ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #35252

An International Wireless Connectivity Capstone Design Project for Electrical and Computer Engineering Students

Dr. Pritpal "Pali" Singh, Villanova University

Dr. Pritpal Singh is Professor of Electrical and Computer Engineering at Villanova University. He received a BSc in Physics from the University of Birmingham, UK in 1978, and Masters and Ph.D. degrees in Applied Sciences/Electrical Engineering from the University of Delaware in 1981 and 1984, respectively. Dr. Singh teaches courses at the undergraduate and graduate levels in the areas of semiconductor microelectronics, renewable energy systems and power electronics. He has been working on thin film solar cell research since 1979 including a Sabbatical Leave at the National Renewable Energy Laboratory in 1993. He has also worked on several photovoltaic system projects

Dr. Singh has also worked on electric vehicle research, working on battery monitoring and management systems funded primarily by federal agencies (over $3.5 million of funding).

Dr. Singh has consulted for several companies including Ford Motor Company and Epuron, LLC. He has also served as a reviewer for the US Department of Energy and National Science Foundation. Dr Singh has over 150 conference and journal publications and holds seven issued US patents.

Dr. Singh's recent work is focused on battery state-of-charge/state-of-health algorithm development, microgrid simulation and humanitarian projects in under-served communities in the areas of renewable energy, wireless connectivity and education.

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Dr. Pritpal Singh

Professor, Department of Electrical and Computer Engineering

Villanova University

Abstract:

International humanitarian student design projects have grown in popularity over the last 20 years, primarily with civil and mechanical engineering students working on clean water system designs for rural communities in developing countries. Yet, there are many opportunities for electrical and computer engineers to contribute to international development projects through renewable energy and information and communication technology-based project designs. Additionally, such projects meet two important student outcome criteria, outcomes 2 and 4. This paper describes an international capstone design project for electrical and computer engineering students to provide wireless connectivity supported through renewable energy to a village in Kenya. Close collaboration with partners in Kenya ensured that the various social and cultural dimensions were considered in developing the design solution. Details of the project and an assessment as to how well the project met student outcomes 2 and 4 are presented here.

Introduction:

Many students are motivated to do projects where they see their engineering skills being used to make a difference in the lives of communities. These so-called humanitarian engineering projects have evolved over the last twenty years. While a limited number of faculty engaged students in international engineering design projects prior to 2000, extensive growth in engagement of students in these types of projects has occurred since then. Bernard Amadei, a professor of Civil Engineering at the University of Colorado in Boulder, witnessed firsthand the lack of access to clean water and sanitation in the community of San Pablo, Belize in 2000 [1]. This experience motivated him to engage engineering students in the design and deployment of clean water systems in this rural community. He was further inspired to launch the Engineers without Borders organization in 2002 [1]. Most of the opportunities focused in the water, sanitation and hygiene (WASH) areas and primarily attracted civil and mechanical engineering students in global development projects. The first humanitarian engineering minor program was started at the Colorado School of Mines in 2003 [2]. Again, the engineering majors who were primarily attracted to this program were civil and mechanical engineers. Water distribution projects have been designed by US engineering students and implemented with community members in various countries [3-5]. Other programs have been formed that focus on innovations for low resource settings. A good example of such a program is the Frugal Innovation Hub at Santa Clara University [6]. In general, electrical and computer engineering (ECE) students have not been very engaged with humanitarian engineering projects. Yet, there are many opportunities for them to participate in such projects through the design and implementation of renewable energy

systems and projects in information and communication technologies for development (ICT4D) [7-9].

Another significant development that has occurred in recent years is the increasing consideration of globalization in the ABET student outcomes criteria. Recent changes to the student outcomes are placing more emphasis on including global, social, and cultural issues into system design considerations as well as in teaching students professional and ethical responsibilities [10].

This paper describes an ECE capstone project as an exemplar to show how humanitarian engineering opportunities may be brought into undergraduate senior design projects to meet some of the broader student outcomes while engaging students in meaningful, motivating project work.

ECE Senior Capstone Project Sequence:

The senior capstone design sequence in the ECE department at Villanova university spans three semesters. The program begins with a proposal development course in the spring semester of junior year. In this semester the students are typically completing their foundational electrical and computer engineering courses and so will be prepared to take their specialty track courses in in their senior year. The project proposal course starts with an introduction to ECE design which cover design topics such as organizing a project, developing system specifications, preparing a system block diagram, organizing and breaking down a project into its sub-parts, consideration of appropriate standards that must be taken account in designs, how to prepare a proposal, technical writing, project management (including budgeting, work breakdown scheduling, human resource management, etc.) The course also includes some technical workshops to orient students to 3D printing, the Arduino microcontroller and the Raspberry Pi microcomputer.

