International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

Multi-University Partnership for Global Service Learning in Sub-Saharan Africa

Jeffrey Seay
Associate Professor
Chemical and Materials Engineering
University of Kentucky
jeffrey.seay@uky.edu

John Lumkes
Associate Professor
Agricultural and Biological Engineering
Purdue University
lumkes@purdue.edu

Abstract **- The African Center for Renewable Energy and Sustainable Technology (ACREST) is an NGO located in Bangang, Cameroon. ACREST has partnered with the University of Kentucky and Purdue University in a joint service learning and engineering program to design and build a low cost, diesel powered Multi-Purpose Utility Vehicle (MPV) and a small-scale biodiesel production plant to generate the fuel needed to operate the vehicle. Students from the University of Kentucky and Purdue University have worked alongside technicians from ACREST to implement these two integrated projects. Lessons learned as well as best practices from the development of service learning in engineering programs for undergraduates will also be presented.**

Index Terms - Appropriate technology, Basic Utility Vehicle, Affordable transportation, Biodiesel, Sustainability

INTRODUCTION

Engineers, regardless of discipline, are trained to find solutions to problems[1]. Unfortunately, the tools and methods we often use require years of study to master, as evidenced by the rigorous curriculum at all undergraduate engineering programs. This often means that students are not free to explore their creativity until late in their undergraduate careers – usually in a capstone design project – and as a result are unable to see how their curriculum impacts real-world challenges. In many parts of the world, creative solutions to everyday problems of public health, access to clean drinking water, transportation, cooking and utilization of clean energy are in short supply. Addressing these problems by engaging students during their coursework provides opportunities for students to see practical applications of fundamental engineering principles and motivation to master more difficult engineering concepts. Although in most cases the engineering curriculum does a good job of teaching fundamental engineering concepts, creative thinking and a problem-solving mindset are skills students must often learn outside the classroom through internships, co-ops or research experiences. Furthermore, the belief that technology alone, independent of societal considerations, can solve the problems faced by humanity is shortsighted[2]. Through the incorporation of global service learning, students are able to not only develop their creativity and problem solving skills, but also, through interaction with local communities, make substantive contributions towards solutions to problems facing underdeveloped or rural communities.

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

The difficulty however, is that it can be challenging to find local stakeholders in underdeveloped communities to serve as partners for global service learning projects. This contribution will describe the establishment of a long standing partnership among the University of Kentucky (UK), Purdue University and the African Center for Renewable Energy and Sustainable Technology (ACREST) to design and build a low cost Multi-Purpose Utility Vehicle (MPV) for use by ACREST and local villagers, a process for converting locally produced non-edible vegetable oils into biodiesel to power the MPV, as well as an electricity generator on the ACREST site. The approaches taken by the UK and Purdue to integrate global service learning into both curricular and extracurricular activities will be described and lessons learned from both universities will also be discussed. Furthermore, the benefits, not only for ACREST, but also for the students involved will be described and assessed.

PARTNERSHIP BETWEEN ACREST AND US UNIVERSITIES

ACREST is a non-governmental organization (NGO) located in Bangang Village in the sub-Saharan African nation of Cameroon[3]. Since its inception, ACREST has been focused on the application of appropriate technology (AT) to develop and disseminate sustainable and renewable energy based products that benefit the economy, environment and society in rural sub-Saharan Africa. ACREST exists to promote information, education and to provide access to knowledge that can promote health, wellbeing and a higher standard of living throughout Africa. ACREST products such as biosand filters, charcoal and biochar produced from agricultural waste and clean cook stoves which are locally produced by ACREST technicians and have been widely adopted throughout the region. ACREST has worked with numerous universities since its founding in 2005. In the cases of UK and Purdue, not only has this partnership has led to a long term opportunity for undergraduates to engage in service learning activities, but it has allowed the students to experience how projects have developed over time and how the effected communities benefit from the partnership.

