88. Using in-country experience to co-create a design for a sustainable solar headlamp for a rural community in the developing world

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Abstract

Designing sustainable technologies for the developing world is a challenge for students in the developed world because the customer's needs and capabilities are generally not well understood by the students. Having a clear understanding of the capabilities of the user is paramount to the success and sustainability of the technology. In this project, a sustainable solar headlamp was designed to be used by medical attendees in rural Nicaragua. An initial design was developed prior to an in-country field experience, and then significantly modified through a co-creation process, working with members of a rural community in Nicaragua. This paper describes the philosophical approach towards the development of the sustainable solar headlamp and how the design evolved through the co-creation process to take advantage of local resources and skills to create a design that could be maintained, repaired, and replicated by community members.

1 Introduction

A community that lacks advanced technology is like a blank canvas for innovation, which is enticing to capitalistic and philanthropic engineers alike. However, numerous well-intentioned projects designed for communities in developing countries have failed due to a lack of contextual understanding. The ways in which the technology fails to be sustainably implemented are numerous. However, many failures are rooted in a lack of understanding of either the recipient of the technology or the infrastructure needed to support the technology. When student engineers from a developed country design technology for implementation in a country with very different cultural, economic and environmental characteristics, the design environment for advanced technology can become quite complex. Current US engineering students are very interested in philanthropic engineering projects as illustrated by the growth of Engineers Without Borders chapters at US universities. Therefore, it is relevant for engineering students to have an awareness of these non-technical design challenges and an approach to find both technical and non-technical solutions.

2 Philosophical Basis for Engineering Approach

2.1 Introduction

Technology implementation in developing countries is inherently unique. A severe lack of local resources and a limited number of external supply chains creates many design challenges. In communities separated by great economic or natural barriers to the global market, often the conditions can be difficult for students to comprehend, especially when they are used to an abundance of such resources in developed countries. A survey compiled by the World Health Organization indicates that technical failure is indeed common as exemplified by conditions in Africa. "The introduction, utilisation and maintenance of health care equipment require substantial financial, organisational and human resources. Often, this is either not recognized, or not enough attention is paid to it. In the Sub-Saharan Africa region, for example, a large proportion (up to 70 per cent) of equipment lies idle due to mismanagement of the technology acquisition process, lack of user-training and lack of effective technical support." (World Health Organization, 2000) Identifying the critical social, environmental and economic characteristics of the area, and designing the technology to fit those characteristics is fundamental to the success of the technology.

2.2 Whole Systems Thinking Approach

Since the task of engineering technology for developing countries can quickly become complex with multi-faceted and interconnected obstacles, it is important to have an approach with clearly defined objectives.

An overarching tactic that should be considered is Whole Systems Thinking. The students should be challenged to state the problem in the context of the larger picture to reveal important links to non-technical conditions. Non-technical conditions such as the literacy rate of a community or the walking distance to the nearest town could significantly affect the success of the project. The risk of failure during implementation can be reduced if Whole Systems Thinking is applied during an iterative design process, because it forces the student to consider more variables that could impact the project.

Students should be encouraged to think about the impact and functionality of their proposed design not just in the use phase but also across the life cycle of the project. A life cycle assessment that considers impacts of a project from an early stage to the end-of-life is an effective process for uncovering challenges and impacts of a project through a whole systems perspective.

2.3 Key Elements: Customer Needs and Infrastructure for Resilience

During the co-creation process, there are two key elements that should be considered for successful implementation of the technology. The first is to consider the needs of the customer. The second is to consider the infrastructure needed to support the technology.

The characteristics of the project recipient (or customer) are highly important for successful implementation. While this may seem obvious, it is a common pitfall for an engineer from abroad to misunderstand the real-life situations that drive the need for technology in a developing country. In 2000, the *World Health Organization* created guidelines for donating medical equipment for developing countries, because its members recognized that "although donors' intentions are unquestionable, often, their lack of awareness of the local realities of the intended beneficiaries leads to unforeseen consequences of the donation at the recipient's end." (World Health Organization, 2000)

2.4 Understanding the Recipient (or Customer) of the Technology

As has been mentioned, a specific challenge to successfully implementing technology in developing countries understanding of the recipient (or customer) of the technology. It is not an easy task to understand the needs of a customer who is living in community where the culture, language, income and education level are very different to those of the designer. In the design phase, it is easy to overlook the influence of these variables if they are not intentionally considered. If these non-technical qualities are not considered, the engineer is more likely to make assumptions about the characteristics of these variables. Even if they are considered, it is often difficult to discover the true characteristics of these variables. The more the intended recipient community is removed from the global market, the harder it is to find accurate, descriptive information about the community from overseas. Essentially, in places where there is limited to no internet connectivity, knowledge of the community must come from first-hand experience, or a reliable first-hand account.

