Student-Aimed Appropriate Technology Engineering Projects in Kenya

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Abstract

The *Baylor in Africa '05* initiative created a two-week on-site service-learning opportunity in Kenya for nearly 150 Baylor students, faculty and staff during May 2005. Included among the discipline-specific student teams were those from the fields of deaf education, outdoor recreation, social work, education, journalism, and engineering. The engineering team consisted of three faculty members and seven students. The principle intent of the effort was to identify appropriate technology projects within Kenya where a solution could be analyzed and designed by on-campus engineering students and then subsequently deployed. Secondarily, on-site hands-on opportunities provided team members the gratification of completing two projects. One involved the design and installation of a solar lighting system at a school for deaf children and another the construction of a 40-meter-long pedestrian bridge. Logistical and communication obstacles with identifying in-country contacts provided considerable time and patience challenges before the team departed Texas. The most fruitful relationships were established with faith-based and non-governmental organizations. The team was warmly welcomed by the partner organizations and many local residents and students. Regions where the team conducted investigations comprised those among the poorest regions of Kenya including the rural regions of Pokot and Lake Victoria, and the slums of Nairobi. The most pressing technology needs the team identified were in the areas of energy generation and water distribution. Among the greatest limitations in achieving more progress in these areas are the lack of working capital, poor communication and information systems, ineffective and fragmented infrastructure, and a long-standing culture of dependence. Baylor engineering students and faculty are currently involved with the stress analysis of foot bridges, producing bio-diesel fuel from coconut oil, and generating electricity from wind turbines and solar panels. A follow-on engineering team will continue on-site efforts in May 2006.

Introduction

Kenya is a country in East Africa, located between Somalia, Ethiopia, Uganda and Tanzania, and borders the Indian Ocean. It has an area of 582,650 km^2 and a population of around 34 million. By comparison, this is around 85% the size of Texas and a population about ⅓ greater than Texas'. The topology is a contrast from deserts to snow capped mountains to savannah grasslands. The Rift Valley stretches across much of south-central Kenya and is acclaimed for spectacular safari tours and its visibility from the moon. The transportation and power infrastructures are weak and sporadic, especially outside of major cities, though there is a remarkably robust cellular-phone network. There are forty-two different Kenyan tribes, and although there is less tribal distinction in most urban areas, it can be quite pronounced in many rural areas. With a 40% unemployment rate, 75% of the working labor force in Kenya is involved in agriculture. 50% of the population lives below the poverty line. The HIV/AIDS infection rate is 6.7%. Over 75% of the population is Protestant/Catholic, 10% indigenous beliefs, and 10% Muslim. The average household consumption is $215.[1] On the *Human Development Index*, a measure of a country's achievements in terms of life expectancy, educational attainment and adjusted real income, Kenya ranks 138 out of 174 countries.[2]

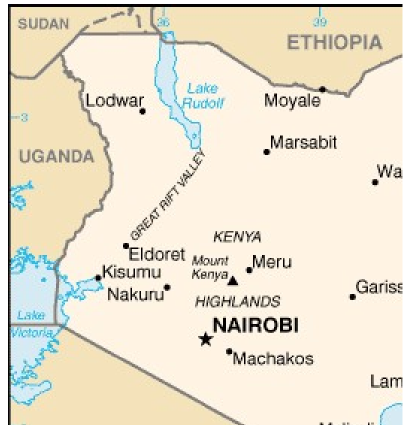

Figure 1: Map of Kenya

Considering the education, economic, and other sociological factors in Kenya and the great need to improve conditions for Kenyans, in many instances solutions applicable within developed countries cannot be successfully implemented and sustained. Thus, technological solutions in developing countries must meet various design criteria that may be very different from those deployed and taught in U.S. engineering programs. "Appropriate Technology is developing and using technology that is appropriate to countries' or communities' resources, climate, and needs. It is primarily used as a way to help the progress of developing countries in an economically feasible manner."[3]

