Sustainability Challenges & the Opportunities for Global Engagement: Linking Caribbean secondary school classrooms and Engineering Departments at US Universities

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Abstract

Sustainability is recognized as being critical for the framing of engineering research and education with unique opportunities for engineering student training through non-traditional university partnerships, including international ones. With limited natural resources, high vulnerability to catastrophic events, and isolated by the sea, Caribbean islands have been pushing for sustainable development and have championed adaptation as the main mechanism to deal with climate change. Actual demonstration projects or widespread educational initiatives needed to solve issues such as water scarcity are limited and only a very small work force has training in Science, Technology, Engineering and Mathematics (STEM). This paper discusses a secondary school student challenge that was developed in the Caribbean to address these issues with particular attention paid to Belize and the types of linkages that evolved with US based engineering students and the ways in which students in the Caribbean and the US were exposed to a global environment.

Twenty-four projects entered the challenge from Belize, two of which were formally engaged with student classes from two different US universities. A teacher and 5 students from a private secondary school in Caye Caulker, a Belizean island, were matched with a mentor at a US University. That mentor required the twenty students in his senior level Geospatial Technologies for Biosystems Engineering class to work on the Belize request to design a composting system based on material, financial, and local environmental constraints. Teams of two or three university students worked with the teacher and students from Belize and presented their findings via SKYPE and as a written report. While being mentored by a local Belizean engineer on a stormwater management project for their school in Belize City, connections were made to a Professor of Civil Engineering at another US university who focused her International Engineering Field Experience course on their project. In May 2013, thirteen students from her class visited Belize to survey the site, teaching survey methods to the secondary school students as well. In May 2014, another group will visit to continue working on the project, which involves the creation of a detention pond and an ecological park for outdoor laboratory experiments.

Introduction

Sustainability is recognized as being critical for the framing of engineering research and education with unique opportunities for engineering student training through non-traditional university partnerships, including international ones (Mihelcic et al., 2003; Mihelcic and Trotz, 2010; Trotz et al., 2009; Zimmerman and Vanegas, 2007). Universities are also investing in mechanisms to ensure they graduate globally competitive and competent engineers (Downey et al., 2006) like that of global service learning (Mohtar and Dare, 2012), field trips, and integrated class experiences (Downey et al., 2006). The Caribbean community (CARICOM), a regional group of Caribbean islands and coastal countries in Central and South America, have supported a sustainable development agenda since 1994 with priority areas of climate change, natural and environmental disasters and climate variability, freshwater resources, coastal and marine resources, energy, and tourism (United Nations, 1994). In 2013, the Sagicor Visionaries Challenge for secondary school students in the Caribbean (an equivalent to a combination of US middle and high schools) presented an opportunity for US engineering students to gain global competency skills through sustainability focused solutions to challenges linked to issues like food and water security.

This paper first describes the Sagicor Visionaries Challenge and then discusses two case studies, showing how engineering undergraduates in the US engaged with the sustainability challenge projects of the secondary school teams in Belize. Using Downey et al.'s (2006) categorizations for global competency pathways, the case studies represent an integrated class experience and an international field trip.

Sagicor Visionaries Challenge

The Sagicor Visionaries Challenge aims to promote sustainable Caribbean communities through innovation in science, technology, engineering and mathematics (STEM). It asks secondary school students to:

1. Identify a challenge facing their school and or community,
2. Propose a sustainable and innovative solution, and
3. Show how that solution uses STEM

In 2013, this challenge was implemented in the following twelve countries: Anguilla, Antigua and Barbuda, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines and Trinidad & Tobago. The emphasis on STEM comes from the fact that each year roughly two thirds of the ~150,000 secondary school students sitting the required general mathematics examination in the Caribbean show poor competence. For example, for the May/June 2012 mathematics examination 33% of the 95,000 candidates received grades I-III (CXC, 2012). While performance in the sciences is much better, less than 20% of the eligible students even take these subjects. This challenge was conceived, implemented & sponsored by the Caribbean Science Foundation (CSF), the Caribbean Examinations Council (CXC), and Sagicor in partnership with the Ministries of Education in twelve different Caribbean countries. The Goals of the Challenge are to 1) Boost institutional capacity in STEM in the secondary schools in the Challenge Countries, 2) Ignite interest among youth in the Challenge Countries for innovation in STEM to help build and integrate

sustainable communities throughout the Caribbean, and 3) Integrate knowledge gained from formal and informal education to enable tomorrow's leaders to build a more sustainable Caribbean.

