AC 2012-5569: CRITICAL IMPORTANCE OF SOCIAL ENTREPRENEURSHIP EXEMPLIFIED IN SENIOR CAPSTONE PROJECTS

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Critical importance of social entrepreneurship exemplified in senior capstone projects

Abstract

Innovation and entrepreneurial skills, combined with technological developments, in conjunction with requisite social and political forces, will likely be required in order to develop solutions to the significant problems affecting the world and to marshal the resources required to improve the lives of people. Social entrepreneurship allows for the evaluation of project success to incorporate explicit criteria related to improvements in "assets" beyond those that are easily measured monetarily. It is well established that projects and programs can typically only succeed when the social requirements and constraints surrounding existing problems and that of the proposed solution are properly understood. This results in the reality that there are no "standard solutions" because each situation has so many unique features. Two recent senior capstone design projects located in Kenya provide a strong learning opportunity for the students in applying the concepts of social entrepreneurship.

The first project, completed in 2011, involved the use of Kenyan agricultural crop byproducts as a source of bio- fuels. This bio-fuels project required that the implementation support agricultural workers in recognizing the social and monetary value of investing in the bio-fuel production technology, and then assist in developing a method to operate an ongoing enterprise to manufacture and use the bio-fuel. The second project with completion scheduled in 2012, combines ceramic water filters, thermal-electric power generation and bio-fuels to improve the health of women and children in the homes surrounding Kitale, Kenya. The project to improve health also incorporates an implementation plan that uses an educational "marketing" of beneficial technologies to early adopters as a method to provide training to new users and to promote the spread of the technologies with funds from project sales.

These two projects are used as examples that allow students to present descriptions of the learning experiences that resulted from incorporating the concepts of social entrepreneurship into these two capstone design projects, and how the project technologies themselves are shaped by the increased understanding of the conditions in Kenya.

1 Introduction

A classic definition of entrepreneurship is given by Stevenson, of the Harvard Business School, in 1983:

> "Entrepreneurship is the pursuit of opportunity without regard to resources currently controlled".[1]

How can we move those students interested in socially oriented responsibilities toward social entrepreneurship?

It is now well understood that in order to ensure the sustainability and success of technology-based projects, acquisition and use of entrepreneurial skills for all stakeholders will be required. Currently, there are many well-organized efforts working to develop these critical entrepreneurial skills[2,3] and entrepreneurial mindset[4] from both a business viewpoint[5] and engineering education perspective[6].

To provide students with foundational entrepreneurial skills, and to enhance the education of engineers in our program, a two-semester course sequence for the senior capstone design experience is utilized. Over the past eight years, a total of seven civil and mechanical engineering capstone design teams have participated in the U.S. Environmental Protection Agency's (EPA) P3: People, Prosperity and the Planet Student Design Competition for Sustainability in Washington D.C. These EPA sponsored senior projects provide challenging engineering constraints for the students and provide a valuable educational component of the education for the students. The 2011 and 2012 projects are sited in Kenya and both teams recognized the necessity that the projects are sustainable in terms of financial, social and natural resource based systems. The framework used to make the projects most effective was to implement strategies of social entrepreneurship.

One motivator for the teams' approach is the work done by Muhammad Yunus for which he received the Nobel Peace Prize in 2006. Yunus defines his understanding of the term "social business" as:

> "Social business is a cause-driven business. In a social business, the investors/owners can gradually recoup the money invested, but cannot take any dividend beyond that point. Purpose of the investment is purely to achieve one or more social objectives through the operation of the company, no personal gain is desired by the investors. The company must cover all costs and make profit, at the same time achieve the social objective, such as, healthcare for the poor, housing for the poor, financial services for the poor, nutrition for malnourished children, providing safe drinking water, introducing renewable energy, etc. in a business way."
>
> "The impact of the business on people or environment, rather the amount of profit made in a given period measures the success of social business. Sustainability of the company indicates that it is running as a business. The objective of the company is to achieve social goal/s."[7]

A further goal for the student teams is to make explicit that innovation and meeting the needs of the adopters of the technology developed in the projects is required to achieve project success. This moves the emphasis from a social business to the development of a social entrepreneurial activity. Definition of what is meant by social entrepreneurship is widely debated, but there are some core elements and qualities that are frequently recognized, for example:

> "Social entrepreneurs are society's change agents, creators of innovations that disrupt the status quo and transform our world for the better. By identifying the people and programs already bringing positive change around the world, we empower them to extend their reach, deepen their impact and fundamentally improve society."[8]

There are large efforts underway to systematically address the development of social entrepreneurs, for example at Duke University's Fuqua School of Business, they present a concept that indicates that the social entrepreneur is a development of the traditional entrepreneur by identifying the difference:

> "We should build our understanding of social entrepreneurship on this strong tradition of entrepreneurship theory and research. Social entrepreneurs are one species in the genus entrepreneur. They are entrepreneurs with a social mission. However, because of this mission, they face some distinctive challenges and any definition ought to reflect this".
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> "For social entrepreneurs, the social mission is explicit and central. This obviously affects how social entrepreneurs perceive and assess opportunities. Mission-related impact becomes the central criterion, not wealth creation. Wealth is just a means to an end for social entrepreneurs." …
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> "It is inherently difficult to measure social value creation. How much social value is created by reducing pollution in a given stream, by saving the spotted owl, or by providing companionship to the elderly? The calculations are not only hard but also contentious. Even when improvements can be measured, it is often difficult to attribute them to a specific intervention. Are the lower crime rates in an area due to the Block Watch, new policing techniques, or just a better economy? Even when improvements can be measured and attributed to a given intervention, social entrepreneurs often cannot capture the value they have created in an economic form to pay for the resources they use. Whom do they charge for cleaning the stream or running the Block Watch? How do they get everyone who benefits to pay?" ...
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> "Social entrepreneurs play the role of change agents in the social sector, by:
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> - Adopting a mission to create and sustain social value (not just private value),
> - Recognizing and relentlessly pursuing new opportunities to serve that mission,
> - Engaging in a process of continuous innovation, adaptation, and learning,
> - Acting boldly without being limited by resources currently in hand, and
> - Exhibiting heightened accountability to the constituencies served and for the outcomes created."[9]

A further effort to delineate those traits that are used by entrepreneurial engineers identifies the following four broad categories of working abilities:

> "Engineers … have four defining attributes: working insights into technical fundamentals, customer awareness, business acumen, and societal needs."[10]

The project teams recognize that implementation of a new technology into the individual homes of adopters of the two projects in Kenya would require a social entrepreneurial effort, in addition to any technical innovations.

2 Fundamental concepts for successful introduction of technological projects

The student teams required significant effort to understand both the general requirements for introducing new technical solutions into a community and also the specific constraints on US based projects introduced into the unfamiliar culture in Kenya.

In countries where markets are less clearly defined, entrepreneurship plays an especially important role in facilitating economic activity.[11] For example, the Ijebu population in Nigeria has experienced greater prominence in trading due to a long cultural history of exchange with other cultures, and a correspondingly higher amount of accumulated wealth.[12]

Where formal sectors of the economy are less reliable, entrepreneurship may be more centered on the informal sector, an intuition verified by interviews with micro-enterprise proprietors in French West Africa.[13] Those interviews showed that when choosing which industry to enter, these "micro-entrepreneurs" were motivated by personal interest (44%) and ease of activity (37%). These survey results help to give some insight on what sort of strategies might be most effective when trying to encourage social entrepreneurship to promote a new product.

The credibility of small-scale enterprises, in providing quality goods and fair business practices, plays a crucial role in their success or failure.[14] Another way of expressing this would be in terms of social capital.[15] Individuals with higher social capital can more easily influence their friends, neighbors, and acquaintances, building more support for a new technology in the culture or in the affiliated business. A series of development studies in India found that social capital was pivotal in solving free rider problems and making more productive use of natural resources.[16] The literature on social capital and development is continuing to evolve as more case studies emerge.

Given the importance of credibility and social capital to development, researchers have looked to high-status individuals within a society as the conduit for development. As a result, some models of entrepreneurship in developing economies have focused almost exclusively on interactions and trades between male members of the society. For example, studies of Melanesian "Bigmen" have emphasized their role as facilitators of exchange and correspondingly higher social status, as compared to the underclass of "Rubbish Men".[17] While this male-centered approach can be criticized for excluding the important role of female contributions to developing economies[18] it does explore the potential for entrepreneurship even in markets that are not fully open. The entrepreneurship practiced by "Bigmen" is of a distinctly social character, exchanging gifts and

social recognition for work effort from lower-status males. Although this effect is present in lesser degrees in Kenya, the importance of gender roles was discussed by both project teams.

In many areas of Africa, the impact of women on household and small enterprise commercial activities is important:

> "Distribution of goods is another economic activity in which African women have been engaged for generations. Most of the marketing began by selling excess farm produce, but today it ranges from petty to international trade. The market women of West Africa are legendary, but it is clear … that these women have their counterparts in other parts of the continent".[19]

The teams wish to emphasize that the household responsibilities of women in Kenya can most easily be modified by other high-status women rather than by introducing male experts into the implementation plan. Also the common experience is that women are more likely involved in small business, as both consumers and entrepreneurs, particularly those that serve women's and children's needs:

> "The household surveys … showed that in each country, men were more likely to be farmers or laborers than women, and that women were more likely to operate small retail businesses than men".[20]

In every case, entrepreneurship depends on much more than the product being offered. Discovery of an entrepreneur's product within a society remains a large hurdle, which even a publicly desirable idea may fail to overcome if the social connections needed to engender market success are absent.[21,22]

Story-telling plays an important role in allowing new businesses to form, or innovative products to be successful.[23] Stories which help to mediate between existing resources and new, potential applications can be referred to as "cultural entrepreneurship." Successful entrepreneurship then requires stories that resonate with potential clients, emphasize a desirable set of core attributes, and align with existing cultural understandings of how the world operates. Entrepreneurs with already-existing social capital will tend to be more successful in meeting this set of conditions. Therefore, when trying to introduce a new good or service in a development context, choosing good story-tellers to advance the narrative surrounding that product will be crucial to successful dissemination of that good.