The travel and broad logistical elements of this project were coordinated by Baylor's Office of University Ministries as a part of *Baylor in Africa '05*. More than 140 Baylor students, faculty and staff partnered with organizations, schools and missionaries in Kenya with the purpose to serve and learn. Some of the teams focused on specific topics such as leadership, women's issues, and medical needs. Other teams were specifically organized to utilize principles students learn and faculty teach in discipline-specific projects and included teams centered around deaf education, education, journalism, outdoor recreation, telecommunications and social work.[4,5]

Project Description

It was the engineering team's plan to identify in advance of their travels potential partner organizations and individuals already involved in appropriate technology efforts in Kenya. Candidates for partnership were identified from web sites, referrals, and personal contacts. In May 2004 under the leadership of Dr. Walter Bradley, Baylor hosted the *Symposium on Science and Appropriate Technology for Developing Countries*, and this event helped introduce a number of academicians and professionals to Baylor's appropriate technology efforts and ambitions. This interface led to a rich list of potential partners willing and anxious to work with and introduce the Baylor engineering team to Kenyan projects fitting to be approached within a predominately undergraduate context.[6]

Because of Kenya's geography, population distribution, and specific needs, the location of appropriate technology projects identified for investigation range over a wide geographic area. And likewise, the scope and expertise needed to address these specific problems were dependent too on the region and population factors. For example, in rural areas, the delivery of water for agricultural purposes was prominent while in the high density slums of Nairobi the delivery of electricity was a common application.

The engineering team consisted of three faculty members and seven students. Five of the students were undergraduate engineering students, one was an MBA student with and undergraduate engineering degree, and one was an embedded journalism student to help document and record the team's activities.

More than half of the other Baylor teams used Nairobi as their home base, as the projects they worked on centered around individuals living in Kenya's capital and largest city. Several of the other teams worked out of different Kenyan cities, and the engineering team was the only group that traveled extensively within the southern region of Kenya.[7] Because the engineering team's aim was to select projects suitable for continued involvement and deployment, it was necessary to visit various locations within rural and urban centers. To help accomplish this, the team divided into two smaller teams so that more future opportunities could be evaluated. Because of travel and safety issues, essentially all in-country travel was accomplished using small vans with Kenyan drivers.

The logistics of finalizing the timing of multiple appointments spread over a relatively large region was complex. The table below shows a portion of the anticipated itinerary at the time the engineering team departed the U.S. Several modifications were made *in situ* to help accommodate unanticipated changes.

Though the principle intent of the engineering team's travel to Kenya was to identify projects for undergraduate students at Baylor to analyze, design and deploy, two valuable hands-on opportunities arose to work on during the visit. The first of these was in partnership with the deaf education team. This team's project was to work at the Kenya Christian School for the Deaf in Oyugis, a small town eight hours west of Nairobi and near Lake Victoria. The engineering project at this school was led by Prof. Thomas and involved designing and installing a solar-powered system for lighting and battery charging. The system was designed by team members prior to traveling to Kenya with the objective of deploying it on site. Because of limitations on luggage and weight, arrangements were made to purchase the solar panel in Kenya. Though such items are available in the largest cities, communications to assure

Figure 2: Students installing solar-powered lighting system.

TEAM ENGINEERING- BAYLOR UNIVERSITY IN AFRICA 2005

Team members- faculty: Dr. Walter Bradley, Prof. Brian Thomas, Dr. Ben Kelley; students: Brian B., Amy B., Bobby B., Sarah C., Sarah G., Jason P., Courtney S.