The three sponsors represent the private sector, a regional institution and a non-governmental organization. Sagicor is a financial services company that operates in 22 countries in the Caribbean, Latin America, the United Kingdom and the United States. The Caribbean Science Foundation (CSF) is an independent non-profit non-governmental organization based in Barbados committed to: stimulating technology-based entrepreneurship; accelerating education reform that supports technology-based entrepreneurship; and providing scientific and engineering advisory services to Caribbean governments. The CSF brings together Caribbean scientists and engineers from within the Caribbean and throughout its diaspora and exemplifies an organic brain gain (Ciumasu, 2010) mechanism that is independent of government funding. Established in 1972, the Caribbean Examinations Council (CXC) provides 18 Caribbean countries with: syllabi of the highest quality; valid and reliable examinations and certificates of international repute for students of all ages, abilities and interests; and services to educational institutions in the development of syllabi, examinations and examinations administration in the most cost-effective way.

Professional engineers, scientists and entrepreneurs judged entries at the national level in March and April 2013 in each of the challenge countries, with the winning school in each country advancing on to a regional competition in Barbados in April 2013. Student representatives and teachers of the winning teams from the national competition also participated in an all-expenses-paid STEM Ambassador Program in Florida during Summer 2013. Teacher and student sensitization workshops were organized in each country between October 2012 and February 2013. Teachers supervised the student projects and submitted online entry forms that included a 250-word abstract of the project. In addition to teacher supervision, the teams were also given support from mentors who were either local or virtual. The CSF recruited mentors and matched them with school projects via email introductions with the teacher and/or students. Some student teams filled out an online form requesting a mentor prior to the challenge submission deadline and others were provided with a mentor after submission based on their project abstracts. Mentors included professionals and faculty and students from institutions like the University of the West Indies, MIT, Georgia Tech, Auburn University, Dartmouth College, the University of Toronto & the University of South Florida (USF).

One hundred and seventy-five (175) projects entered the competition, representing 900 students ranging in age from 11 to 19 years. In Belize, an environmental engineering faculty member from USF led challenge sensitization workshops with Principals of all secondary schools, some science and mathematics teachers, and students at seven schools in October 2012. In January 2013, two USF civil and environmental engineering graduates – one with a bachelor's degree who was based in Belize and one with a doctoral degree who volunteered for this project – led sensitization workshops with students at 28 schools. Table 1 lists the twenty-four projects that entered the challenge from Belize which were submitted by 27% of the country's sixty-four secondary schools. US engineering undergraduates worked on three of the projects either before the national competition in March 2013 (Ocean Academy Compost and Gardening Project) or after it (Yorker Ecological Educational Park). These interactions are discussed in detail next.

Table 1: List of 2013 Sagicor Visionaries Challenge projects from Belize and mentors