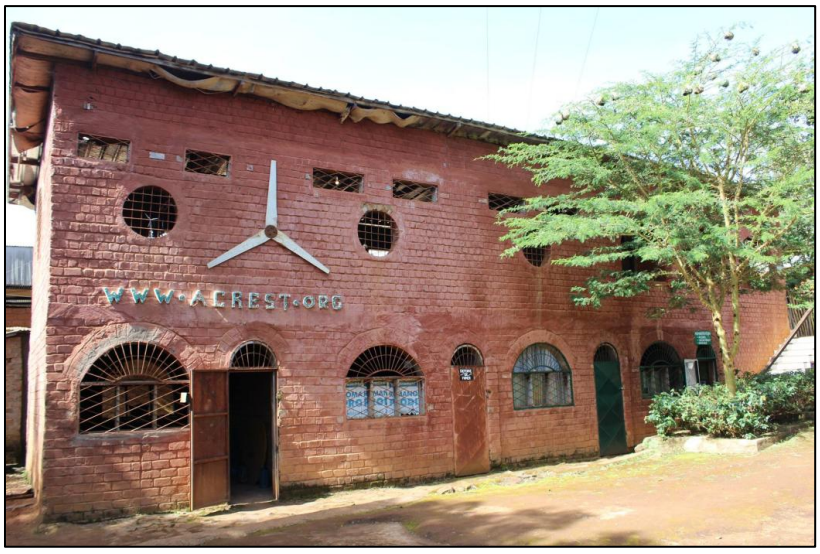

FIGURE 1
ACREST WORKSHOP AND TRAINING FACILITY IN BANGANG VILLAGE, CAMEROON

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

PROGRAM BACKGROUND

Description of Current University of Kentucky Program

Curricular

Global Service Learning in Engineering is a multidisciplinary elective course offered in the College of Engineering (EGR 390) at UK. This course is available to instructors who wish to offer an international service learning experience to engineering students. A travel component is not required – the specifics of the course are left to the discretion of the course instructor. Although not required for graduation, Global Service Learning in Engineering can be counted as a technical elective for fulfilling degree requirements in any discipline of engineering. The course described herein is aligned with the objectives of the UK Appropriate Technology and Sustainability (UKATS) research group. UKATS is an undergraduate research group focused on the application of engineering principles to solve energy and sustainability problems in rural or underdeveloped regions around the world. All students enrolled in this EGR 390 course section are also a part of the UKATS research group.

The course offering described here includes an embedded study abroad component. The embedded program model allows the course instructor to include a travel component into any class where it is useful to meet the course objectives[3]. For this course, travel to the ACREST facility in Cameroon was included as the embedded travel component. The travel component was a requirement for the course and counted for one-third of the course grade. Students were made aware of this requirement, as well as the program costs before being allowed to enroll in this section of EGR 390. The course is marketed through the Education Abroad office, as well as via the online course catalog for the College of Engineering. The principle benefit of the embedded program model is that the participating students have the opportunity to spend time at the university learning not only about the technical aspects of their project but also about the culture of the region. This allows the students to be better prepared for travel and eases some of the culture shock they may otherwise experience. This is a key lesson learned from this project.

The organization of this 3-hour course is as follows: 1 credit hour of lecture, 1 credit hour of lab time to be used developing the project and 1 credit hour for the embedded travel component, where the students implement their projects. The travel component consisted of 2 full weeks at the ACREST facility, plus travel there and back. As will be further described, the projects undertaken by the UK students involved the development of a low-cost processor for producing biodiesel, soap and biochar from locally available resources. The Spring 2014 offering was the second time a course, based on a collaborative project between UK and ACREST has been offered[3]. The project was essentially a continuation of the original project begun in 2012[3]. To date, the global service learning course with the embedded travel component has been offered every other year, with students who are interested continuing to be involved with the project on an extracurricular basis on the off years.

Extracurricular

In addition to participation during non-travel years, some students are interested in participating in these research projects, but for personal reasons do not wish to, or are unable to travel. Students are permitted to work with the UKATS team on a volunteer basis without the

requirement to travel. This broadens the scope of participation and the potential impacts of the program. Although it is impossible to get a full appreciation of life in an underdeveloped region without traveling, it is important that students who are unable to travel be able to participate if they choose.