Kenya Appropriate Technology Itinerary, May 15-30, 2005

Monday 16-May-05		Tuesday 17-May-05	Wednesday 18-May-05	Thursday 19-May-05		Friday 20-May-05		Saturday 21-May-05	
Blue team(4): Dr Bradley, Dr. Kelley, Bobby B, Jason P (May 19-21) Malaria medication		Green team(5): Prof Thomas, Dr Kelley, Brian B, Amy B, Sarah G ↯(Dr. Kelley & Sarah G change to Gold on Wed, 25-May)	Gold team(5): Dr Bradley, Bobby B, Sarah C, Jason P, Courtney S ↯(Dr. Kelley & Sarah G join from Green on Wed)	**Travel to Deaf School** (6 participants)	Oyugis	**Deaf School solar lighting/re-charging project** (6 participants)	Oyugis	**Travel to Kitale** (6 participants)	Kitale Club entire team
				Travel to Moringa Re-search Agency (4 participants)	Homa Bay	**Moringa Re-search Agency- travel to Kitale** (4) Parker Dinner	Kitale	**Kitale Bridge Project** (4 participants)	Kitale Club entire team

Monday 23-May-05		Tuesday 24-May-05		Wednesday 25-May-05		Thursday 26-May-05		Friday 27-May-05		Saturday 28-May-05	
West Pokot-International Harvesters (5 participants) Malaria medication	Kitale Club	**West Pokot-International Harvesters** (5 participants)	Kitale Club	**Travel via ↯Nakuru↯to ITDG Micro-Hydro in Chuka** (5→3) **↯Nakuru Kuste :** *(2)* **New Dawn James Keriuku**	Embu	**ITDG Micro-Hydro & travel to Nairobi** (3) **Nairobi visits: ApproTech & Harrell** (3) (A: WB, CS, JP)	Nairobi entire team	**Nairobi visits: ISTG** (4) *Masai Market* (Baylor team) **Nairobi visits: Ojienda** (4)	Nairobi	Orange(4): Prof Thomas, Sarah C, Jason P, Courtney S; Turquoise(4): Dr. Kelley, Brian B, Amy B, Sarah G Pink(2): Dr. Bradley & Bobby B	Nairobi entire team
East Pokot-International Harvesters (5 participants)	Loruk	**East Pokot-International Harvesters** (5 participants)	Loruk	**Elmeteita-Moringa Farm & ↯- to Nairobi** (5→7)	Nairobi	**Okello & Frank dinner** **Nairobi visits: Okello** (4) (B: BK, SG, SC, BB)	Nairobi entire team	**7:45- To/in Mombasa for coconut project** (2 participants)	Mombasa	**In/return from Mombasa** (2)	Nairobi entire team

the proper specifications proved a challenge. The associated battery was purchased in the U.S. and checked as luggage, as was the controller, and miscellaneous tools, wiring and connectors. The lights themselves were constructed in a Baylor laboratory and comprised of multiple low-wattage white LEDs embedded in a polymeric matrix.

While it was envisioned that the lighting system would be used as dim night lights, that turned out not to be the case. The actual need as communicated by the head teacher was for evening reading lights for the students. Although energy available from the system was capable of providing this level of lighting, the design components were not configured for this more intense purpose. In altering the design on site the students received a valuable education in engineering improvisation, as the system was redesigned and installed to satisfy the newly communicated need. Among the more innovative Apollo 13-like alterations was the use of silver-lined cardboard intended as a solar oven as a back reflector to help focus the light downward. Though this project required timely and appropriate re-design, the outcome did meet the needs of the students and teachers at the deaf school and now students can read and study in the evenings and teachers can recharge the batteries for a lap top computer and cell phone.[8]

The other on-site project involved the construction of a 40-m pedestrian bridge over a river that divides a village in the West Pokot region. This area is among the poorest regions in Kenya where a quarter of the population earns less than $1 per day and only 10% have access to clean water. The site was several kilometers from the nearest passable road and could only be reached using a four-wheel-drive vehicle. This project was in conjunction with the organization, Bridging the Gap of Africa. This non-governmental agency has been responsible for constructing several dozen foot bridges in East Africa. Most recently the favored bridge design has been a suspension bridge comprised of cables and pre-bent re-bar deck supports. The super structure of the bridge the engineering team helped construct had already been erected. Team members provided the semi-skilled labor of planking the walking deck of the bridge. This consisted of bolting eight-feet-long, 2-in.-by-x-6-in. pressure-treated boards, three wide, to pre-bent hangers suspended from the suspension cables. This was done while standing on the bank of the river. After several sections had been assembled, they were pushed out toward the other bank, and the worked continued.