Project Title	Mentor
W.A.T.E.R (Wise Allocation To Every Raindrop)	Consultant[1]
Wesley College Coastal Development	Director, Coastal Zone Management[2]
Yorker Ecological Educational Park (Stormwater Management)	Consultant[1]
Recycling Broken Glass Bottles To Art 'N Pottery	Consultant[1]
Nature Buddies Assembly Point (Sustainable Building)	Graduate Student[2]
Green Team	Consultant[1]
The Future For A Natural Paradise (Biodiversity Conservation)	Assistant Professor[2]
Enzy Friends	Science Advisor[1]
Coconuts 4 Life	Assistant Professor[2]
Delille's Dream Passion (Sustainable Structure)	Consultant[2]
Dropping The Stench (Improved Onsite Wastewater Treatment)	Graduate Student[1]
Embracing Belize Using Biogas	Professor[2]
Plastic Surgery by Solar Power (Greenhouse and Food Security)	Graduate Student[1]
Chickens For Children	Consultant[1]
Feed Me More Nutrients	Consultant[1]
From Pollution to Green House Creation	Professor
Ocean Academy Compost And Gardening Project	Lecturer[2]
The Making of Biomass Fuel And Organic Fertilizer	Consultant[1]
Heat From Peat	Graduate Student[1]
Go Green (School Waste Management Program)	Graduate Student[1]
Recycling Paper	Consultant[2]
Banana Leaf Project (Waste Reuse)	Graduate Student[1]
EcoFeAdd (Biodegradable Polymer Products From Poultry Feathers)	Consultant[1]
Sun To The Rescue! (Renewable Energy)	CEO, Engineering Firm[2]

1 – mentor based in Belize; 2 – mentor not based in Belize

Case Study 1: Integrated Class Experience

Twenty students (5 females and 15 males) in a senior level 3-credit Geospatial Technologies for Biosystems Engineering class at Auburn University spent two weeks on a class project focused on a composting project for a private high school in Caye Caulker, Belize. Table 2 summarizes the abstract submitted to the Sagicor Visionaries Challenge. No sensitization workshops were conducted there or with any of their teachers or administrators. Responding to an email announcement sent from the local Registrar of the CXC, the teacher submitted a mentor request on October 31st, 2012 and was matched with a lecturer in the Honors College & Biosystems Engineering Department at Auburn University who was teaching Geospatial Technologies for Biosystems Engineering.

According to the Biosystem Engineering Department's website, "Biosystems engineers ensure that we have the necessities of life: safe and plentiful food to eat, pure water to drink, clean fuel and energy sources, and a safe, healthy environment in which to live. Biosystems Engineers apply engineering to problems and opportunities presented by living things and the natural environment" (http://www.eng.auburn.edu/bsen/about/index.html). Therefore, being assigned a client with a composting challenge fit well into the scope of what a biosystems engineer should be able to deal with. Of the 20 students, most were in their final semester and had taken a Waste Management course that focused on composting. The mentor was aware of the challenge and had incorporated it into his course plan that semester. In order to provide an integrated classroom experience for the biosystems students a two week case study was structured to incorporate team work, geospatial techniques with use of ESRI ArcGIS software and some cultural and social studies of Belize.

Table 2: Sustainability challenge, proposed solution, and partner information for composting project in Caye Caulker, Belize.

Project Title: Compost and Gardening Project: Turning waste products into solutions on the island of Caye Caulker, Belize *Project Challenge:* The school is located on an island where all trash is dumped in an open-pit dump and burned and where fertilizers and freshly land-based agricultural products are limited. A previously successful compost system at the school processed waste from the island community; however, their compost suffered from structural challenges and interference from rodents and other animals. *Approach:* The students wanted to improve their composting and gardening program that would reduce the volume of trash burned on the island and support local agricultural needs. They surveyed the local community to determine best-selling plants and evaluated best growing plants for their environment. They selected the most suitable compost design for their school based on recommendations from their mentor and were raising funds to expand their greenhouses and to construct the new compost bins.
Secondary School Information: 5 students ranging in age from 12 to 14 years old. *Mentor:* Lecturer in Honors College & Biosystems Engineering Department at Auburn University *Interaction:* Undergraduates spent two weeks on a required class project with the Belizean students. Skype and email were modes of communication. Deliverables for each team included a team report and a 5-minute Skype presentation to Belize. The mentor coalesced the teams' reports and forwarded a final report to the Belizean teacher who was supervising the project.