The teams were also aware of the rising importance of social media on all societies. Use of social media to ease adoption of new approaches is in its infancy, but is likely to play an important role. For many adopters, comfortable and accessible introduction to technology that is made in social media by trusted or familiar interlocutors is essential to making adoption decisions. Therefore, rather than emphasizing hard-science literacy for adopters, higher acceptance is possible by emphasizing realistic general awareness of the technology and its important risks and benefits.[24]

3 Framework for the projects in capstone design

Every engineering student is required to complete a two-course sequence for senior capstone design and to sit for the National Fundamentals of Engineering (FE) Exam.

The diverse skills required of modern engineers cannot be learned solely in a classroom or from a textbook. Design skills are best learned through a combination of observation, emulation, analysis, and experimentation. This demands a high degree of interaction between the student and experienced designers. Interpersonal skills are best developed through team work. Industry has discovered that the give-and-take process that characterizes a well-motivated team is a key element to a project's success.

Our Center for Engineering Design and Entrepreneurship enhances the design experience of students in the engineering programs by promoting interaction between the industrial and academic communities. Student teams, under the guidance of industry engineers and faculty, undertake design projects defined by sponsors from both the private and public sectors. A project team typically consists of three to five students, some from different fields of study in the School of Engineering and Applied Science (SEAS). Students are assigned to projects based on their interest, knowledge and experience. Team members must make effective use of available resources to perform and manage the project activities. By working on a real-world problem, each student has the opportunity to make decisions, to work as part of a team, and to interact with professionals in the private and public sectors. Further, working on technical projects that have real value to business, non-profits, and the government, encourages students to acquire new skills.

More than half of the faculty members who advise the student teams have at least five years of industrial experience. A faculty advisor lends knowledge and experience to the project team by guiding and counseling the students in the technical and managerial decisions required by the project.

A liaison from the sponsoring organization provides technical direction and advice to the student team, monitors the project's progress, and ensures that the project meets the needs of the sponsor. The liaison also assists the team in making the best use of the sponsor's resources and facilities.

At the end of the spring semester, student design teams present their projects and reports, and demonstrate models and prototypes. Industrial sponsors, faculty members, members of the Design Advisory Board, prospective students, and members of the university community are invited to attend the event and to interact with the project teams.

4 Recent capstone projects with social entrepreneurship components

This paper presents two recent projects that were completed for the EPA P3 Program that are described in some detail below to identify the reasons the social entrepreneurial approach was required. The EPA P3 program imposes a minimum two-year time table on projects. A Phase I proposal must be submitted by December for a project award in August. This would encourage students that would span at least two years to participate. Juniors are encouraged to apply for the EPA project and then could participate as seniors. To promote continuity, faculty are now encouraging sophomores to apply for the EPA projects at the time the Phase I proposal is submitted, they could fill minor roles in the project team as juniors and then participate as seniors and assist in the Phase II proposal submitted at the time of the Phase I report in April. Many of the winning and competitive teams at the EPA Sustainable Design Expo contain graduate students in addition to seniors. Teams from our university have only undergraduates.

4.1 2011 - Briquettes from agricultural residue and other wastes for use in biomass syngas fueled power generation

This project developed and established performance characteristics for a modular, electric-powered feedstock processing machine that forms corn stover waste into pellets. Corn stover is the portions of the corn plant that is not used as food, and is normally a by-product of harvest. Development of the machine also incorporated multiple educational objectives while allowing the students to design and fabricate a machine in a multi-disciplinary team. Educational objectives included the need to consider sustainability of the finished machine, consideration of culturally-appropriate methods of support, maintenance and safety, and suitability for construction in Africa. The machine was required to be small enough to be mobile so it can be moved to where corn stover is common in order to increase sustainability and reduce transportation of the biomass. The need to have a mobile capability influenced the project outcomes in several ways.

If implemented, the project will greatly increase the sustainability of small generators that are currently used to supplement or replace an unreliable power grid. Use of syngas produced from corn stover will also reduce air pollution and carbon emissions when compared to gasoline, diesel, or wood charcoal fuels, and also will reduce the monetary cost of fuel.

