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Co-Curricular Programs in Liberia for Student Pipeline into Engineering and Agriculture*

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After a fourteen year decimating civil war, the country of Liberia was left with the challenge of rebuilding its human and institutional capacity, particularly at the higher education level. The University of Michigan's College of Engineering was awarded part of a United States Agency for International Development grant to improve higher education in Liberia, namely the Excellence in Higher Education for Liberian Development program. Specifically, the University of Michigan's role in this grant is to increase the capacity of and enthusiasm among young students toward the two most crucial fields in the future of the country: engineering and agriculture. To accomplish this, the University of Michigan developed co-curricular programs at the secondary and university level that (i) create a pipeline of higher educational opportunities for students committed to pursuing careers in engineering and agriculture and (ii) increase the field-specific practical skills and breadth of experiences of those students. A specific focus of these co-curricular programs is on the development of soft skills of the participants—which are key for their future professional success. Already, within the first two years of implementation of these programs, unique and positive results have been demonstrated by the participants. The enthusiasm and commitment of the students toward engineering and agriculture has markedly increased. Furthermore, students have developed and improved their soft skills, such as public speaking, presentation skills, group work, communication skills, study skills, goal development, and critical thinking. In addition, the students exhibited a tremendous ability and initiative to work on open-ended community design projects.

Keywords: Engineering education; agriculture education; engineering outreach; agriculture outreach; K-12 and higher education partnerships; project-based learning; soft skills development

1. Introduction

Over a decade ago, the West African country Liberia suffered a devastating civil war that left it in ruins. As a result of the war, approximately one-third of the population was displaced, and the public infrastructure—including roads, power supplies, and communication systems—was destroyed [1]. As Liberia rebuilds, engineering and agriculture are two sectors that are vital to the success of its development. Yet, presently, the country is facing challenges to find youth interested in becoming engineers or agriculturalists, and giving those who are interested the adequate preparation to be successful in engineering and agriculture careers. The focus of the United States Agency for International Development (USAID)-funded Excellence in Higher Education for Liberian Development (EHELD) program is to address the educational and personnel gaps in the fields of engineering and agriculture at two universities in Liberia. As a subcontractor to the EHELD program, the University of Michigan's College of Engineering (UM CoE) has a specific focus on co-curricular educational outreach programs for the engineering and agriculture students.

1.1 Current state of higher education in Liberia

The Liberian higher education system faces unique challenges as the country continues to rebuild after its civil war. The destruction of buildings and large displacement of the population impacted education at all levels. In many schools during the war teaching was sporadic, and in some instances even non-existent. The University of Liberia (UL)—the premier public institution in Liberia and one of the oldest higher education institutions in West Africa—was paralyzed from its loss of intellectual capital. For example, during the war the majority of its 500+ foreign-trained faculty left [1]. Furthermore, war halted the modernization of the university's teaching facilities, curriculum, and materials. As a result, UL currently has substandard tertiary teaching and a poor learning environment. A similar situation is true for Cuttington University (CU), a private institution founded by the Episcopal Church in 1889. During the war, CU was forced to close and its buildings underwent extensive damage.

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Since its establishment in 1976, the Division of Engineering in the T.J.R. Faulkner College of Science and Technology at UL has historically been responsible for the training of most of the country's engineers (civil, electrical, and mining) and geologists [1]. However, since the war, its research activities and academic standards have drastically declined. For example, only 60% of the faculty in the Division of Engineering hold an advanced degree, which is largely due to UL's loss of the majority of its pre-war faculty [1]. Furthermore, many courses are taught by teaching assistants, who are often recent graduates with only a baccalaureate degree. Attrition of engineering students also poses a challenge to the engineering programs at UL. Oftentimes, those enrolled as engineering majors will dropout or change majors within the first year due to unpreparedness and/or lack of support. For example, in 2009, over 800 students were enrolled as engineering students; however, the graduating class that year was less than 50 students [1]. Furthermore, universities are not able to provide remedial education to those students whose secondary education did not sufficiently prepare them for engineering studies at the university level. Of final concern is the lack of women in the fields of engineering; of the 800 engineering-enrolled students in 2009, less than 10% were women [1].