Since 2010, the secondary school had implemented a compost system that was used to grow plants that were sold to the local community. Income generated from the plant sales was used to help pay tuition of the students who helped to maintain the garden. Recent floods forced the school to use the scarce concrete blocks from the compost for a walkway and the student team wanted a more resilient system. Initial correspondences between the teacher and the lecturer framed the questions that the secondary school students had: 1) How can we rebuild our compost bins in the most efficient way? 2) Should we

recreate our original design, or do you have modifications to suggest? 3) How can we ensure pests (i.e. crabs, lizards) do not enter? and 4) How can we maximize heat and decomposition in the bins?

Teams of two or three biosystems undergraduate students worked on the following mini projects based on the school's requests: composting design options (Preliminary compost design, Turning compost design, Suspended 55 gallon drum assembly, Improved compost bin design, Multi-scale design), compost mixture preparation, getting rid of crabs and lizards, waste management on an island, and potential funding avenues for school based waste reuse and food security projects.

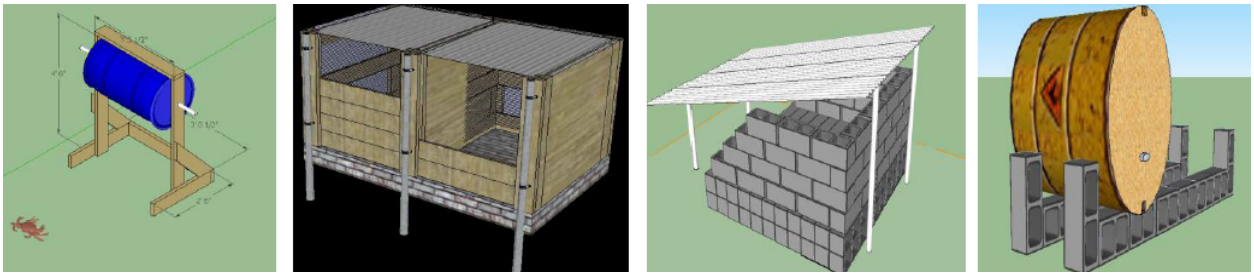

Figure 1: Examples of compost designs produced by the undergraduate students for the Caye Caulker secondary school team.

Table 3. Biosystems Engineering students' comments about the Caye Caulker, Belize, case study.

"Not to be selfish but this project with Belize totally solidified how things I've learned in other classes all come together in trying to come up with true engineering solutions. Hopefully the students that we worked with had as good a[n] experience as I did."
"I honestly wasn't sure where Belize was in the world before working on this project. It was very refreshing to learn about Belize and its ties to the Caribbean. I wanna visit!"
"It was pretty cool to get to work with the students over there and to get to Skype with them about the project……I have never visited another country and now I feel that I did, at least a little bit."
"This was a nice way to use our profession and our knowledge to serve others. Before working with the Belize[an] kids I always struggled with how I could use my biosystems engineering training to serve others and this experience has certainly helped to clarify that for me."
"…..it was great to see that whenever I interact[ed] with the Belize[an] students they were always so eager to learn and be sustainable with whatever materials and resources they had…."
"I thought it was pretty nifty to get to use Skype in the class to get to talk to folks in another country. We have never done this in any other class but it would have been nice to [have done so] since freshman year. Thanks, Dr. XXX….."

This Belizean case presented an opportunity to expose the biosystems students to a new culture and ways of doing things in the world. According to the Office of Institutional Research & Assessment at the University, only 6% of senior level students registered in the College of Engineering at Auburn University actually study abroad as compared to 15% of all senior level students across the university. These statistics prompted the biosystems engineering department to not just promote study abroad, but to

create academic integrated experiences even in the classroom. All students completed an anonymous feedback survey after the entire case study was done and the final report submitted. Ninety-five percent of the students appreciated the case study as a learning tool. Representative student comments are provided in Table 3.

Like most engineering departments around the US, there is continuous need to improve student's written and oral communication before they enter the world of work. The use of Skype, along with email communication between the biosystems seniors and their clients, through to the production of a final report all assisted in providing a platform for improved communication of the biosystem students.