A best practice to avoid the pitfalls associated with these non-technical challenges is to develop a preliminary prototype based on the best-available information about the intended customer and environment, and then continue to develop the prototype with real-time input and assistance from the customer and any local people critical to the sustained functionality of the project. While it seems like an arduous task, the most effective way to co-create is to spend quality time in the country. If the student is not able to experience the variables of the country first-hand, he/she should be in direct contact with someone who is.

Being that the ultimate goal of the project is to implement technology in a developing country, quality time should be spent considering how the design can be improved based on input from local people before the technology is formerly introduced into the community.

2.5 Developing an Infrastructure for Resilience

The other critical piece of successfully implementing technology in developing countries is developing the infrastructure that will support the creation, maintenance and repair of the technology into the future. This might be referred to as *resilience*, as it is these elements that will give the technology a greater chance of sustaining mechanical failures or changes in environmental or economic conditions. The infrastructure will also increase the likelihood of in-country innovation or scaling.

At the most basic level, the need for resilience is rooted in the first-mentioned aspect, which is maintenance and repair. No technology - no matter how robust - will never break or degrade in performance. In places that lack reliable communication to the global economy, this can bring swift failure for advanced devices. For example, imagine a small solar powered device built by engineers in the United States with globally sourced components. The power system is a self-contained, intuitive device, and the local people are knowledgeable on how to use it. However, consider for example that the micro-controller stops working due to unforeseen exposure to high temperatures. The members of the community want to tell the engineers in the United States that the system is broken, but they have no internet or telephone connection. Even if they did have a means by which to communicate with the developers, it would be very difficult to get a replacement micro-controller to the community. In many developing countries, customs at the border and the greater system of mail delivery are corrupt or unreliable at best.

Therefore, it is very important to develop a technology that is partly based on the existing available resources and partly based on the projected availability of an intentionally developed infrastructure. Both of these can be achieved through the co-creation process. Local community members will transfer a good understanding of the currently available resources and skills. Engineers visiting a community will have the ability to build capacity for the technology by getting local community members interested and involved in the project. If interested individuals are identified and educated on the technology, the local community members are more likely to take responsibility for maintaining or repairing the technology.

3 Development of a Sustainable Solar Headlamp in Nicaragua

3.1 Introduction

The inspiration to develop a sustainable solar headlamp came from two separate groups developing solar power systems for rural health clinics. One was *WE CARE SOLAR*, which builds and implements a suitcase-sized solar power system, which powers medical lighting, radios, computers and small medical devices. The WE CARE Solar Suitcase was originally designed to support timely and efficient emergency obstetric care, but can be used in a range of medical and humanitarian settings."(WE CARE SOLAR, 2013) However, a Solar Suitcase costs between $1,000 and $1,500 USD. While a Solar Suitcase may be purchased by a well-supported clinic or hospital, Dr. Stachel expressed that there was a need for an even lower-cost solution that could be distributed to the clinics without a significant investment of time or money.

Another organization, Power Up Gambia, works on larger solar installations for rural health clinics in The Gambia. While their completed and forthcoming projects do bring incredible benefits to the recipient community, the solar installations can cost anywhere from $105,000 to $300,000 USD. (Power Up Gambia, 2011) Lynn McConville, a member of Power Up Gambia, expressed that she felt there was a real need for an expedient, simple, and inexpensive product to address the lack of rural lighting in developing countries. It was initially suggested that even a small device like a headlamp would be effective in assisting rural health care workers during the darkest hours of their patients' lives.

Over two years in the United States, first and second generation prototypes of a solar headlamp for rural medical attendees in developing countries were developed. The prototypes were built using the resources available in the United States, which was not suitable for implementation in Nicaragua. Therefore, only the electrical component of the prototype was taken by Amanda DelCore to Nicaragua with the intention of designing the rest of the headlamp in the country. Due to the nature of the place where she chose to develop the headlamp, there were already interested, educated community members willing to learn about the construction of the headlamp. However, building a supportive infrastructure and understanding the needs of the recipient would be a more gradual process.