Cuttington University's College of Agriculture and Integrated Development Studies (now named the College of Agriculture and Sustainable Development) was established in 2002 and is the only post-secondary institution outside of the capital, Monrovia, to offer a degree in agriculture. While CU's curriculum was recently revised to reflect modern needs, its faculty expertise does not provide the depth necessary for the curriculum. For example, faculty are well represented in the fields of crop science, but are not trained to teach courses such as agribusiness [1]. As for the student population at CU, many of its agriculture students are ex-combatants that entered the university on scholarships that have recently ended [1]. Thus, a great need exists for these students to continue in their education, and then find success and livelihood in agriculture upon graduation. Moreover, similar to UL, a need exists to increase the diversity of students in agriculture—only approximately 13% of CU's agriculture students are women, even though it is estimated that women produce approximately 60% of agricultural products in Liberia [1, 2].

1.2 Engineering/agriculture demand and youth prospects

For youth in Liberia (here defined as persons between ages of 15 and 35), there is an estimated 78% unemployment rate [3]. Young people are unprepared to enter university and vocational training programs because they lack basic literacy, math, and soft skills, such as such as presentation skills, group work, communication skills, study skills, goal development, and critical thinking [4]. Of the population over 15 years of age, only 1.7% hold an undergraduate degree [3].

Despite a strong demand for engineering professionals and good job prospects for engineers in Liberia, engineering remains an unpopular major at universities. Liberian students lack engineering role models and an understanding of the different fields and careers possible in engineering [1]. Because demand for engineers is so high, many times foreign engineering firms must train their own technical staff or hire foreign engineers to fill jobs [1].

While over 70% of the population in Liberia is engaged in subsistence agriculture, either directly or indirectly, youth are generally uninterested in pursuing careers in agriculture-related fields [1]. Moreover, more than 40% of Liberia's population is still vulnerable to food insecurity and more than two thirds of the households cannot afford three meals a day [5]. As with engineering, demand for agriculturalists in the public, private, and NGO sectors is high. However, since the local human capacity for large-scale agriculture was depleted during the war, it has been difficult for the country's agriculturalists to move beyond subsistence and meet the diverse needs of agriculture in these various sectors [1].

When students do graduate from the university, they lack soft skills and computer skills needed to be competitive for available jobs [1]. Due to large class sizes, minimal laboratories, and the lack of project-based learning at the universities, students do not develop soft skills necessary for success in their future careers. Furthermore, students lack access to computers, which prevents them from gaining contemporary technical communication skills essential in the modern economy.

1.3 The EHELD program

The EHELD program was commissioned by the USAID to reconstruct higher education in Liberia in the fields of agriculture and engineering, and to catalyze any activities that will improve those areas and lead to advances in capacity building, academic development, and research opportunities [1]. The EHELD program is the first USAID grant in Liberia specifically aimed at improving higher education. It is being implemented by the international development arm of Research Triangle Institute International (RTI International); a consortium of US Universities including the University of Michigan, Rutgers University, and North Carolina State University; and through the partnership with and

for the benefit of two Liberian universities: Cuttington University (CU) and the University of Liberia (UL).

As part of its role in the EHELD program, the UM CoE was tasked with carrying out co-curricular programs for Liberian students. The objectives of these programs are to:

(i) Encourage more students to consider careers in engineering and agriculture—particularly women.
(ii) Strengthen enthusiasm and motivation among the students for their careers.
(iii) Broaden student ideas and expectations of their careers.
(iv) Increase student capacity to excel at the university level.

After the first two years of implementation of the co-curricular programs, over 500 high school and university students—approximately half of them women—have participated in multi-day educational co-curricular programs. Student participants have increased their understanding of and motivation toward studying engineering and agriculture; students have improved their soft skills; and junior-level university students have worked on independent design and community development projects. Furthermore, based on journaling from the student participants, we have witnessed unique themes and secondary results develop as a result of these programs. Yet despite the initial successes of the programs, the future lack of funding and university commitment to these educational outreach programs as they are transferred over to Liberian personnel remain significant challenges in the final three years of the EHELD program.

2. Teaching/learning methodology

The co-curricular educational outreach programs have been carried out in Liberia by the UM CoE for the past two years, and will continue to be carried out for the remainder of the EHELD program over the next three years. Summer Start, a month-long program for incoming freshmen and sophomore university students, was the first co-curricular program implemented in the initial year of the EHELD program. In the second year of the program, Summer Start was expanded to include returning junior-level participants in addition to incoming freshman and sophomores, and an additional program targeting high school students was implemented.