To develop the mobile and modular corn stover processing machine the team reviewed current bio-mass densification methods and subsequently moved through a series of iterative conceptual design and evaluation cycles. The project team used real “on the ground” information gathered by the project partners, the Catholic Diocese of Kitale (CDK) and the Small World Educational Foundation (SWEF), to develop and evaluate conceptual process designs to select the preferred alternatives. Information gathered from the Kitale, Kenya, area included cost of electrical power from the grid, local material costs, availability of types of “salvaged or reusable” materials,

workers' wages, and business attitudes. This information was essential to address the social entrepreneurial approach for presenting the processing machine to potential adopters.

At the time of this publication, the Kenyan Shilling (KSh) exchange rate is 83 KSh = 1.00 USD, the cost of a liter of diesel is 100 KSh ($4.55/gal), and an agricultural worker earns between 200 to 300 KSh per day.

A hammer mill was fabricated using salvaged 18-inch diameter steel pipe for the case and 12 discarded connecting rods from a car engine for hammers. Power is provided by a reused 5-hp (3.8 kW), 220-volt, single-phase motor driving v belts. This hammer mill will process the corn stover into particles suitable for densification.

Evaluation of fabrication costs for densification of agricultural biomass using alternative methods supported the selection of the small roller and die pellet mill. Slurry waste in mixed into the stover material by using a salvaged, single-cylinder, two-cycle engine from a weed trimmer to act as a positive displacement pump. The stover material is moved by a salvaged auger from the hammer mill to the pellet mill. Pellets are collected in metal baskets to cool and for loading into the type of locally-sourced fiber sacks used to transport shelled corn kernels throughout Kenya.

Figure 1. Student team for bio-fuel project presenting their work at the National Sustainable Design Expo in Washington D.C., April 2011.

The machine is sized to process between 100 and 200 lb./hr. (50-100 kg/hr.) of corn stover. Estimates are that the biomass pellets can produce 0.50 kW-hr/lb., and to produce the pellets

consumes approximately 0.1 kW-hr/lb. The net energy content for the pellets would then be estimated at 0.40 kW-hr /lb. The net electrical energy from the biomass from 360 acres of corn would be between 22,800 kW-hr and 46,000 kW-hr and have a monetary value of between $4,560 and $9,200 using the cost from the Kenyan grid of $0.20/kW-hr. However, using a biomass syngas for the production of this amount of net power would replace the consumption of between 2,760 gallons and 5,520 gallons of diesel fuel for a 10 kW generator, and that displaced fuel would have a current monetary cost of between $12,558 and $25,116. Until performance testing is possible, the project team has used a Monte Carlo simulation of performance models to provide a distribution of likely performance measures.

Safety is a primary goal of the project. The safety of the operator is addressed from the standpoints of exposure to dust, noise, flying fragments, waste, and moving machinery parts. All five of these concerns were considered during the development.

The purchase, collection, transportation, and processing of the stover and pellets are costs of the biomass fuel and are estimated based on the information from project partners.

The most uncertain cost estimated will be the price that must be paid to each farmer to provide the stover material to the machine operator. Monte Carlo simulation provides a distribution of the estimated costs of the stover. Estimates are based on a rate for collection of 150-250 lbs. (75-125 kg) of stover per hour of labor for eight hours each day. A preliminary estimate for the cost of the stover material ranges between $0.015 and $0.04 USD/lb. (1-3 KSh/kg). Simulation provides a range of total material cost at the location of the machine of between $300 and $5,200 USD. The operation of the machine will require two people to process and load the resulting pellets into the sacks for storage. The cost of labor to operate the gasifier system is estimated to range between $1,090 and $2,515 USD per year. Machine maintenance is estimated to be 15% of the machine cost each year for a 5-year life.

The total estimated annual costs for the processing equipment, including stover material, operation and maintenance, plus purchase amortization range from $6,060 to $10,590 USD (503,000 – 879,000 KSh). In the Net Annual Benefit table, Table 1 below, this cost is compared to (a) the avoided cost of diesel fuel and (b) the avoided cost of grid electrical power.

The total cost to purchase and fabricate this demonstration processing machine is estimated as $3,800 USD. The estimated machinery costs for adding a gasifier and genset to produce electrical energy in implementation of the project are $4,500 USD for a 10kW generator and engine and $4,900 USD for the gasifier needed to fuel the generator. The financial analysis of purchase, financing, and expected business sales results, using Monte Carlo simulation is used to inform adopting entrepreneurs about the benefits and risks of the project. These detailed simulations indicate an 84.3% probability that this biomass syngas fueled generator project can achieve a 15% annual return on investment, even excluding the social and environmental benefits that are related to using non-fossil fuels to generate power in the Kitale, Kenya area.