Description of Current Purdue University Program

Curricular

Global Development opportunities at Purdue are available to students through several different channels. For engineering students, most participate through the Global Engineering Program (GEP) on Global Design Teams (GDT) or Global Engineering Projects in Community Service (EPICS). GDT students can sign up for GEP courses with variable credit and course levels (100-500 level; freshmen through graduate school). Beginning in 2008, GEP has partnered with NGOs, universities, and foundations in Cameroon, Columbia, Ecuador, Ghana, India, Jordan, Kenya, Lebanon, Palestine, and Tanzania. A typical scenario is to facility interaction between a Purdue faculty member and the international partner to define the scope and objectives for each project. A Global Design Team (GDT) Expo is held in the Fall (October) where students can apply for the different projects. GEP staff and faculty then review the student qualifications, application letter, and their project preferences to choose the students for each team. Students that are not selected are notified of the decision with a strong encouragement to apply again next year. For the students accepted to participate in GDT projects, they begin meetings with the faculty advisors in preparation for the primary course credit in the Spring Semester. During the Spring semester the students have regular meetings, correspondence with the international partner, and work on their design challenge. The travel portion for each GDT is optional and typically occurs during the summer, depending on the team and location.

A new 1-credit requirement was added Spring 2014 for each GDT student. To develop cross-cultural design and communication skills, the course requires students to participate in a variety of enrichment events (i.e. invited speakers, movies, etc.), keep a design journal with answers to reflective questions, and attend several workshops organized by GEP. The design journals and various design reports are collected by GEP for further assessment[4].

Project types vary but generally are focused on low-cost scalable technologies around energy, food, water, health, labor-saving technologies, and education[5]. In Cameroon, projects have included a multipurpose utility vehicle, hydroelectric, biomass fuel briquettes, and wind power[6,7]. There is generally a strong correlation between a faculty's research area and the GDT project, with faculty from Agricultural and Biological, Biomedical, Building and Construction Management, Civil, and Mechanical Engineering frequently involved. Engineering faculty may also partner with faculty from other colleges such as agriculture, technology, and liberal arts. Students reflect this diverse background as well, and it is not uncommon to have anthropology, agriculture, and technology students on the GDTs and participate in the travel portion.

Most projects are multi-year and it is important in many projects to begin with more than a single-year perspective. When the faculty, international partners, and students have a longer term viewpoint the projects have time to become successful and expectations are more realistically managed. Students generally participate over multiple years if they begin earlier in their academic standing. A group of students elect to participate only during their senior year where

the project fulfills their capstone design requirement. Since 2012 about 70 students participate each year and approximately 20-25 travel each year.

As faculty and staff in GEP gain experience, the program is continually improved and adjustments are made to the structure and requirements (i.e. the one-credit required class described above). Both faculty and students become more aware of different funding sources, the importance of a multi-year view with a committed partner, the value and necessity of including other disciplines (including social sciences), and the importance of thinking entrepreneurially during the design process.

Purdue's Engineering Projects in Community Service (EPICS) has more recently added international service learning projects in Columbia, Ghana, Haiti and India. EPICS also offers variable credit and variable level courses with most projects focused on local community organizations[8]. Also, some faculty members choose to work through their individual department and offer capstone design, independent research, or technical elective credits for international projects. These projects are usually the result of an existing relationship that the faculty member has with an international partner. Participation numbers and assessment varies in each project.

Extracurricular

Some students elect to participate through organizations like Engineers without Borders, which has a chapter at Purdue. GEP has provided logistical support for EWB student teams, and some EWB teams have received credit through the methods described above, depending on the faculty's willingness to offer an independent study or capstone project. It is possible for EWB students to propose their project as a GDT or EPICS offering.

Partnership between Universities

Because of the linkage between the MPV and biodiesel projects, there is natural partnership between Purdue and UK. The Purdue Utility Project (PUP) launched the partnership with ACREST. Once the vehicle platform (MPV) portion of the project had been established, ACREST reached out to UK to develop the biodiesel production project. Since the MPV in Cameroon utilizes a small diesel engine with a simple mechanical injection system, and only operates in a tropical climate, the MPV is a great candidate to use local biofuels without stringent filtering or anti-gel additive requirements. Relying on fossil fuels and being dependent on fuel availability is a concern for rural areas where the MPV is designed to operate. With UK's experience in biofuel production using locally available input sources the potential by working together with ACREST is significant. The MPV becomes less dependent on local availability of fossil fuels and ACREST has the potential of both lower operating costs for their MPVs and possible future income streams if there is excess biofuel produced.