2.1 Student pipeline

Creating a *pipeline* of students through programs available to those interested in specific careers is a common strategy amongst universities and educators. Oftentimes, universities will strategically partner with secondary and elementary schools to create K-12 engineering programs to introduce students to and increase interest in engineering fields before students reach the post-secondary level [6–8]. This strategy has also been used by universities to increase the amount of women interested in STEM fields [9–11]. Previous pipeline programs that targeted a range of different educational levels is summarized in Table 1. The student pipeline here refers to the implementation of programs that reach a diverse population of K-12 students and whose goal is to enable and prepare those students to pursue careers in engineering and agriculture.

Initially, the UM CoE implemented Summer Start, which specifically targeted university-level students. However, there was a desire to not only increase the amount and quality of students going into engineering and agriculture careers, but to also increase student diversity. Specifically, the EHELD program is working to increase the amount of women and the geographic representation of students interested in the fields of engineering and agriculture. To achieve these goals the UM CoE team implemented additional co-curricular programs beyond Summer Start to reach high school students across the country through programs known as Smart Start and Fast Start. The hope is that Smart Start and Fast Start participants will progress on to Summer Start and eventually into

Table 1. Previous studies that described student pipeline programmatic efforts, or summarized the need for student pipeline efforts, and the target group(s) of the pipeline programs

Pipeline program	K-12	Undergraduate	Postgraduate
Hyton and Otoupal, 2009 [6]	X		
Salas-Morera et al., 2012 [7]	X	X	
Yilmaz et al., 2010 [8]	X		
Blickenstaff, 2005 [9]	X	X	X
Espinosa, 2011 [10]		X	
Hathaway et al., 2001 [11]		X	
Meadows et al., 2009 [12]		X	
Summers and Hrabowski, 2006 [13]	X	X	X
EHELD program	**X**	**X**	**X**

internships and jobs. Top students are supported by university scholarships (these scholarships are decided upon by the corresponding Liberian university and RTI International personnel). A schematic of this student pipeline, and the programs developed and implemented by the UM CoE team is shown in Fig. 1.

The three educational intervention programs—Smart Start, Fast Start, and Summer Start—are intended for different school levels and durations. *Smart Start* is a one-day recruitment event for the other outreach programs (Fast Start and Summer Start), and was implemented in the second year of the EHELD program. In Smart Start, EHELD staff visit high schools with the objective to inform the students about the mission of the EHELD program and its other co-curricular programs, Fast Start and Summer Start. During this visit, students who are interested can sign up for further follow-up. The one-day event is also an opportunity to provide high school students with information about engineering and agriculture careers. Presentations by the EHELD staff give an overview of these careers, how they can overlap, and how they are critical to the future of Liberia. The goal of Smart Start is to spread the word about the EHELD program across all of Liberia and encourage interest in engineering and agriculture careers starting in high school. It is hoped that in future years, there will not be as great a need to visit every high school to discuss EHELD and its objectives, and rather, students will readily sign up for the programs on their own.

Fast Start consists of weeklong camps held at teaching institutes and agriculture campuses at five locations across Liberia. These camps were also implemented the second year of the EHELD program. Approximately 80 secondary students attended each camp, and about half of the participants were women. Participants were selected through the collaboration of the teachers and principals at the secondary schools, as well as Peace Corps volunteers serving at each school, with an emphasis on students who participated in the Smart Start event. The objectives for Fast Start are to: (i) introduce all students to the engineering and agriculture fields, their intersection, and potential careers in those fields; (ii) provide students with counseling and encouragement on the college application process; (iii) to improve the students' basic technical skills in computers, the scientific method, and the engineering design process; and most importantly (iv) to improve the students non-technical skills, including test-taking strategies, goal setting, job skills, and interpersonal relations.

The main program, *Summer Start*, is a four-week intensive residential program for university undergraduates. The objectives of the Summer Start program are three-fold: (i) to increase students' preparedness for the coming school year, (ii) to make students more knowledgeable and enthusias-