Figure 3: Construction of pedestrian bridge.

The river over which this bridge was constructed divides a remote village. The market, medical clinic, and school are located on one side of the river while most of the agricultural production and residences are on the other side. The other nearest bridge is around ten kilometers in either direction. Every year several residents drown attempting to cross through the river. It is estimated that four million kilometers of walking each year will be saved because of the new bridge.

Baylor freshman engineering students now complete an analysis project where they analyze the simple stresses in a similar pedestrian foot bridge as an assignment. Though Bridging the Gap did have access to a spreadsheet that calculated the factors of safety for such bridges, with variables such as the cable diameter, span, and angle, this analysis has been improved by a upper-level mechanical engineering student, and assembled into a more user-friendly format.[9] On-going work with Bridging the Gap includes the feasibility analysis of constructing more complicated bridges over spans in excess of 200m.

Several other types of projects were also investigated. A number of them related to water distribution in rural areas. Typically such a project involves the need to pump water from a source such as a river to a near by village. Often this would entail a piping system of several kilometers over regions with substantial changes in elevation. Another water-source project the team investigated involved the possible re-design of a bore hole outfitted with a hand pump. These pumps are very labor intensive to operate, especially for women and children, and as a result sometimes are of limited usefulness. Because of the substantial capital outlay, relative lack of faculty expertise, and the low population of these rural areas, none of these water distribution projects were selected for immediate continued exploration.[10]

Another project that was considered involved Moringa trees, sometimes called "the miracle tree". Though there are a number of varieties, at least one species of Moringa is drought resistant, generally grows well in Kenya, and is also reported to have a number of beneficial characteristics. Among these are medicinal uses for colds and coughs, nutritious and vitamin rich greens, seeds for perfume, oils for machinery lubrication, coagulant for water purification, nectar for honey (and clarifier), and fiber for rope making.[11] Currently in Kenya there is little commercial production of Moringa products, although in a few other developing regions processing machinery has been developed. Among the ideas shared with the engineering team included developing village cooperatives where local farmers would harvest the Moringa products and use the community processing machinery to create and sell value added products. The team will work locally with the World Hunger Relief Farm near Waco, Texas, to further analyze future possibilities. While visiting the Moringa Research Agency in Homa Bay, the team was able to sample a Moringa dish. It looked and tasted somewhat like spinach.

Figure 4: Dr. Bradley and a small Moringa tree.

Most Kenyans use biomass as a source of energy for cooking. The result of burning these fuels indoors results in substantial indoor air pollution and numerous health problems, including pneumonia and chronic lung disease. Wood is often the fuel of choice. Wide deforestation has greatly de-plenished the availability of wood stock. The result has been that villagers must forage over increasing larger areas for wood fuel. This is often at the demise of girls and women to whom this responsibility lies, as this time commitment often prevents them from attending school or contributing otherwise. A number of innovative new stove designs with greater efficiency have been introduced in developing countries and yielded significant improvements.[12,13] The engineering team took to Kenya several low cost cardboard backed reflective solar cookers that can also be used to sterilize drinking water and cook meals. While these cookers were intriguing to those to whom it was demonstrated, we observed little evidence of concern for or recognition of the need for use of improved cooking systems.