The multi-university partnership has allowed the original MPV project to grow and expand beyond the original scope to include not only the vehicle but also the fuel. The key to this partnership is ACREST, the driving force behind establishing this partnership. A key learning from this experience is the importance of having an engaged in-country partner. This ensures that the projects are meeting the needs of the local community. In the authors' experience, service learning in engineering should be focused on the community as well as the technical problem solving. The ability to maintain a long term project is only possible with a committed in-country partner, like ACREST.

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

Finally, since travel is an integral part of the projects describe herein, sufficient funding is required. Both Purdue (hydropower) and UK (biodiesel) have received funding through the US EPA's People, Prosperity and the Planet Student Design Competition program. Both programs have been a part of the National Sustainable Design Expo, held annually in Washington, DC.

LOGISTICS

Each year, 8 – 10 students have been involved from UK and 10-30 students (8-12 typically travel) have been involved from Purdue. From UK, all of the participating students have come from either chemical or mechanical engineering. Purdue engineering students have represented majors in agricultural, biological, civil, electrical, industrial, materials, and mechanical engineering; and students from agronomy, agricultural systems management, anthropology, and mechanical engineering technology have also participated. The biggest expense for the program is the cost of airfare from the U.S. to Cameroon. The cost of room and board at the ACREST facility as well as in-country travel is less. Other expenses required of students include vaccinations, passport application fee for those who don't already have one, visa application and university required traveler's health insurance. Because the UK program is organized using the embedded program study abroad model, students are eligible to apply for a $500 scholarship to offset some of the travel costs. The UK group also participates in fundraising via external donors to help cover the remaining costs. When all funding sources are included, approximately 90% of the total student travel costs are covered.

At Purdue the GDT teams that travel utilize a variety of funding models, depending on faculty preferences, success writing grants, and external support raised by GEP. Most students cover a portion of their travel costs (between $500-$1000, plus all shots, visas, etc.). GEP provides funds to offset the cost, and students can apply for travel grants both internal to Purdue and from external funding sources to further reduce their cost. GEP notifies students of various grant opportunities and offers to provide feedback on grant applications before they are submitted by the students. The Cameroon teams, beginning in 2014, followed a short-term Study Abroad model with the benefit of standard travel and approval procedures, the ability for the students to receive course credit for traveling, and access to university study abroad scholarships.

COMMUNITY ENGAGEMENT

As previously described, by working with an established NGO like ACREST, the students from Purdue and UK are able to more effectively engage with the community. ACREST has worked hard to prepare for the students, represent the community and manage local expectations, and provide a diverse set of student experiences. Students are included in local cultural events and have the opportunity to visit local schools and churches to further interact with the community. Although Cameroon has both English and French as official languages, the area around the ACREST facility is predominantly French speaking. Many of the ACREST staff speak English, but much of the communication with the local villagers is done through a translator, making communication sometimes difficult.

Despite these difficulties, ACREST has taken an active role in ensuring that the university students engage with the local community. This includes visiting local community leaders and participating in local cultural events. As a good will gesture, during each visit to the ACREST

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

facility, both UK and Purdue students have brought school supplies and textbooks to donate to local schools. These efforts have been reported by local media, raising the profile of the student activities. Additionally, the scheduling of the travel in the late spring coincides with the National Day celebrations in Cameroon. The visiting students have been invited each year to participate in the local National Day parade. Being invited to participate is an indication of how well the student groups have been appreciated by the locals. This goodwill between the student groups and the local authorities has added to the success of the projects. Engaging the local community through personal interaction and goodwill gestures is important to building the strong relationships necessary for a successful multiyear project.

PROGRAM ISSUES

One of the critical issues involving conducting student research experiences in sub-Saharan Africa is the ongoing political and public health issues in the region. Political instability in the region, coupled with a U.S. State Department travel advisory to certain regions of Cameroon[9], have hampered travel. Not only do these programs place students and faculty under higher risk than would perhaps be experienced in other regions, the presence of U.S. students places an added burden on the host organization – ACREST in this case – to ensure security.