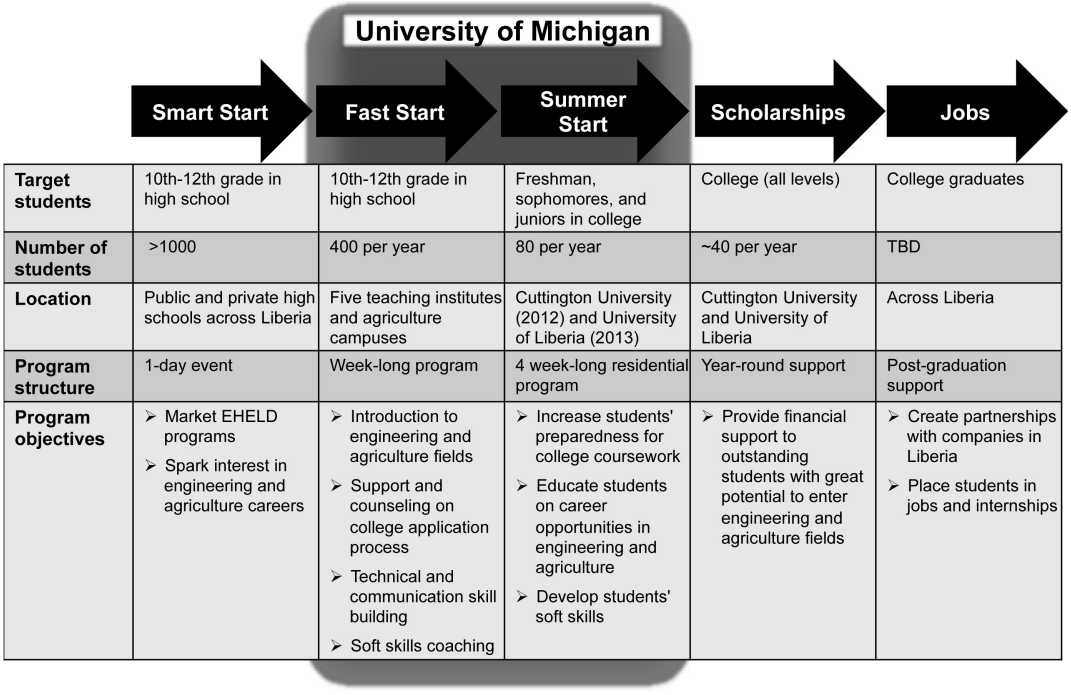

Fig. 1. Student pipeline implemented by the EHELD to place students in engineering and agriculture careers. The highlighted programs were developed and implemented by the University of Michigan team.

tic toward their career choices, and (iii) provide nontechnical skills vital to success in their future careers. The program participants consisted of eighty incoming university students split evenly between freshmen and sophomores; engineering and agriculture; and male and female students. The subsequent years of the program include returning students at the junior level. Furthermore, in each subsequent year, a group of approximately 12 undergraduate students from the University of Michigan also participate in the Summer Start program through their own faculty-led study abroad program with faculty from the UM CoE. The design of the Summer Start program was largely based on the M-STEM Academy at the UM CoE which uses the Meyerhoff Scholars Program model [12, 13]. The purpose of the M-STEM Academy is to groom and support a diverse set of engineering students at the UM CoE who might not normally be successful in pursuing a UM CoE degree for such reasons as socioeconomic class, first generation college student status, race, gender, or lack of high school rigor. Part of the M-STEM Academy is a summer high-school-to-college transition program to prepare them for their university experience.

2.2 Curriculum

At the core of Summer Start are *remedial courses*, which prepare students to succeed in their coming courses at the university; *labs*, which include computer and hands-on labs; and *life skills*, which develop the students' nontechnical (soft) skills. The program was created to give the students intensive preparation for their upcoming school year, while also providing them with experiences not currently available at their university. A breakdown of the programmatic components can be seen in Table 2.

A unique part of the Summer Start curriculum was the Life Skills course, which focused primarily on soft skills development. The course lessons included critical thinking, journaling, interview skills, presentation skills, interaction with faculty, study skills, group work, and community building. From the onset of the program students were taught to work as a team and to build a community. It was emphasized that succeeding as an individual would not be enough, just as the development of their country is dependent upon a community of active citizens working together. The students read the book *The Boy Who Harnessed the Wind: Creating Currents of Electricity and Hope* by and about William Kamkwamba, which was used to underscore the following: (i) agriculture and engineering overlap; (ii) education can be a tool to better the quality of life of people, communities, and countries; and (iii) youth can be proactive in using the resources around them to create solutions to local problems. Journaling throughout Life Skills allowed the students to reflect on those points, as well as their general experience at Summer Start, and develop and practice their writing skills with personalized feedback from instructors.