3.2 Co-Creation Process: Building and Infrastructure for Resilience

As part of this research, three months were spent by Amanda DelCore in the northern region of Nicaragua in a small town called Sabana Grande. The town was close to a major highway, but was otherwise a small town. There was a nearby health clinic with limited services, very small stores run out of peoples' homes, and the Solar Center, which was a satellite project of the National Engineering University (UNI) in Managua, Nicaragua. During this time, she worked with a local engineer, Mauro, who was familiar with solar technology to build electrical prototypes of the solar headlamp. Mauro developed soldering skills while Amanda learned from him where to find commonly available local materials. Often, this was a matter of understanding *who* to contact for these materials. As Amanda, a student engineer, and Mauro worked alongside one another, the solar headlamp design took on characteristics that were unique to Nicaragua.

It was also revealed who in the community would be able and willing to be part of the infrastructure. Bamboo for the body of the headlamp could be purchased from a local farmer cultivating bamboo; the wood worker who had power tools was interested in building a prototype, a shoe repair shop could supply rubber components, and an intelligent young student who had dropped out of high school had his own creative ideas for the project. Identifying these people in the community was the first step of building an infrastructure for resilience.

The next critical step in building an infrastructure for resilience is education. Indeed, the local people can teach engineers abroad about the environmental, social and economic conditions of the area, which is discussed in the section "Understanding the Recipient (Customer) Needs through Co-Creation". Educating the interested community members about the solar headlamp is equally as important. The headlamp is a teaching tool for electrical engineering, but also for appropriate technology and sustainability. Because people in developing countries are still exposed to advanced technology, the concept of appropriate technology still needs to be introduced.

To illustrate this last point, it is fitting to describe a particular stumbling block that the young Nicaraguan student, Miguel, experienced while developing his prototype. Somehow, Miguel had acquired a small switch fit for an electronic device. He incorporated this switch into the design of his own solar headlamp prototype. Figure 1 shows his simple but functional design.

Figure 1: Locally Designed Headlamp Prototype

However, Miguel lost the tiny switch. Despite visiting every hardware store in a nearby town, a similar replacement switch could not be found. Miguel's mishap was exemplary reinforcement for finding a balance between building up the infrastructure for advanced technology and reducing the complexity of the prototype to fit the resources and needs of the local community. This experience led to the creation of a switch that was made out of readily available materials that could easily be replaced. Figure 2 shows the template ultimately used for a switch to be used with a bamboo body.

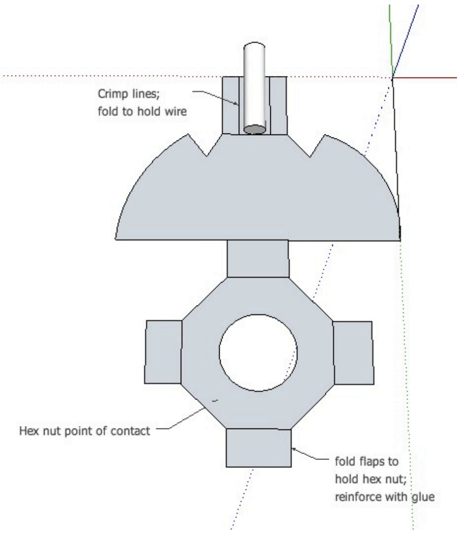

Figure 2: Sheet metal cut-out template

Figure 3 shows the folded and installed switch.

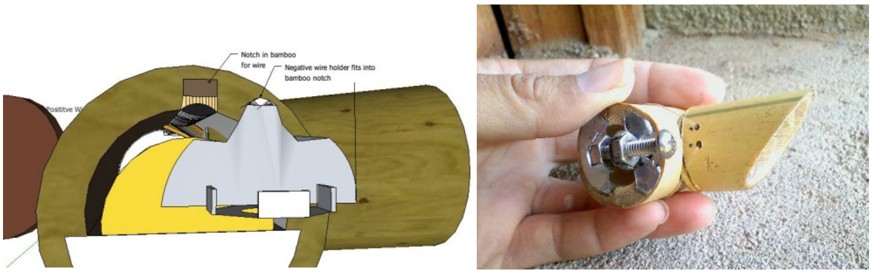

Figure 3: Installed Switch

The event also reinforced the importance of education as a building block to resilience for advanced technology. Through the co-creation process, innovative and locally-appropriate ideas are cultivated, and can be refined with guidance from an engineer from abroad.

Identifying and educating interested community members lays the foundation for further development of an infrastructure for resilient technology. After this foundation is established, it is more likely that the region could support incremental advances in technology. Teaching this principle to university level student engineers aspiring to work in developing countries could have immense benefits to the overall project success. Considering the infrastructure for development emphasizes the need to consider the larger context than in traditional engineering, which can be very focused on only the technical variables. It could also have a very positive impact on the overall intellectual development of the students. It will also help the student engineers consider the life cycle of the project if they need to ask questions about the systems in place to continue the project after their involvement dwindles.