Table 1. Predicted Net Annual Benefits of Project

Economic Measure	**Lower 90%Bound**	**Upper 90%Bound**
Total Annual Costs to Produce Biomass Pellets	$1,490 USD 123,700 KSh	$3,770 USD 313,00 KSh
Value of Grid Power (net) contained in biomass pellets @ $0.20/kW-hr.	$2,600 USD 215,800 KSh	$5,200 USD 431,600 KSh
Avoided cost of diesel to produce equivalent amount of electrical power	$7,330 USD 608,400 KSh	$14,600 USD 1,216,800 KSh

Note that the above results do not monetize various environmental benefits generated from the use of the bio-fuel pellets.

It is important to highlight the most significant result of this difference in cost. A person who has a need for electrical energy that is valued highly enough that the cost of diesel generation is acceptable, will realize an annual benefit of $20,529 using a biomass fueled generator when all monetary costs are considered. In addition, replacing the fossil fuel use has significant additional non-monetary environmental benefits and a biomass business will supplement the prosperity of the community more than fuel importation can. This is the value proposition for a Kenyan entrepreneur to implement this project.

4.2 2012 - Integrating Improved Sustainable Technologies into the Heart of the Home—the Kitchen

Many areas in East Africa are undergoing rapid growth and as a result there has been a significant increase in the number of people who live in the peri-urban zones that connect urban areas and farms in surrounding rural areas. In this boundary zone, the insufficient urban infrastructure does not meet critical health needs. Potable water, sanitation, and energy requirements must be satisfied if the families are to move towards a sustainable future. This project goal is to develop an innovative integration of sustainable technologies that address a household's immediate needs by focusing on activities in the kitchen. This goal will be pursued by using social and cultural entrepreneurship with the education and training required to empower women to participate in the implementation of technologies for mediating existing problems. Gonzaga students have completed three previous projects in Kitale, Kenya, and this project benefitted from the established partnerships and working relationships in Kenya with the Catholic Diocese of Kitale (CDK) and the Small World Education Foundation (SWEF). We can use these connections to train and encourage women as entrepreneurs to adopt the technologies developed.

The components of this project are:

a) Develop a prototype of a simple ventilation system that improves indoor air quality by using thermoelectric (TE) cells, driven by waste heat from the cooking fire, to energize a

12-volt battery charging system and power a small fan in a duct. Energy not required for ventilation can be stored for lighting, charging a mobile phone, or other needs.

b) Develop and test an improved ceramic filter geometry based on the Filtron filter. The improved filter requires less fuel per filter to fire the kiln, reduces production breakage, and simplifies shipping on local roadways.

c) Examined the use of corn stover briquettes as a cooking fuel in a typical Kenyan cooking application. The corn stover briquette production process was the result the 2011 EPA P3 project above.

d) Thoughtfully integrated outputs from objectives a through c above, applying innovation and entrepreneurial methods lead by engineering and business students. The team will develop required entrepreneurial resources so that the women can be empowered as agents of change who can promote adoption of these technologies into daily activities in the kitchen.

In relation to objective (a), women who prepare food commonly have young children with them at the cooking hearth. The majority of cooking in the developing world is still done by burning wood or charcoal. Smoke from burning fuel-wood exposes children and women to fine particulates that negatively impact their health and the cost of burning fuel-wood reduces the economic prospects of the family. An appropriate system to vent smoke from the kitchen will directly improve health and prosperity.

As for objective (b), an unacceptable proportion of homes in Africa, and throughout the developing world, do not have reliable access to clean water. Women are commonly responsible for providing the household water where infrastructure is limited. The work of hauling water also is often undertaken by the children in the family. Drinking water storage, including water used for cooking, is typically located in the kitchen. The Filtron is a ceramic pot water filter designed and promoted by the Potters for Peace organization as an effective method to remove 90%-99% of bacterial contamination, and is produced in facilities all over the world. Production of the Filtron is complicated by the size and geometry of the filter; it has a tall shape with pronounced bends that promotes production losses due to cracking and slumping. Because of the volume occupied by each Filtron, the kiln in which they are baked holds relatively few units.

Figure 2. Smoke Present in a Kitchen in Kitale, Kenya (Zimmerman-SWEF, 2009)

A filter shape that is flatter and seals against the walls of the bucket while still effectively removing water-borne pathogens is a superior design. A flattened shape allows a larger number of filters to be produced with each firing of the kiln, which in-turn reduces the amount of fuel-wood consumed and, thus, increases sustainability of filter production. A flattened shape also will simplify the shipment of completed filters and reduce the breakage of filters during shipment, improving the sustainability of production.

At the Maji Water Filter Company facility in Kitale, Kenya, it costs $1.00 to fire one Filtron, based on the kiln holding 50 Filtrons for each firing and a total fuel-wood expense of $50.00 per firing. Plans for the Maji facility are to add another kiln to increase production. The added capital and fuel-wood expenses could be avoided if an improved design is implemented to increase firing capacity and reduce breakage.