Despite these potential risks, the general reception to the program at both UK and Purdue has been overwhelmingly positive. Projects like the MPV and Biodiesel projects allow students to engage in fundamental problem solving and apply coursework to practical and challenging problems. The authors view this kind of learning as essential to the development of engineers. These projects foster creativity due to the numerous economic and technological constraints placed on the designs by the fact that they are to be implemented in a rural, underdeveloped region. Additionally, there is a built-in societal aspect to service learning projects. Because there is a community of people who will directly benefit from these projects, there is an extra sense of responsibility placed on the students. Not only must they meet the technical objectives of the projects, but they must meet the needs of the community as well.

In addition to the project results themselves, international service learning projects are well received at national and international professional and student conferences. These conferences give the students the opportunity to share their research experiences and engage with other students with similar interests. UK students have presented their research work conferences such as the American Institute of Chemical Engineers Annual Student Conference, the International Congress of Sustainability Science and Engineering, the International Conference on Sustainable Product and Process Design and the Foundations of Computer Aided Process Design Conference. Additionally, UKATS students have had to the chance to publish their work in peer reviewed conference proceedings[10,11,12]. Likewise, Purdue has been able to publish their work in various journals, proceedings, and magazines—in some cases by the students[13]; have had numerous articles and television coverage in the local media; displayed their projects at the State Fair and at outreach events around the state; participated in the Clinton Global Initiative; and participated in several entrepreneurial competitions. Being able to include these types of experiences on a resume is important to students as they apply for jobs or graduate school. Presentations and publications illustrate the students' ability to communicate effectively in written and verbal form. Finally, international travel experience is often attractive to potential

employers who are increasing looking to hire graduates who can operate effectively in a global economy.

CASE STUDIES

Low-cost Biodiesel Production

The project undertaken by the UKATS research group involved the development of a low-cost processor for the production of biodiesel from locally available resources. The constraints placed on the project were that the processor contain no moving parts, be constructed of locally available materials such as used oil drums, scrap metal and used car parts, and make no utilization of electricity or automated controls. An initial design was proposed by the UKATS research team in preparation for the first visit to ACREST in 2012[14]. However, following this first visit, several design changes were implemented based on the experience of trying to operate the original prototype in Cameroon, (see Figure 2).

Although the technical details are beyond the scope of this contribution, the need for a modified design was only clear to the student team after having visited the ACREST facility and spent time working side-by-side with the ACREST technicians. This is an indication of the type of learning that occurs during a service learning project in another country. The initial visit to Cameroon dispelled many misconceptions held by the group. Only by engaging with the community and learning how the technology would be operated could an appropriate design be achieved. The second trip to the ACREST facility yielded a technologically acceptable result. The 2nd generation process met all the technical requirements for producing biodiesel, as well as the constraints imposed by working in a rural, underdeveloped region.

Despite the technical success of the process, one of the key remaining challenges, however, is the cost of producing biodiesel at the ACREST facility. Pure virgin vegetable oil, particularly palm oil, is a staple of the local diet. Therefore, not only does its use as a fuel compete with the local food supply, but it is often more expensive than petrodiesel – making palm oil biodiesel an unsustainable option. Therefore, the UKATS team, pictured in Figure 3, will continue researching locally available, non-edible oils like castor and jatropha that will be more socially and economically sustainable. Additionally, based on the positive outcome in Cameroon, the team will be traveling to India in the summer of 2015 to begin implementation of a similar project with an NGO in the Indian state of Tamil Nadu.

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

FIGURE 2
2ND GENERATION UKATS BIODIESEL PROCESSOR

Finally, one fundamental problem with multiyear projects at the undergraduate level is ensuring that knowledge and experience is maintained from year to year as upper division students graduate and new students join the project team. This is addressed by the UKATS research group by allowing students to get involved with the project during the freshman year. As upper division students graduate and move on, the younger students who have been involved for a one or more years are available to step into leadership roles. Although freshmen may often lack the technical experience for many types of research experiences, projects aligned with appropriate technology are as much reliant on creativity as technical experience. Because of this, students in their freshman or sophomore years are often able to make substantive contributions.