Feedback from the supervising teacher in Belize, six months after the challenge, demonstrated that the school continued to work on the project, "One very positive outcome of participating in the contest was the wider exposure for our project work. We are on the island of Caye Caulker and people and schools on the mainland tend to be unaware of island accomplishments sometimes. A professor from the University of Belize was so impressed with our student project that she arranged a field trip for her Natural Resource Management class to come to Ocean Academy, meet with the students, and view the compost/garden site as a model that other schools could emulate. This was a very good experience for all parties involved. We also welcomed an American high-school volunteer group to the school, and one of the projects they funded was an expansion of our garden shed area to include shelving, shade, and a new compost bin adjacent to the shed."

Case Study 2: International Field Trip

Thirteen civil and mechanical engineering students at University of Mount Union travelled to Belize from May 12-22, 2013, as a part of their EGE 320 International Engineering Field Experience course. Of the 13 students involved 4 were female, 9 were male, 5 were civil engineering majors, 8 were mechanical engineering majors, and 9 students had never travelled outside of the US. For 12 of the 13 students this was their first time visiting a developing country. Table 4 summarizes the Sagicor Visionaries challenge project on which they worked.

A primary focus of the Department of Engineering at the University of Mount Union is to develop and deliver innovative curricula. Consequently, all engineering students (both civil and mechanical engineering) are required to participate and fulfill a mandatory international experience component – currently housed under the EGE 320 International Engineering Field Experience course that is offered during the Spring semester. In this junior level, course, students participate in regular coursework in addition to working, in teams of 4 or 5 students per group, on a project or projects from a developing country. . They work closely with the primary instructor of the course and the collaborators on the ground in the project site(s). At the end of Spring semester (around May) the students and the instructor travel to the project site for about 10 days. During this time, the students meet their collaborator(s) and stakeholders. Moreover, they either collect more data to help refine the design, present their designs to the collaborator(s), and/or implement their designs/solutions in coordination with the relevant stakeholders.

Table 4: Sustainability challenge, proposed solution, and partner information for stormwater project in Belize City, Belize.

Project Title: Edward P. Yorke "Yorker Ecological Educational Park for Belizean Biodiversity" *Challenge:* The school was built on land that was once swampy and the area was ineffectively filled with soil with no plan for stormwater. Every time it rains the land floods in certain areas. *Approach*: The students surveyed students at their school for support, surveyed the compound and identified the main areas that flooded, researched solutions, and conducted soil surveys with a practicing civil engineer. Their solution was the creation of a mini ecological park with a stormwater pond and a hydroponics garden to supply the school community with fresh vegetables. The ecological park would also provide an onsite location for students to carry out ecological studies in a live laboratory setting. Students from University of Mount Union began interacting with those at Edward P. Yorke after the challenge competition in March 2014.
Secondary School Information: 8 students, ranging in age from 15 to 17 Mentor 1: Consultants Interaction: Multiple school visits were made to the school prior to the competition by consultants. Mentor 2: Assistant Professor of Civil Engineering at University of Mount Union Interaction: Communicated with one of the consultants on the school project beginning in February 2013. Visited the school site in March 2013 and returned with students in May 2013. Between March and May, undergraduate team leaders interacted via email with the high school students. During the visit, students from both institutions and mentors conducted working lunch meetings and team building exercises.

The 2-credit EGE 320 course exposes students to the grand challenges of engineering and the need for various stakeholders (engineers, scientists, policy-makers, etc.) to collaborate and to develop, test, and implement innovative and sustainable solutions. Topics such as sustainability and life cycle assessment are covered. Some of the primary objectives of this course include:

1. Introducing the student to open-ended problems, current global challenges in engineering, and technical and non-technical aspects in engineering decisions.
2. Developing the student's skills to solve open-ended problems from a systems, holistic, and sustainable perspective considering economic, environmental, and societal aspects in engineering designs.
3. Developing the student's cultural and social awareness.
4. Developing the student's ability to work in a multidisciplinary environment, and
5. Expose the student to engineering in a developing country.