Three projects were selected for continued exploration. The first of these involves the processing of coconuts into several valued added products. Coconuts are renewable and very abundant in many developing countries near the equator and coastal regions. Among the greatest potential of coconuts is the extraction of oil for use as bio-diesel. This fuel can be used in a generator in rural villages to provide electricity for night-time lighting, water purification, battery charging, and medical clinics. Further, other byproducts of coconuts, including the husks and meat, can be processed into other value-added products including particle board, livestock feed, food and juice for human consumption, and cooking fuel. While in Kenya, the engineering team investigated the coconut supply and production near Mombassa. Unfortunately, coconuts harvested at various stages of maturity and intended for experimentation were confiscated by the U.S. Customs Office on the return trip from Kenya. The follow-on work with this project will actually be piloted in a remote village in Papua New Guinea with the intent to generate electricity at an inexpensive and sustainable price. Among the first goals for this project are to process 400 coconuts per day, which should make enough electricity to power two light bulbs in 300 homes and allow limited refrigeration for fisherman and sewing for clothes. This project is moving forward in partnership with a local retired engineering faculty member and a proposal for funding has been submitted to the World Bank.[14]

Figure 5: Different stages and sizes of coconut maturation.

A second project is expected to be deployed in Kenya by a Baylor engineering team during Summer 2006. The location will be at the same school for deaf students in Oyugis that was visited last year. This project will be the installation of a water well and water purification system. Some of the older students will help with digging the well. The pumping system will likely be a pair of human-powered stair-step-type pumps that will transport water from a well into a storage tank, and then into a water purification tank. A solar panel will be used to generate the electricity to power a water chlorinator system. The purified water will be used for drinking and cooking. The water from the pre-storage tank can also be used for irrigation, clothes washing, and bathing. Currently, water for these uses (except for irrigation) is carried in buckets from a river a few kilometers away. The Baylor deaf education team will also be on-site at the school.

Perhaps the project with the potential to soon affect the greatest number of people in Kenya will be in partnership with the Intermediate Technology Development Group (ITDG) and PACE International. The project's goal is to use the power from a wind turbine to generate enough electricity to provide evening lighting and battery recharging for 24 near-by homes. This concept may be implemented in concert with ITDG's existing sanitation station project. This project provides centralized bathroom and shower facilities within high-density slum areas, and uses the methane generated from the sewage to heat the shower water. An on-site operator collects a fee and maintains the facility. The wind turbine may be mounted on top of the latrine station, and remarkably there are twenty-four households within a twenty meter radius. The implementation of this project is envisioned for the Kibera slum which has a population near 750,000. Currently, kerosene lanterns are used for lighting, which poses a fire hazard, creates indoor pollution, and is relatively expensive.

The preliminary design for the distribution system is based on a hub-and-spoke system. A 300-watt generator will be connected to the twelve volt distribution lines that will run from a breaker box to each residential unit. A limit controller will prevent the 240-amp-hour battery pack from falling below 20% of discharge and provide for 48 amp-hours of power in the event the wind turbine doesn't generate power for three consecutive days. The lighting system will consist to 36 LEDs per light and will require 0.65 amp-hours per light considering six hours per day of usage.

A marketing and business plan for this project was developed, spearheaded by the graduate student member of the Baylor engineering team. This overview estimates that the cost of the system will be $854.50 and that all of the materials can be purchased in Kenya. The estimated working revenues for the system are $144 per month, yielding a cost per household of 14¢ per week. This represents about 12% of household income, which is less than the current kerosene-based lighting system, and also includes power for battery charging and a radio. The marketing/business plan developed for this project was entered in the Global Social Venture Competition.[15, 16]