For objective (c), the Kenya project of 2011 developed sustainable biofuel briquettes from corn stover. A corn stover biofuel is carbon-neutral because the local maize fields are typically burned at the end of every harvest and use of the briquettes would reduce the consumption of fuel-wood in the home. Tests to confirm the corn stover biofuel briquette suitability as a cooking fuel for both a traditional 3-rock fire and a “Rocket” Stove are completed.

Figure 3. Filtron Filter (Earth Awards)

For objective (d), the project team will utilize the experience garnered from the previous projects completed in Africa to most effectively present the integrated technologies to the women in Kenyan and Ugandan homes. Our partners in Kenya and Uganda provide a reliable source of "on-the-ground" information and insight and information that will be used to prepare the operation and maintenance materials appropriate for the adopters.

5 Student learning and social entrepreneurship

There is a great variation in the content and complexity of projects, and in the requirements that student design teams meet. In addition there is a variation of the number of students on teams and the approach of the advisor and liaison. After examining methods of survey data collection, we determined that having the students develop a general narrative would present a more useful summary than a table of responses.

This paper presents narrative results from the two student teams. Both teams were comprised of a total of five students. Each student was asked to respond to a general question: "Describe how the project increased an understanding of the application of social entrepreneurship and address how applying concepts of social entrepreneurship affected the outcome of the project and your learning." Not all students submitted a response to the survey question. Responses are below.

5.1 Project 1. 2011 “Biofuels” project student learning and social entrepreneurship

5.1.1 Student 1. Male – Civil Engineering student

To me personally, the greatest strength of the EPA P3Biofuels competition project was the emphasis it placed on the need for the project to benefit the people, their prosperity and the planet. These goals tie in so completely in the framework of social entrepreneurship. To succeed in the P3 competition a project team must not only focus on designing and building a project that works, but one that is both feasible and improves the lives of the people in the region it is designed for.

So much of our discussion and effort throughout the design process revolved around ensuring that our design would not only operate in a profitable and reliable fashion but also that it would be useful to the people of Kitale and would positively affect the standard of living and the environment for the people. This concentration on an outcome that must perform and at the same time have a positive effect is missing in some of the more corporate themed projects available for students involved in senior capstone projects.

The P3 aspect of the project was the only reason I was ever interested in being involved in the project. If the project had simply been about building a good machine that could operate in a profitable way then there would have been no need for the multi-disciplinary team of civil and mechanical students assembled to meet this challenge. It would have been a very straight forward mechanical design project and could have been done in half the time. The problems presented by the incorporation of waste into the project to find a beneficial use for feces and the limitations presented by attempting to design a project suitable for construction in Kenya made this project infinitely more challenging and complex.

These challenges caused the team to stretch their abilities and research topics that they may never have studied had they been on a design project designed to be used in a developed area of the world. The cultural research and considerations brought to light how fortunate the people of this country are and how much more difficult even simple design tasks are for people in other parts of the world.

The true challenge of the project in its most real and basic form is to sell the concept and market it in such a way that it will be adopted on the ground by the people that it is designed to help. If it can be packaged in such a way as to get their support and their cooperation then it is much more likely to be a wining project in the eyes of the competition judges. Too often the goal of the project team will be to create a project that works, to design it, build it and test it. These accomplishments are not enough however. The project must sell itself to the people that will be implementing it and that ability to sell itself must be apparent to the EPA judges.

These challenges all combined to provide a challenging and beneficial learning experience that I don’t feel could have been duplicated in any other project outside of the P3 or some other type of

NGO sponsored project competition. Most students will end up working in a corporate environment and will therefore gain valuable experience in a corporately sponsored project but the luck few who find themselves in a P3 project have the opportunity to go one step further and strive to make a difference for people who need their fresh ideas to make a difference and begin real change.

5.1.2 Student 2. Female – Mechanical Engineering student

Although a new concept, social entrepreneurship is not radically different than its parent, entrepreneurship. The biggest difference between the two forms of business creation is the expected lifetime of the business model. Traditional entrepreneurs implement a continuous growth pattern to drive the development. Social entrepreneurs acknowledge that if their business plan is successful then it will eventually cease to exist. The goal of a social entrepreneur is to permanently solve a problem facing an underserved population. The original business plan will become obsolete as the economy is strengthened by the support of the enterprise. Ideally, the economy will not be affected by the once the social enterprise discontinues its service. All social missions have an end date even if it might not be in the predictable future.

The implementation of the 2010 EPA Phase I project was influenced by this idea. The original goal of the briquette project was to provide individuals in the areas surrounding Kitale, Kenya with a low cost means for electrical generation and independence through biomass waste. Using this aspect of social entrepreneurship, the students saw an opportunity to create a social business plan to inspire a wave of new business people in Kitale, Kenya. The students created an implementation plan to advertise and sell these machines as a means for a small business. Partner NGOs and the students would provide technical and business support to the first time buyers. As these newly minted business people gain an understanding of the process and technology, our support will no longer be required. The early adopters are then leaders in innovation in their community and are sources of knowledge for the new and profitable energy generation market.