The first half of the course is focused on preparing students to be able to write an effective senior design project proposal. At the same time, faculty submit and present project topics for the students' consideration and students may present their own projects for consideration to the course coordinator. At the completion of all the faculty proposal presentations, students fill out forms expressing their first three project choices as well as supporting rationale for wanting to work on a specific project. The course coordinator then assigns students to projects with almost all students receiving either their top choice or second choice project. During the second half of the semester, the students meet with the faculty project sponsors (who serve as project advisors) and prepare a project proposal. They present their project proposals both in writing and orally at the end of the semester to both the course coordinator as well as other interested faculty.

During the fall semester of senior year, students work on their project designs and perform a mid-term technical progress demonstration, typically in the sixth week of the semester, and a final technical demonstration, usually in the twelfth week of the semester. The students prepare a final technical report and give their oral project presentation to faculty and industry judges in the spring semester of their senior year.

Exemplar ECE Humanitarian Project – A Wireless Educational System in Kenya:

Prof. Singh has been engaged with the various Institute of Electrical and Electronic Engineers (IEEE's) humanitarian engineering activities since the first IEEE Humanitarian Technology Workshop was held in June 2009 in Washington, DC. Through his IEEE humanitarian network, he was introduced to the Maa Trust, an NGO based in the Masaai Mara reserve in rural Kenya [11]. The mission of the Maa Trust is to promote economic opportunities for the Masaai tribespeople in the Masaai Mara. Traditionally, these tribespeople have been engaged in livestock rearing and jobs related to the tourists who visit the Masaai Mara for safaris. In discussing some of the issues that the Maa Trust is facing, education of school children was a challenge that they brought to our attention. There are three schools within a few kilometers of the village and the Maa Trust would like to connect their training hub to the schools through a wireless communications network and offer video education from their hub to the schools. Also, the schools lacked reliable energy and so the schools would need to have solar electric systems deployed in the schools to meet the power needs of computers in the classrooms to access the educational videos being broadcast from the Maa Trust's central hub.

This design project was proposed to students in their junior design proposal development class and was assigned to a group of four students, three electrical engineering students and one computer engineering member. The students organized themselves into two sub teams, one focused on the communications link and the other focused on the solar electric system. Weekly meetings were held between the students, their advisor, and a representative from the Maa Trust. The proposal was developed and presented at the end of the spring term. The meetings and presentations were conducted remotely because of the COVID-19 restrictions.

The actual design project was conducted during the fall semester and while many of the design meetings were held virtually, the advisor did meet the students in person (following all COVID-19 protocols) to loan out equipment and go through specific practical questions regarding the designs. Also, the outdoor testing of the integrated system was performed in person with the advisor. In addition to the advisor, additional expertise was brought into help guide the students, specifically a network engineer from Kenya, Josephine Miliza, who has established her own local area community network in a poor neighborhood of Nairobi and could better guide the students on suitable equipment to use within the Kenyan context and on the Kenyan regulatory environment and standards vis-à-vis wireless communications.