FIGURE 3
UKATS TEAM WITH ACREST INTERNS, BANGANG VILLAGE, CAMEROON

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

Multi-Purpose Utility Vehicle (MPV)

Purdue's partnership with ACREST started with a basic utility vehicle (BUV) project in 2008, and traveling to Cameroon 2009. At that time ACREST had purchased a BUV from the Institute for Affordable Transportation and wished to have several design modifications done the vehicle, primarily with the goal of making it a 100% locally manufactured vehicle and not relying on imported parts. After the first visit in May 2009 the team generated a list of potential projects, including the utility vehicle, hydroelectric power generation, wind power, biomass fuel briquettes, and agricultural mechanization (water pumping, food processing, tillage, etc.). Several of these projects have been highlighted in previous publications[6,13]. The hydroelectric project successfully received an EPA-P3 phase I and phase II grant and is continuing, along with the utility vehicle and agricultural mechanization projects, while the other projects are finished. The utility vehicle project will be used for the case study in this section.

After the initial visit in 2009 and through discussions with partners, the design challenge was refined with the goal to develop a 100% locally manufactured multi-purpose utilities vehicle (MPV) for rural communities like Bangang. The multi-purpose aspect (water pumping, maize grinding, portable electricity generation, etc.) was important since each function provided additional value with minimum extra cost, improving the value proposition for long-term sustainability. Since the single most expensive component is the 6-8kW diesel engine ($500-$650), being able to use it to fulfill multiple functions in addition to transportation significantly improves the return on investment for end users.

Reflecting on the project successes and failures in the first few years, it is clear that without a multi-year commitment this project would not have been successful. The first vehicle designed (2010) utilized wood for nearly everything, since wood was common in Cameroon. Although a prototype was built it did not last the year between visits, and through conference calls with our partner, a different approach was taken. If the partnership did not have a long term viewpoint, both parties might have decided to end the project at this point, However, with guidance from local staff in Cameroon, a new vehicle was designed with a 3-speed belt transmission (no reverse) and a truss frame using 'commonly' available square metal tubing[7]. Again, problems arose since upon arriving in Cameroon (2011), no tubing of this size could be found in the area markets. With the team splitting up into 'redesign' and build groups, one group of students modified drawings trying to keep ahead of the students building the chassis. A lot was learned about problem solving, flexibility, and creativity, and at the end of the trip the team managed to have an operating vehicle; and the vehicle was built using locally available materials. One decision during the trip proved especially valuable: every time someone goes shopping in the local market, that person needs to take a camera and notepad and document the types of material available for future projects. This information became instrumental the following year and the library of parts and materials is appended to each year.

During the next year (3rd year of the project), while corresponding with ACREST, feedback was provided that the truss frame was working very well, but more speeds and a reverse gear, along with suspension on all three wheels, would be beneficial. This lead to the first prototype of the current platform that incorporates a recycled automotive transmission with 4 or 5 forward speeds and reverse, and a recycled front strut to provide both suspension and braking on the front wheel. Also, a power takeoff (PTO) shaft was added for powering attachments like a water pump, and the entire chassis was designed to use a very common size of angle iron

(30x30x3mm). A major milestone was reached in 2012 when the team arrived in Cameroon to build the prototype with ACREST: due to a recent rain the taxis were not able to reach the village, but ACREST was able to drive the MPV from the previous year to meet the students, and all the luggage and students were transported back to the village.

In 2013 and 2014 the basic platform remained the same with many small improvements made each year. Most design modifications simplified manufacturing, reduced the cost, improved performance, and increased the safety (noise emissions, lower center of gravity, ergonomics, etc.). The 2012 and 2014 Purdue vehicles are shown in Figure 4, and example applications are shown in Figure 5.