Additional Observations

Though the purpose of the efforts described in this paper are aimed at student involvement in engineering applications of appropriate technology, technical challenges were not the only obstacles the Baylor engineering team faced. The culture and expectations in Kenya are very different than they are in the United States, and this facet affected virtually every aspect of the team's efforts. In Kenya and some other African nations there is known to be a culture of dependence.[17] This was evident in many of the team's investigations and work. For example, solutions for many of the rural water projects did not involve technology or know-how not already in practice and application in Kenya. Limitations of Kenyans to replicate existing in-country successes are hampered by poor infrastructure, including transportation and communication systems. Another example of this culture of dependence is depicted in the bridge project, where the engineering team members provided semi-skilled labor for one day while hundreds of villagers watched on. It was gratifying for the team members to contribute to this project and the feast that followed was a special and life-memorable experience. We observed with some of our Kenyan contacts a different interpretation of appropriate technology. On several occasions we were treated as dignitaries by schools (which are virtually all church supported) that taught carpentry to boys and sewing to girls as proactive examples of appropriate technology. Kenya's culture is based more on family and community relations than corporate and personal successes. Much of this is derived from their past as a colonial colony, corrupt government, and foreign missionary aid and influences. Though progress is slower and more sporadic than many would predict or hope for, progress and opportunities remain, and appropriate technology projects hold great potential.

Appropriate technology efforts within Baylor's School of Engineering and Computer Science include the efforts reported here and the continuation of selected projects. And it has now invaded the classroom and student organizations. In the Spring 2006 semester, Dr. Bradley and Prof. Thomas are co-teaching a course on Appropriate Technology as a technical elective. And a new student organization, Engineers with a Mission, has formed and is participating in appropriate technology projects and hopes to charter chapters on other university campuses.

References

1. The World Fact Book, Central Intelligence Agency, 2005, http://www.cia.gov/cia/publications/factbook/.
2. Water for Africa- ensuring safe and sustainable drinking water for the urban poor in Kenya, 2005 http://www.waterforpeople.org/WaterforAfrica/WFACountryKenya.htm.
3. As defined by the student chapter of *Engineers with a Mission*, Baylor University.
4. Spain, Sara D., 2005, —"Africa '05", Baylor Magazine, Vol. 4, No. 1
5. Wright, Haley, July 12, 2005, —"Multiple Disciplines Join Together for Africa Mission Trip", http://www.baylor.edu/pr/news.php?action=story&story=34756
6. Long, Judy., August 31, 2004, —"Baylor Engineers Focus Talent, Interest On Needs In Developing Countries", Baylor News, http://www.baylor.edu/pr/news.php?action=story&story=20443.
7. Wright, Haley, August 12, 2005, —"Baylor students apply classroom skills during mission to Kenya", The Baptist Standard, http://www.baptiststandard.com/postnuke/index.php?module=htmlpages&func=display&pid=3773
8. Schultz, Courtney, August 12, 2005, "Students Install Solar Lighting System for Kenyan Deaf School", The Baptist Standard, http://www.baptiststandard.com/postnuke/index.php?module=htmlpages&func=display&pid=3768
9. Bradley, W.L., Heffley, D., —"Building Better Suspension Bridges in Africa: An Analysis of Pre-tensioning Requirements", February 3, 2006, Baylor University School of Engineering and Computer Science Scholars' Day, Waco, Texas.
10. Njuguna-Githinji, Wanja, — "Guidebook to Global Water Issues- Kenya" http://www.ittind.com/waterbook/Kenya.asp.
11. "Moringa oleifera The Miracle Tree" 2000, the Moringa Tree Project, http://www.moringatrees.org/TMTintro.html.
12. Doig, A., Bates, L., Gitonga, S., Bruce, N., "Kenya Smoke and Health Project", 2001, ITDG, http://itdg.org/docs/advocacy/Smoke_Project.pdf
13. "Wood fires that fit" http://journeytoforever.org/at_woodfire.html
14. Bradley, W.L., Poel, J. —"Converting Coconuts into Value-Added Products for Economic Development in Third World Countries", February 3, 2006, Baylor University School of Engineering and Computer Science Scholars' Day, Waco, Texas.
15. Global Social Venture Competition, http://socialvc.net/index.cfm?&stopRedirect=1

16. Brock, B., Herron, R., Li, X., Hartley, K., Gallimore, M., —"Providing lights to the world's underprivileged", a confidential business overview-Kibera project, November 29, 2005.
17. Maranz, D.E. "Friends and Money Matters", 2001, SIL International

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