After the national competition, the undergraduate project team leaders communicated with the student leader from Belize on the various topics via email. The undergraduate students were divided into teams

of 3-4 students per group with each group working with the Belizean students on 1) feasibility, 2) surveying, and 3) the design of the retention pond. Using the stormwater solution proposed by the high school team, the Mount Union undergraduates checked calculations and refined the designs. Surveying of the site and training on surveying equipment was identified as a need and teachers and students asked for this to be done during the visit. While on the ground, the Mount Union undergraduates presented their projects to the high school and worked with them to implement some of the project's goals. During the visit, surveying, digging of a drainage system and a pond were all partially completed. The Belizean students were granted permission from their Principal to participate in the activities, half in the morning and half in the afternoon, with lunch being a critical time where Yorke and Mount Union students got to interact. Moreover, it was a time used to build cultural competency as well as the discussion of the project's status, problem solving, and developing new strategies when necessary. The Mount Union engineering students also taught the Edward P. Yorke High school students how to use the surveying equipment that they travelled with to Belize. The secondary school students, as a part of their challenge project, made arrangements for equipment like an excavator and a backhoe and materials to implement their project. Another University of Mount Union field experience will occur in May 2014 to continue with this project.

Faculty reflection on the inaugural EGE 320 course identified the following areas for improvement for 2014: 1) More strategically planned interaction and engagement of Mount Union Engineering students with the Belizean High School students; 2) Incorporation of a detailed educational piece, whereby the Mount Union students prepare a module and present it with the students on the ground to various stakeholders, and 3) Incorporation of pre- and post-assessment that assesses cultural and social awareness and global competency.

Summary and Conclusions

This paper presents two pathways for global engagement of engineering undergraduates, an integrated class experience and an international field experience, that took advantage of opportunities to interact with Caribbean secondary school students who were participating in a sustainability and STEM challenge to improve their school and/or community. Figure 2 shows the modes of interaction that were virtual and in person, with travel to Belize only for the international field experience case study.

Faculty involved with these case studies currently teach in engineering departments where global engagement has been identified as critical for student preparation. At the University of Mount Union, engineering students are now required to have an international field experience. The cost associated with international travel could be prohibitive and the student feedback from the integrated class experience presented in Case Study 1 demonstrates that the virtual collaboration with an international partner also contributes to global competency. Case study 1 was built on a virtual connection made through an online request for a mentor through the Sagicor Visionaries Challenge website. The mentor matched on the project had incorporated the project into an undergraduate class. Case study 2 involved a network of collaborators on the ground who were able to align a high school project with the faculty member in charge of a required international field experience. Belize is appealing as an international

field experience destination for US students because it requires no visa for US students, has English as its main language, is relatively safe, easy to get to and affordable.

Figure 2: (a) Final Skype session where the secondary school students talked to each mini-team of biosystems undergraduate students (11/28/12). (b) Final land excavation of biodiversity pond at Edward P. Yorke with Belizean students and team of undergraduate students from University of Mount Union (05/20/13).

The Caribbean Science Foundation partner, responsible for mentor recruitment and matching for the Sagicor Visionaries Challenge, is supported by many US based science and engineering faculty originally from the Caribbean. The challenge itself was designed with their input and highlights another resource that can be used to integrate global engagement into undergraduate engineering education. The U.S. Department of State is also interested in science diasporas and in 2012 announced the Networks of Diasporas in Engineering and Science (NODES), a partnership with the American Association for the Advancement of Science (AAAS), the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE) that seeks to support and benefit from diaspora knowledge networks. The case studies presented in this paper provide examples of how connections made through a diaspora network initiative can benefit engineering undergraduate programs in the US and STEM education in high schools in Belize.

The next Sagicor Visionaries Challenge launches in Fall 2014 in seven countries, including the US. US schools will be limited to middle schools in the Hillsborough County Public Schools, a district serving ~ 197,000 students and one where the sponsoring company has its US headquarters. The approach used in these case studies should serve as examples to follow for other projects and their mentors. The challenge website, www.sagicorvisionaries.org, could evolve to provide that virtual space where students and educators from secondary school through university level can interact and learn from and with each other, build their global competency, STEM skills, and sustainable communities.

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