The curriculum at the Fast Start program was based upon the Summer Start curriculum. While Fast Start had less depth than Summer Start, it added much more breadth and reached many more students across Liberia. The Fast Start program included an exploratory lab and class, where students learned about and carried out experiments in the different fields of engineering and agriculture under the topics of food, water, and energy. Moreover, the exploratory lab highlighted the intersection of the two fields. For example, the students

Table 2. Summer Start curriculum components

Component	Objectives	Method
Remedial courses	Better prepare students for their coming university courses.	Botany class Physics class Math class English class
Life skills	Help students develop skills to succeed in school. Prepare students for jobs after college. Develop a sense of community amongst students.	Journaling Guest speakers Book discussion of "The Boy Who Harnessed the Wind" Group work Class presentations
Computer lab	Learn how to use a computer. Develop graphical communication skills. Gain experience using office software.	Google Sketchup OpenOffice Calc, Writer, and Impress Computer presentations
Hands-on lab	Build team work. Learn the design process. Practice construction skills. Communicate technical design.	Design competitions Written reports Final presentations

performed experiments and design projects simulating aquifer use and irrigation distribution; anaerobic digesters for gas production from animal waste; renewable energy from water, wind, or solar; and rainwater harvesting and purification.

Project-based labs at both Fast Start and Summer Start allowed students to develop their engineering and agriculture design skills and apply them through group projects. At Summer Start during the hands-on labs, engineering students learned engineering principles, design skills, and teamwork by designing popsicle-stick bridges and ground-level catapults. From these design labs, students were able to not only improve their technical ability, but also their presentation and communication skills. Agriculture students designed their own agriculture company with cash crops not currently produced on a mass-scale in Liberia. Students were required to use what they learned in computer lab to write up reports and develop presentations based on what they performed in hands-on lab. Students also created CAD drawings of their catapult and bridge designs using Google Sketchup. Presentations were made in front of the entire student body on the final day of the program.

All of the materials developed and used in the Fast Start and Summer Start programs were compiled into student and teacher manuals. These manuals were used to train non-UM CoE instructors at the programs. They are currently being published on Open.Michigan, the University of Michigan's open education initiative, and will be available for use by any interested parties to implement similar programs and/or curriculum.

2.3 Returning participants

In the second year of the Summer Start program, participants from the first year were invited to return and participate again in the program. These students partook in advanced core courses and life skills, as well as a combined computer and hands-on lab. In the combined lab, the returning students worked in three different teams on open-ended design projects. The projects included a drip irrigation system for a student farm at CU, a solar power system for the Engineering Building at UL, and a communal bio-sand filter for a local high school. These students were encouraged to create a proposal of their design that they could submit for funding from their university, the EHELD program, and/or a local NGO. Furthermore, students built a physical prototype of their technology for demonstration, and created CAD drawings of their final designs using Google Sketchup. In the coming year, returning students will continue to build on these designs and proposals, and hopefully begin implementing them when funding is secured.

3. Results

The EHELD student pipeline has only been in place for two years, thus, the full impact of both programs on student graduates will not be understood until the completion of the EHELD grant as the first participants begin to graduate. However, positive results are already apparent in student journals and student-led initiatives, particularly with respect to the university participants. Journals show that students' thoughts on their careers expanded to encompass entrepreneurial activities and moved beyond subsistence farming. Furthermore, students have strengthened their academic social network with their peers, and developed a nuanced view of their career and its subsequent importance to their country's development. Finally, participants have begun working with local communities on engineering and agriculture projects.

3.1 General results

Both years at Summer Start, students were provided with a post-program assessment by the UM CoE instructors to gain insight on their thoughts of the program. This post-program assessment was developed based on similar post-program assessments distributed to M-STEM Academy students [12]. The results of the UM CoE assessment are shown in Fig. 2.

The UM CoE assessment shows that more than 93% of student respondents considered the program successful in achieving its overall objectives. More than 90% of the students agreed or highly agreed with the assertion that the program improved their general problem-solving skills. The students felt that the program allowed them to learn what it is like to work in a community to achieve a common goal, and that their capacity to work in groups was improved. About 89% of them agreed or highly agreed that their computer, studying, math, and engineering skills were improved. All respondents felt that their oral and written communication skills were improved. Finally, more than 94% of the respondents agreed or highly agreed with the assertion that the program taught them what it is like to study science and engineering in college.