FIGURE 4
VEHICLES BUILT BY THE PURDUE TEAM

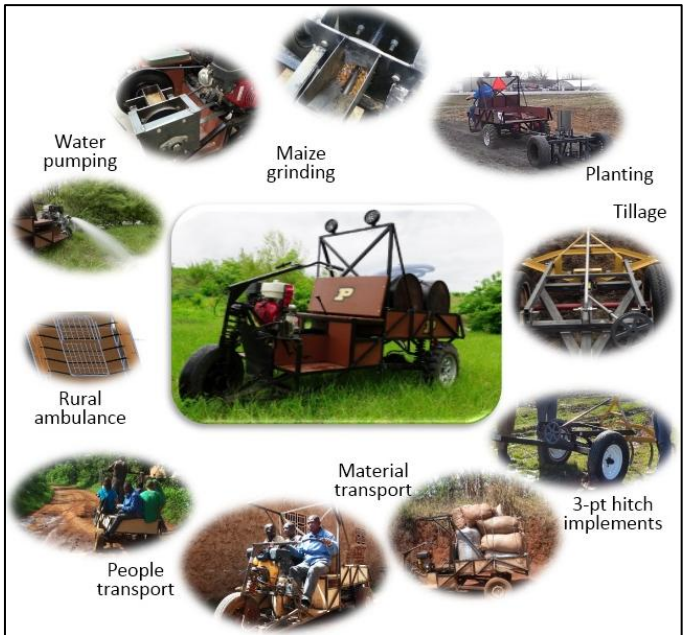

FIGURE 5
EXAMPLE APPLICATION OF THE PURDUE MPV

International Journal for Service Learning in Engineering
Special Edition, pp. 367–380, Fall 2014
ISSN 1555-9033

Many lessons have been learned since beginning this project. Of primary importance is an engaged partner who is mutually invested and able to have a longer term view. As previously described, without an engaged in-country partner, getting the vehicle built would have been much more difficult. The in-country partner provides credibility with the local community and is essential in locating difficult to find resources. The first two years of this project consisted of a steep learning curve and more failures than successes. This is typical for projects in developing regions due to the lack of well-developed infrastructures and supply chains and again underscores the need for an engaged in-country partner. The team, pictured in Figure 6, also formed an extracurricular unofficial club, the Purdue Utility Project (PUP), which helped with team building, continuity, writing grants, identity, etc. A project website was also started, initially as a way to share results with project alumni and partners (https://engineering.purdue.edu/pup/).

FIGURE 6
PURDUE TEAM WITH ACREST INTERNS, BANGANG VILLAGE, CAMEROON

Future work has shifted to developing a business plan and strategy for scale-up, now that the vehicle has accumulated multiple years of field data in Cameroon. The project (since its inception) has fielded requests from interested organizations around Africa and other developing areas like Haiti.

ASSESSMENT, RECOMMENDATIONS AND PATH FORWARD

From a technical perspective, the integration between the MPV project and the biodiesel project was a success. The ACREST staff has been using MPVs designed and built on-site by the Purdue team since 2010. Additionally, the UK student team successfully designed, built and operated their UKATS Biodiesel Processor in Cameroon and produced biodiesel that was used in the MPV. However, reducing the cost of the biodiesel to be competitive with petrodiesel continues to be a challenge that must be addresses in order for it to be economically and socially sustainable.

Although the assessment is anecdotal in nature, from a student perspective, the two projects have been a tremendous success. Having the students working side-by-side with the ACREST technicians while living and dining at the ACREST guest facilities gave the students a real sense of the challenges faced by the people of the region. Without spending time at ACREST, the authors' contend that the projects would not have achieved the same level of community impact. It is vital for the success of any project focused on underdeveloped regions that the needs of the community be met. Despite the expense, travel is critical for service learning in underdeveloped regions. This is a key learning from these projects. From the UK research group, all the students from the 2012 trip to Bangang Village who were eligible to return in 2014 chose to do so. This indicates the level of dedication shown by the students. In summary, the key learnings from these projects are summarized as follows:

- An engaged in-country partner is critical to success,
- Travel to the target region in necessary in order to understand the needs of the community,
- Engagement with the local community leaders is necessary to gain trust and credibility,
- Committing to a multi-year time horizon rather than a "one off" approach allow for improvements due to the ability to respond to feedback from the project beneficiaries,
- Multi-year projects allow the team to retain "institutional memory" as upper division students graduate and new students join the team.

