- I know now more about ethics and the care that must be taken when making decisions (13)
- I now have a desire to make a positive contribution to the world (6)
- I realized I must think about society as a whole/culture/local traditions (5)
- This class confirmed my choice of major/career or gave me knowledge about my future career (4)
- I have more knowledge of the problems that need to be addressed (3)
- I realize we need to see the big picture/global impacts and connections (3)
- I have a new world view (3)
- I learned that engineers want to help (2)

- I realize we can learn from others in the world (1) or need to take into account their views (1)
- I worry I'm not creative enough to be an engineer (1)
- Engineers have to worry about all details of a design (1)
- Long-term solutions to global problems are needed (1)

Conclusion

In this paper we have presented a summary of various projects that integrate globalization and humanitarian issues into engineering and technology coursework. The projects have been made possible by the Mandela Washington Fellowship for Young African Leaders. These example projects have been implemented in a wide variety of courses, ranging from freshmen introductory level, to junior facility design, to senior level capstone. The projects have enabled students to learn and apply skills needed for product development for global market needs, while maintaining coverage of our traditional domestic design based course outcomes. Students also learn to design for global facilities standards. Assessment shows that the projects enable students to successfully meet ABET Outcome H and changed their perceptions on humanitarian engineering. It is hoped that engineering colleges with YALI fellows at their universities will develop engineering projects with the fellows that will benefit both the students and the fellows' home countries.

Acknowledgments

The authors thank Dr. Tina Lee for her assistance with assessing the survey data. The humanitarian engineering assessment tools and results derived from them are based in part upon work supported by the National Science Foundation under Grant No. EEC-1540301. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

The authors would also like to thank the University of XXXXXXXXXX Office of Research and Sponsored Programs and the Schneider Professorship which also helped support this work.

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