Due to the variety of stakeholders and the highly subjective nature of the skills that are being taught in the program, an objective assessment of Summer Start was difficult to establish. There most likely exists some bias in the assessment results as the assessment questionnaire was developed and distributed by the Summer Start instructors on the final day of the program. Furthermore, we believe that some of the students had difficulty with the Likert-scale questions used in the assessment because they were not familiar with it. It would be worthwhile to

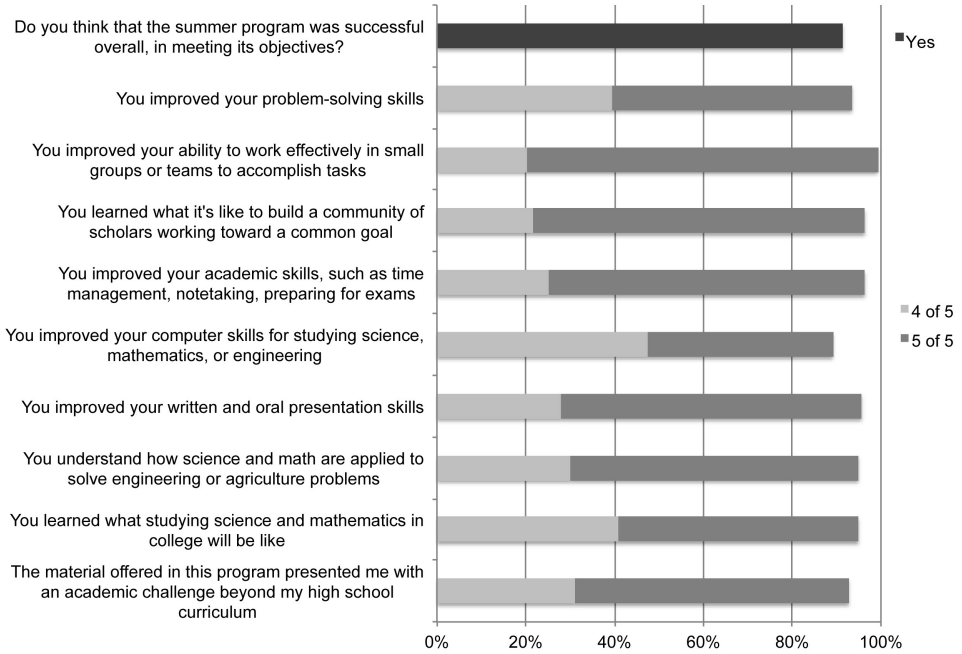

Fig. 2. Results from students of post-program assessment for first two years of Summer Start program.

develop a better instrument to measure the impact of the program while minimizing potential bias. For example, an instrument that uses a basis of measurement other than the Likert-scale, as well as an instrument that can be distributed well before and after Summer Start without program instructors present. Also, as the program moves forward, grades and overall performance at their respective universities of students who participated in EHELD can be monitored to develop a better understanding of the program's longitudinal influence on the participants.

3.2 Themes from student journals

Qualitative data has been important for analyzing the impact of the programs on the participants. Some of the main feedback mechanisms in the program came from student journal entries. Each student was provided with a notebook where they were asked to journal about their experience in the program. At different points the instructors asked the students to journal about specific topics such as their favorite learning experience, main takeaways from the program, thoughts on their career, etc. Significant themes emerged from the results of these journaling exercises: engineering students began to see the versatility their degree could provide, agriculture students began to see their career as more than just subsistence farming, all students began to see how their careers can benefit their communities and country, female students identified role models, and all students strengthened their academic support network.

Engineering students began to see other possibilities a degree in engineering could yield beyond just obtaining a job at existing companies upon graduation. Some students began to realize that they could start their own businesses, conduct consultancies, and work collaboratively with agriculturalists in designing better processes for their country.

> "I grew up with the notion of looking for job upon my graduation as engineer, but this program had revealed that engineers have the capacity to be self-employed and [to] employ others."

> "I have been made to understand that every engineer connects one to the other, whether geology, civil, mining, electrical, etc., and even agriculture. We all can work together as a team to build our country Liberia."

It was surprising to see the number of agriculture students who initially believed their degree would only train them to be subsistence farmers. Attitudes shifted toward believing that their degree in agriculture could lead them to be a significant part of Liberia's economy and development. Some of the students became aware of opportunities to start businesses, utilize agriculture for medicinal production, and even develop energy alternatives through agriculture.

> "I thought becoming an agriculturalist was just to grow more food to meet the hunger needs of the majority of hungry citizens. I have learned so many good things at Summer Start which I am going to apply to my everyday life."