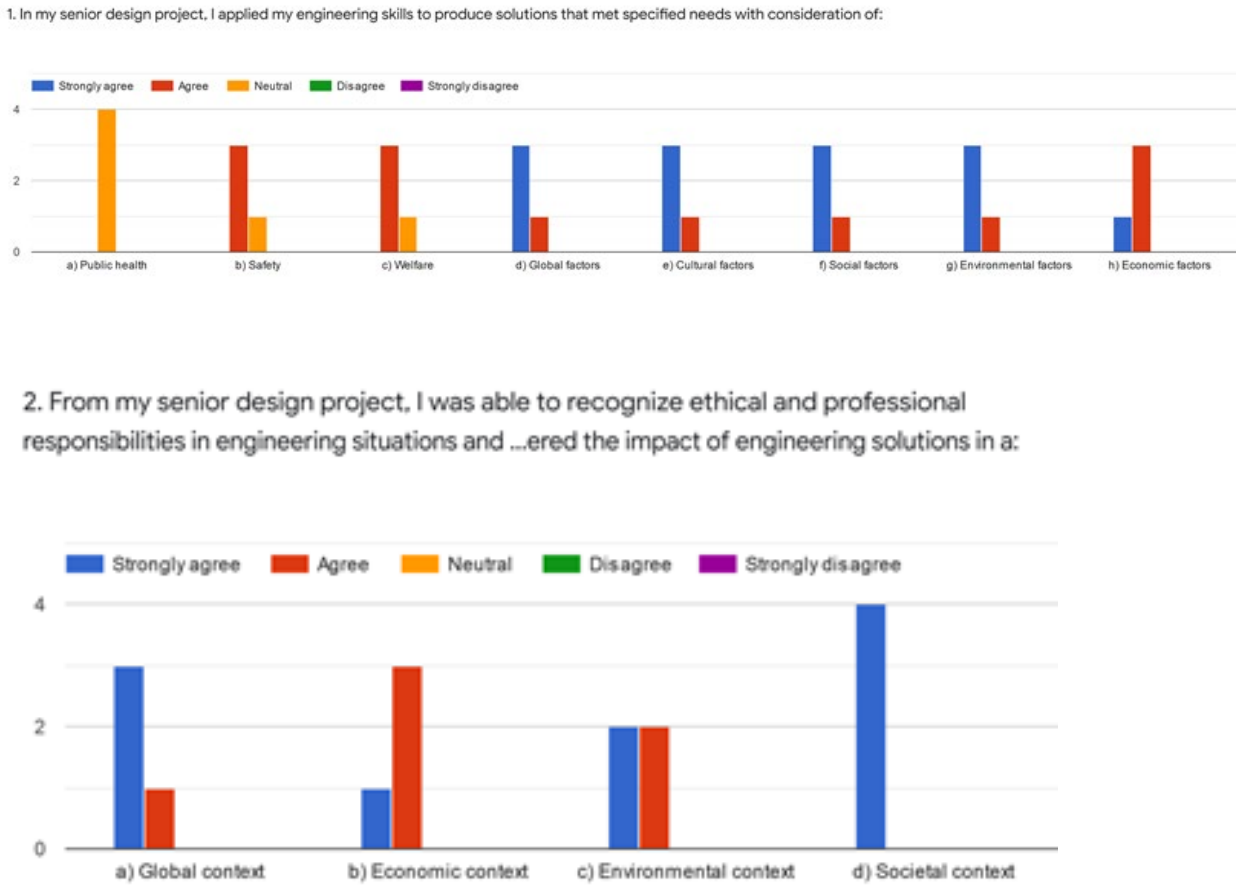
The students completed their design and presented their midterm technical demonstration, which was primarily simulation, and their final technical demonstration, which included a hardware deployment and complete system demonstration. The students are presently preparing their final technical report and presentations and will be making their final presentations on April 9, 2021.

Student Outcomes Assessment:

The two student outcomes that were assessed in this project were student outcomes 2 and 4. Student outcome 2 states: an ability to apply engineering design principles to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors." Student outcome 4 states: an

ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts." An anonymous survey was administered to the four students on this team and all four completed the survey. The results of the survey are shown in Figure 1. While most of the dimensions related to student outcome 2, including global, cultural, social, environmental, economic, safety and welfare factors were clearly well covered by this project, while the public health issue was not particularly well covered. Furthermore, the ethical and professional responsibilities for engineering for student outcome 4 were all very well hit by this particular project. Achieving these student outcomes effectively are often difficult and so this project has demonstrated that it was well designed to meet many of these outcomes.

Figure 1: Results of Survey



Discussion:

Clearly the results of this survey show that the humanitarian capstone design project are meeting the student outcomes that were expected.

In addition to the exemplar project described in this paper, three other international humanitarian design projects were supervised by Dr. Singh. These included a mobile software application to connect farmers to staff from Catholic Relief Services (CRS) in Guatemala, a Galapagos Sea Lion identification software system, and a community intranet educational system for the Galapagos Islands. There are many more humanitarian projects that could be developed for ECE students. There are organizations within IEEE, specifically the IEEE Humanitarian Activities Committee (HAC) and the IEEE Special Interest Group for Humanitarian Technologies (SIGHT) that provide funding to support community engagement, prototype development and field deployment projects. Other projects that have been performed in this domain have been presented at the IEEE's Global Humanitarian Technology Conference, the flagship conference for presentation of research in humanitarian technologies.

Conclusions:

Like engineering students in other disciplines, ECE students would like to be engaged in humanitarian projects where they can use their technical skills to impact communities in low resource settings. This paper has described a particular project, the design of a wireless communication network and solar energy system for schools in the Masaai Mara in Kenya. The students were very motivated to work on this project and did an excellent job. The student outcomes 2 and 4, that include considerations of global, cultural, social, environmental and economic considerations as applied to designs and solution development, were assessed in this project. Survey results of the students showed that several of these dimensions were strongly achieved in this particular project.

It is the hope of the author that this exemplar project will stimulate other ECE faculty to consider offering humanitarian capstone design opportunities to their students.

Acknowledgements:

Dr. Singh is grateful to the group of motivated students who did an excellent job of conducting this project. The students are: Steven Amalfitano, Guido Modano, Reyna Scafide, and Rachel Voloshin. The author is also very grateful to the guidance provided by Mercy Chelangat and Crystal Morgensen of the Maa Trust and Josephine Miliza of the Internet Society in Kenya.

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