Once the famers gained energy independence from the unreliable national grid and the new market was established, we would no longer provide support to the project. The success of the project would be measured in the amount of new entrepreneurs that were filled our void.

One of the cardinal rules within social entrepreneurship is to work within your community. Only community members truly understand the workings and politics of their family, friends and the environment. Although change from an outside source is possible, internal change is the most efficient and effective way to inspire a status quo change. An endorsement from a trusted friend or leader of a community is the quickest way to spread adoption of a new way of life. An "outsider" needs to spend additional time gaining the trust that these community members already share with each other.

Before the project began, the students knew that their partnerships with "on the ground" NGOs and local farmers would be invaluable to the success of their project. Without this input, the design would not be appropriate to the situation or environment of Kitale. The students also relied on these locals to spread the word of this technology and aid in its distribution to the community. These partnerships were critical to the success of this project because it allowed a viable point of entry into the community. Through the observations of other people, we were given a looking glass to examine the culture and environment of the people we wanted to serve.

An unexpected, but critical, factor to the success of any social enterprise is using the littlest amount of money to make the biggest impact. Any large amount of money or capital makes a project or enterprise very difficult to sustain. Although the main objective of a social enterprise is to go out of business, few, if any, economies can survive a one-time injection of cash. The most effective social change comes from generating internal wealth and growth in a community.

This idea was important to the formation and implementation of the capstone projects. Although the end users have a very limited, tight budget, they will still be required to purchase the pellet mill and gasifier. The ownership of capital is crucial to any small, start-up business. The students understood that it would be difficult to attract customers to a new and, relatively, expensive product. A lot of time was dedicated to proving that this technology was the cheapest to generate power. The students also spent considerable time ensuring the machine could pay for itself by a certain amount of years. The customers were required to purchase the machine because the students knew the investment was low risk and would generate profit. Financial incentives would have made the implementation of this technology easier but the customers would be able to generate their own independence and wealth by spending the necessary capital.

All social enterprises require a huge amount of forethought and consideration in all aspects of the situation. The addition of a social entrepreneurship aspect to these capstone projects increased the complexity and scope of the original problem drastically. Without the necessary consideration of social enterprise, the capstone project would never succeed.

5.2 Project 2. 2012 "Integrated Sustainability to Improve Health" project student learning and social entrepreneurship

5.2.1 Student 1. Male – Civil Engineering student

As an engineering student at a Jesuit, Catholic university I am often asked to considered the "human aspect" of my work. How am I able to use my skills as an engineer to enact positive, lasting change with each project? By working on a project to improve indoor health conditions I found myself improving both my engineering skills and my ability to create that positive, lasting change. To increase the adoption rate of our solution, the team opted to approach this project similar to how a businessman would approach a new venture. To be successful, we had to intimately know our customers.

The customers' needs were easily definable: many were living in poor health conditions because they cooked in a particulate-filled kitchen and drank unclean water. Given that African women are primarily responsible for the household cooking, we could further tailor our product and implementation plan. Understanding our customers also helped us define parameters that we needed to work within. Our solutions needed to be low-cost, easy to use and created from local materials.

I believe that our final water filter design was significantly improved by approaching this project in an entrepreneurially-minded manner. Ceramic water filters have been developed all over the world and an enormous amount of literature exists on their design and removal efficiencies. While we could have easily taken a previous design and made minor modifications we understood that those minor changes wouldn't amount to the change that we wanted to create. We wanted a filter that would be durable and cost effective. It needed to remove particulate and bacteria as well or better than existing filters, but not be so difficult to produce that it couldn't easily be done with the limited resources found in a rural African village.

Understanding our customer played a critical role in the design process. Our filter design initially resembled a plate sealed to the side of the bucket with a rubber gasket. While we knew that this design would be durable, use less material and achieve our target removal rates, we realized that it would create a new problem for its users: finding a rubber gasket. Instead, we sought to eliminate the rubber gasket, an item that inevitably would have had to be imported, by inverting the filter and simply sealing it the bottom of the bucket with a ribbon of beeswax for a seal. Beeswax, readily available to African farmers, would be cheaper and easier to obtain than a gasket and could provide the water-tight seal that was necessary to prevent cross-contamination. By thoroughly understanding the limitations of our customers, the villagers of rural Kenya, we were able to develop a solution that met their needs in an efficient manner.

5.2.2 Student 2. Female– Civil Engineering student

The importance of a senior design capstone project is in teaching students to utilize the theory and discussion from their classroom experiences with real world examples. During these two projects, students were subject to another level of understanding by adding the difficulties of cost and integration of solutions in a third-world country as well as being both practical and sustainable.