Having established the partnership among UK, Purdue and ACREST, the groups plan to continue to collaborate on other projects. The UK group is focusing on designing a process to collect pyrolysis oil, or wood vinegar as it is commonly called, from the production of charcoal. Wood vinegar can be used as a non-synthetic pesticide and herbicide and is a valuable co-product from charcoal making[15].

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of the African Center for Renewable Energy and Sustainable Technology in the development of this partnership, Particularly ACREST founders Dr. Vincent Kitio and Dr. Isaac Zama.

REFERENCES

[1] National Academy of Engineering (NAE) (2004). *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC, The National Academies Press.

[2] Lucena, J., J. Schneider, and J. Leydens (2010): *Engineering for Sustainable Community Development*, Morgan and Claypool Publishers.

[3] Seay, J., I. Zama and B. Butler (2012): "International Partnership Helping to Bring Appropriate Biofuel Technology to Rural Cameroon", *International Journal of Service Learning in Engineering*, Vol. 7, No. 2.

[4] Dare, A., R. Mohtar, J. Lumkes, P. Imbrie, and A. Ciftci (2011): "Assessment of Global Competencies within Purdue University's College of Engineering", Written for presentation at the 2011 ASABE Annual International Meeting, Louisville, KY., August 7-10. Paper no. 1111597.

[5] Dare, A., R. Mohtar, and J. Lumkes, (2011): "Global Design Teams: Case Studies of Student and Community Impact", Written for presentation at the 2011 ASABE Annual International Meeting, Louisville, KY., August 7-10. Paper no. 1111593.

[6] Lumkes, J., D. Wilson, and A. Dare (2011): "Undergraduate Students Solving Transportation and Energy Problems through Service Learning Projects in Cameroon", Written for presentation at the 2011 ASABE Annual International Meeting, Louisville, KY., August 7-10. Paper no. 1111498.

[7] Lumkes, J. (2012): "Design of a Sustainable, Locally Manufacturable, Agricultural Utility Vehicle for Developing Countries", *International Conference Of Agricultural Engineering*, CIGR-AgEng 2012, Valencia 8-12 July 2012, Book Proceeding ISBN 978-84-615-9928-8.

[8] Coyle, E., L. Jamieson, and W. Oakes (2005): "EPICS: Engineering projects in community service", *International Journal of Engineering Education*, 21(1), 139-150.

[9] United States Department of State (2014): "Cameroon Travel Warning", http://travel.state.gov/content/passports/english/alertswarnings/cameroon-travel-warning.html (on-line, accessed 8/31/2014).

[10] Croft, M. and J. Seay (2013): "Interfacial Phenomena in the Production of Low-Cost Biodiesel in Rural Africa", *Proceedings of the 3rd International Conference on Sustainable Chemical Product and Process Engineering*, CD-Volume, Dalian, China.

[11] Croft, W. and J. Seay (2013): "Developing an Optimal Chemistry for Producing Low Cost Biodiesel from Local Feedstocks in Rural West Africa", *Proceedings of the 3rd International Conference on Sustainable Chemical Product and Process Engineering*, CD-Volume, Dalian, China.

[12] Croft, W. and J. Seay (2014): "Sustainability Assessment Methodology for Process and Product Design of Appropriate Technology for Developing Regions", *Proceedings of the 8th International Conference on the Foundations of Computer-Aided Process Design*, Elsevier, Oxford, University UK, pp. 279-284.

[13] Pawletko, P. (2013): "Community Power from Hydropower Systems: A Capacity-Building Project in Bangang, Cameroon", *The Journal of Purdue Undergraduate Research*, 3(1), 11.

[14] Whipple, W., B. Butler, C. Sterrie and J. Seay (2013): "Design and Optimization of a Novel Process for the Production of Biodiesel Suitable for Underdeveloped Regions", *Journal of Green Building*, Vol. 8, No. 3.

[15] Tiilikkala, Kari, L. Fagernäs and J. Tiilikkala (2010): "History and Use of Wood Pyrolysis Liquids as Biocide and Plant Protection Product", *The Open Agriculture Journal*, 2010, 4, 111-118