> "The Summer Start program has made me realize that there is more to agriculture that what I thought. In my country most people see agriculture as just making a

backyard garden and rearing a small amount of domestic animals which we thought that anyone can do. With the huge knowledge I have gotten from this program and have heard visiting professors speak on different topics relating agriculture. Professor Simon spoke to us about medicinal plants [which] is also a branch of agriculture and how the world depends on agriculture for so many things like food, clothing, shelter, drugs.

I know now that I'm very much important to the world because the world needs me to provide all these important [things] to survive.''

''However, since the Summer Start, I have realized that agriculture is not just about making [a] farm to feed your household, but it is a field of complexity. I have concluded that this wonderful area of study may have been responsible for man's survival on planet earth for the past billions of years and the rest to come.''

Students not only learned how to be successful in the fields of engineering and agriculture, but the significance of their fields and the corresponding potential to benefit their community and country.

''I don't see my career as just a career anymore, but as something that is very important to the world and also as very challenging, so I need to be very prepared in order to meet up with the task out there.''

''The Summer Start program has helped me to become more passionate about the people in my community and the country at large. As a student of mining engineering I see myself creating things that would benefit my community. It makes me love my career and I see engineers as living engines to power the economy of a nation.''

''This program has also made me to visualize my career in the real world and with that I can't wait to start opening my own mineral industry. I've developed the ideas of building my country in the next 5 years. But I will first start with my community. Not only the idea of having my own mineral industries but also the ideas of building infrastructure for my country.''

''Another aspect that changed my attitude about my career is the story about the boy who harnessed the wind. William Kamkwamba who refused to let go of his dream. A story that shows that big change can start small. With this, I have confidence that I can make a great change in family, community and even be a good example that others will follow.''

For the female students, the program provided them with role models, as well as introduced them to other female students in their field.

''As a middle age woman, I have been thinking that it was useless to enter college. Since the program began, I have courage when I meet students of my age range. What changed my attitude about career are the different kind of activities within the program. Especially the different lecture or speakers that share the experiences about how they became successful. Above all, the first speaker who explained his struggle during school days. This means that I can be successful if I am determined, focused, willing to learn and honest.''

''By seeing a lady as an engineer and not BSC but PHD really encourages me and changed my attitude positively and increased my drive for being an engineer.''

Finally, students were able to improve their interpersonal skills and develop their academic social network with fellow participants.

''Socially, this program has made me meet many friends from diverse fields which is very great. This interaction allows you to adjust to group work or study, loving your friend and guiding them through trouble. This interaction also help's in the future when you shall have met, and this friend could be very helpful.''

''One of the classes I love to attend is the life skills class in that it has taught me things I didn't know about myself. This program has also build up my skills, take away my shyness and make me to interact with others including my professors. Where would I be if it wasn't for this program or how was I going to start college without knowing much about my career.

I would love to be invited back for this program because it has transformed my life and made me a new person. Since I came here, I've learned a lot of things both physically and mentally and [am] wanting to learn more. This program has taught me more about interpersonal relationships. From my high school days, it was always me alone. I never had a friend or worked in groups. So due to this my interpersonal relationships [were] very poor. But it all changed from the very first day I came here. If it wasn't for this program, how was I going to make it in college with my poor interactions. I know when I leave my life won't be the same again.''

3.3 Projects with returning students

The proposals, prototypes, and implementation plans for the returning student projects represent several tangible results of the program. These deliverables showcase the accomplishments of the students in developing communication skills, teamwork, hands-on skills, and technical skills. The second year of the Summer Start program, three returning student teams developed proposals. One team implemented their project, one team built a prototype, and the third team delivered a proposal for future consideration. All teams delivered presentations and final written reports.

The first team worked on the development of an irrigation system for a nearby farm. They were given a short tutorial to use the free software, EPAnet, which allows the easy design of water distribution systems. A UM CoE professor provided technical support to learn the software. Using this software the students were able to specify the pipe, pump, and storage needs of the farm. With the help from other students and staff, this team was able to implement the design at the farm. The farm now has irrigation capabilities. In the future, this team hopes to implement a similar system at CU.

A second team worked on a drinking water project. This team investigated the possibility of using point-of-use biosand filters for water disinfection. The team built a prototype biosand filter, which they demonstrated to their classmates by

filtering the water from the dormitories. The students worked alongside a Peace Corp volunteer and wrote a funding proposal to use biosand filters in the Peace Corps volunteer's high school. Their proposal would use the filter to bottle clean water for the students at the school and sell excess drinking water to subsidize school fees. This project allowed the students to see how their skills can make immediate impacts in their life. It also allowed them to explore the business aspect of a project and how to work towards making a project financially and socially beneficial. The students were also able to experience hands-on practices as they built their own biosand filter prototype.