Personal growth was seen when something as simple as using silicon to seal the redesigned ceramic filter to the bucket had to be further simplified to minimize cost and be readily available in Africa. During a brainstorming session, the trial solution of beeswax became a viable option. I further learned that the problem is not whether our design team could develop a simple, low-cost solution, but whether those in need of the solution see a problem to the original methods they are using. This is where social entrepreneurship becomes as important as the solution itself. It first begins with educating the community in question. It is important to go in with the goal of a hand

"up" versus a hand "out". An individual will be more receptive if they understand the problem as well as the solution.

As a design team, we see that combining social entrepreneurship with respect to our project, by seeking out, educating, and enabling a respectable woman in the community to teach others and improve her own income, will increase the likelihood of successfully implementing our solutions thereby improving the health of others.

5.2.3 Student 3. Male – Engineering Management (Business minor) student

The two projects, briquettes from agricultural residue and other wastes for use in biomass syngas fueled power generation and integrating improved sustainable technologies into the heart of the home - the kitchen - have both led to an increase in my understanding of the application of social entrepreneurship due to their ability to force me to focus on not just monetary good, but the most basic good, the well-being of others. Although it is inherently difficult to measure and compare, these two projects were able to bring the social good to the forefront of how we were to develop and go forward with our ideas.

Having been asked to join this team late my perspective at the beginning of the project was a little skewed. I came in with an engineering, entrepreneurial, and business background. Being a part of the School of Business Entrepreneurial program had allowed me to be exposed to not just entrepreneurship, but social entrepreneurship as well, but what I expected the project to be focused around was how much money could be made from the products that were being produced. After the first meeting though I quickly figured out that the project was not centered on making money, but making people's lives better. It was in this light that I found a new way to view social entrepreneurship. In the entrepreneurship classes that I have taken, many of the social views were from those that had started their own small businesses in third world countries and did not often discuss examples of outside entrepreneurs coming into these countries and making a large impact. Not to say I had not heard of examples of this happening, the book Three Cups of Tea is a great example of this, but these cases did not seem like the norm to me. Having now been on this project for a semester my understanding of the application of social entrepreneurship has greatly broadened. I did not realize that a handful of motivated engineering students could come up with a product that has the ability to changes hundreds of lives, if not more, for the better due to their ingenuity, creativity, and ability to work together through the different obstacles that were brought to them. It does not bother me that I may never know the true value of our product, the fact that it in some way has the ability to help others allows me to not worry over what kind of value the products might have.

As was said above, social entrepreneurship is a pretty over-arching idea in our project and because of this, its concepts were used often and helped to improve the outcome of the project. With the ideas of social entrepreneurship floating around our meetings, we were constantly reminded of how our goals were to bring about the most good, not necessarily to make the most money. Because we know our end goal is not to make as much money as possible and that these

people do not have a lot of money to spend in general, our ideas as to where we would be getting our supplies for certain pieces of our products got quite creative so that they would be affordable and everyday things that could be readily obtained. Along with helping to improve our project, the concepts of social entrepreneurship helped further what I learned as well. With its unique perspective, in today's world, that the greatest good does not necessarily mean acquiring the most money, social entrepreneurship has taught me that entrepreneurial ideas can come from anywhere and relative to nearly any idea.

6 Conclusions and future actions

Based upon the experiences of the authors and narrative summary of the student learning experiences, we draw several conclusions from these two projects.

Having a real need to employ social entrepreneurship makes the learning of many detailed concepts more relevant to students. Application of the engineering design process to achieve a novel solution to relatively complex problems in an unfamiliar cultural context makes many more of the learning objectives contemplated in the ABET criteria achievable.

Having projects in developing countries provides increased opportunity to employ creative and innovative applications of engineering fundamentals since there are fewer codes and standards that are applicable and/or available. Using U.S. standards is sometimes not possible due to material, fabrication and maintenance requirements.

Students commonly report that projects that offer to make significant improvements in people's health and that can even save lives provides a powerful experience that they often mention even several years after the project ends. This experience has been a motivation for large interest in humanitarian service by many graduates of our program. Our university has notably high student participation in Peace Corps and other NGO activities.

Projects with social entrepreneurship content provide natural and significant opportunities to integrate business and social science knowledge with engineering technologies in ways that are essential to the consulting industry. This integration is difficult to emphasize in conventional engineering coursework.

These projects provide context to students so in the future they can take more easily consider what is really needed to achieve project objectives, to understand what does a client want, what does the client need, and to distinguish from what the engineer wants the client to want or need.

The two projects that are used as examples in this publication were both more challenging to advise and mentor by the faculty team members than what could be termed typical projects. Based on these two experiences the faculty members will scale down the scope of future projects so objectives can be achieved with a more reasonable schedule.

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