3.3. Co-Creation Process: Understanding the Recipient (Customer) Needs

The co-creation process can also help students understand the needs and characteristics of the recipient as well as the characteristics of the people needed to sustain the technology. For example, by working with local community members, it is possible to understand what materials were and were not readily available. Scrap metal, metal hardware, electrical wire, rechargeable AA batteries, bamboo, rubber and string were all good examples of materials that could easily be procured. Small electrical components such as switches, battery holders, solder and small springs could not. Economic limitations also became apparent through the co-creation process. By working with local community members, it is possible to understand what the average person was willing to dispose of on a weekly basis for non-necessity items. This kind of information is critical to the success of advanced technology in developing countries, and it is often hard to obtain without visiting a region. Due to the remote nature of communities in developing countries, information is not readily available online as it might be in the developed world. Through first-person experiences or first-hand accounts, students should be exposed to these critical details before attempting to implement advanced technology.

For example, the perceived need for a solar headlamp was communicated from other engineers visiting developing countries. With this background knowledge, it is easy for an engineer to go to a developing country with a pre-conceived idea of the problem and its solution, which is devoid of a grounded, contextual basis. The research and co-creation process for the solar headlamp took place in Sabana Grande, which is neither an extremely remote location nor a well-connected communication. For the research conducted in Sabana Grande, it wasn't immediately apparent that the recipient needs for a solar headlamp in Sabana Grande would be different than the needs communicated by other engineers with experience in remote areas. However, after having time in-country to observe the non-technical aspects of Sabana Grande, it was apparent that the customer needs and capabilities would vary greatly depending on the specific social, economic and environmental setting.

For example, there are people living in very remote regions of Nicaragua that can only be reached by a combination of treacherous unpaved roads and trails navigable only by foot or horseback. The inhabitants of this region are effectively disconnected from any timely, modern health care. After speaking with the medical attendees in these regions, it was apparent that they had an identifiable need for a robust and resilient solar headlamp. However, in the Sabana Grande region, the community was connected to modern health care by a major highway. (A major highway in this part of Nicaragua is a paved, two lane road.) Because so many of the cultural characteristics were the same in Sabana Grande as in the very remote regions, it was incorrectly assumed that the need for a solar headlamp would be the same.

The nearby highway changed the way local health care workers attended to their patients, and it created a different set of needs for the end user of a solar headlamp. I spoke with local health care volunteers, the regional doctor that visited the local health clinic on a monthly basis, and finally, the nurses at a nearby hospital. I discovered that the hospital was typically able to send an ambulance for extreme emergencies in Sabana Grande. As a result, the local health care workers were less skilled in emergency care, and would probably only need a headlamp to guide patients in critical condition to the ambulance in the dark of night. What this town really needed was a better radio.

Engineering students with a preconceived idea of a problem in a developing country need to spend a significant amount of time understanding the needs of the recipient in order to avoid common pitfalls. Non-technical aspects like economic limitations, cultural tendencies, geographic location, and educational level of the recipient are very important factors that should be folded into the technologic design parameters.

4. Results and Summary

The final design of the solar headlamp is the most recent iteration of the design, because the design should change based on a growing understanding of regional nuances and the infrastructure for sustainable technology. The most recent iteration of the solar headlamp features a design that sits on the forehead and provides directional light, which is shaped by a cylindrical piece of bamboo (see Figure 3). The switch sits on the side of the lamp that corresponds to the battery negative contact, and a rubber closure holds the battery on the opposing end. The headlamp uses one AA NiMH battery, which is charged by removing it from the headlamp and placing it in a very simple solar charger. The whole system cost is $30.00 USD; however, the solar panel cost is $20.00 USD, which was made by the local engineer and is a fair price for materials and labour. This design is effective for use by the intended recipient (as affirmed by volunteer medical workers), and could be brought back to the Solar Center where it was 'manufactured' for repair or maintenance. This design meets the customer's needs by providing a reliable source of light at night, and by providing education to the local people who support the device.

In summary, it is imperative that students in higher education pursuing improvement projects in developing countries are educated on the non-technical aspects of the project. Engineers especially, would benefit from considering a wider set of variables when designing the project. Student engineers can learn the non-technical aspects of a project through the co-creation process in partnership with interested, local people in the recipient community. This will greatly increase the project's chances for sustained success, because the final design will inherently have qualities that reflect the formal education of engineers abroad as well as local intelligence. This balanced approach ensures that the engineered solution is more advanced that the existing technology but is also socially, economically and environmentally appropriate for the region.

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