The final team of returning students worked on the energy infrastructure of the Engineering Building at UL. The campus currently runs large diesel generators at very high costs to obtain their electricity. The students did research on the options for solar and wind power in their campus to supplement the electricity generation, and were able to interview suppliers, teachers, and staff who work in the renewable energy sector. The students were able to see first-hand how to conduct a research project to provide alternatives to decision makers, and what many of the limitations and tradeoffs to these alternatives may be.

4. Future issues

The future success of the programs is dependent upon local adoption of the programs, and will be the major focus of the UM CoE team in the final years of the EHELD program. Throughout the first couple years of the programs, strategic partnerships were made with the Peace Corps, Liberian Teacher Training Institutes, and private companies in Liberia to ensure the continuation of the Fast Start programs. Through these partnerships, and thanks to the availability of the student/teacher manuals previously described, much optimism exists that the Fast Start programs will continue.

Of much larger concern is the continuation of the Summer Start program at the universities. As mentioned in the introduction, the higher education systems in Liberia must overcome many obstacles in the coming years. While the EHELD program will help with much of the infrastructure, technological, and personnel deficiencies at the two universities, it is unclear if the changes at the university will be enough to ensure successful turnover of the Summer Start program from the UM CoE to the Liberian universities.

Furthermore, the operating costs for teachers and students to attend the programs will need to be covered by parties other than the students. Students may contribute modestly to the cost of the program but it is not expected that they can cover the cost of running the program in full. Thus, funding must come from either the universities or private enterprises. Some options the UM CoE and the EHELD program are pursuing include private enterprises such as Firestone, Liberia Agricultural Company, and APM Terminals. These organizations must be convinced that sponsoring these programs is a worthwhile investment for producing a pool of highly qualified graduates from which they can later recruit to work at their companies.

5. Conclusions

After only two years of implementation, the University of Michigan components of the EHELD student pipeline have reached over 500 secondary and university-level Liberian students. It has been shown that the student participants in Summer Start believe the project has accomplished its goals and significantly increased their capacity in both technical and soft skills. The level of student satisfaction demonstrates that the programs are providing engaging and enriching experiences for students. However, a longitudinal study of the participants would be required to provide a more comprehensive understanding of the benefits these students have received.

Fast Start was able to reach a geographically diverse set of students across the country of Liberia. Top students were recognized after participating in the Fast Start program, and will be encouraged to apply to either Cuttington University of the University of Liberia for their post-secondary education, and further encouraged to participate in the Summer Start program prior to enrollment.

Summer Start was able to fill educational voids in students' K-12 and post-secondary education. By integrating the development of both technical and nontechnical skills within the Summer Start components, it enabled students to accelerate overcoming these gaps and become better prepared for their university courses. Prior to Summer Start, many students never had access to functioning laboratories or computers. The classes at Summer Start built upon each other; for example, skills learned in computer lab were used to prepare presentations on projects developed in the hands-on lab; measurements taken in introductory labs were used to gain skills with spreadsheets also in computer lab; and design skills developed in the hands-on lab were turned into class presentations in life skills.

Furthermore, Summer Start placed emphasis on teamwork, solving open-ended problems, and being able to design and implement solutions to relatively complex problems. First year participants demonstrated their ability to work on open-ended pro-

blems with significant guidance from the instructors. Returning students, however, demonstrated an ability to work on open-ended problems independently, and created technically sound designs and prototypes. Additionally, they showed initiative by using their newly developed skills in community-based projects.

The logistical success of the implementation of these programs was in large part due to the combination of strategic partnerships between U.S. universities, private companies in Liberia, Liberian teacher training institutes, Liberian public high schools, the Peace Corps, and Liberian universities. For these programs to continue to succeed, these same partnerships must be maintained, and new partnerships must be fostered, such as with private engineering and agriculture companies. These future partnerships will be the focus of the final years of the EHELD program as the student pipeline will soon be turned over to the Liberian universities and secondary schools.

Altogether, the students have expanded their initial, limited understanding of careers in engineering and agriculture to include an expanded set of possibilities. Already, many of the students are more aware of entrepreneurial potential and their personal ability to create economic opportunities within their respective careers. Of significant importance is the emergent theme in the student journals of their desire and belief to support their own communities through engineering and agriculture development efforts.

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