AC 2007-2499: ETEAMING WITH DEVELOPING NATIONS: SOCIAL OUTREACH WITH AN ENTREPRENEURIAL TWIST

Mario Blanco, California Institute of Technology

Ph.D., Chemistry, UCLA (1983). 1993 - present, Director Process Simulation and Design Collaboration, MSC at the Beckman Institute, Caltech, Pasadena, CA. 1990 - 1993 Senior Scientist, Product Manager,Biosym/MSI, Sunnyvale, CA. 1984 - 1990 Senior Scientist, Computer Applications Research, Rohm and Haas Company HONORS: 2002 Winner 2002 1st Prize in Nanotechnology Design, Institute for Molecular Manufacturing 1991 Science Nominee, Smithsonian Institution 1990 Recipient of Cray Research 1990 Supercomputing Award 1979-84 NICO Canadian Mining Graduate Fellowship PROFESSIONAL SOCIETIES: American Chemical Society American Academy of Nanomedicine (Founding Member) UCLA Alumni Association

Kenneth Pickar, California Institute of Technology

Visiting Professor of Mechanical Engineering (1998-present),J. Stanley Johnson Professor (1999-2003)California Institute of Technology, Pasadena, CA. Teaching courses in Entrepreneurship, Management of Technology, Product Design for the Developing World. Coaching start-up Ventures; Presidents Advisory Board for JPL, Co-PI of NSF-funded Entrepreneurial Postgraduate Fellowship Program 2005 Award for Excellence in Teaching by Undergraduate Students of Caltech Board of Directors, Level One Corporation (1997-1999) (was on NASDAQ, later sold to Intel in 1999). Board of Directors, Neustar Corporation (2000-). IPO NYSE in June 2005. Board of Directors, H2Scan Corporation (2005-) Operating Committee, Idealab (2004-) (1999-present) Tech Coast Angels (LA) UCLA Anderson School of Business Visiting Lecturer, Global Access Program (2005-) 1993-1998 - Senior Vice President, Engineering and Technology Allied Signal Aerospace, Torrance, CA (now Honeywell), Chief Technical Officer 1983-1992 - Manager-Electronic Systems Research Ctr.General Electric Corporate Research and Development, Schenectady, New York Corporate Manager for Electronics Technologies

Luz Marina Delgado, GEMA

Anthropologist Luz Marina Delgado has a 30 year career devoted to the improvement of the lives of Guatemalan indigenous people. She is the author of "Manos de Mujer" (Woman's Hands), a book documenting indigenous technologies for rural areas in the highlands of Guatemala. Bill Garret, National Geographic Senior Editor, called this book a Survival Manual for Indigenous Guatemalan women.

Jeff Kranski, California Institute of Technology

Engineering Graduate Student, Teaching Assistant, California Institute of Technology

Oscar Arce, Universidad Rafael Landivar

Professor, School of Architecture and Design, Universidad Rafael Landivar. Director of the Instituto de Investigación en Diseño (INDIS, Design Research Institute) at Universidad Rafael Landivar.

Francoise Herrera, Universidad Rafael Landivar

Vice-Dean, Facultad de Ciencias Ambientales y Agrícolas (FCAA), Universidad Rafael Landivar

Charles MacVean, Universidad Rafael Landivar

Dean, Facultad de Ciencias Ambientales y Agrícolas (FCAA), Universidad Rafael Landivar

e-Teaming with Developing Nations:
Social Outreach with an Entrepreneurial Twist

Abstract

The World Bank estimates that over 2.8 billion people live in poverty, earning less than $2/day. Financial assistance alone has not been able to solve the problems generated by poverty in a sustainable way. We are testing the hypothesis that the teaching of product design principles together with basic entrepreneurship skills might be a way to provide longer-lasting solutions. These ideas are based on the premise that *although cash might be the most pressing need of the poor, the most vital need is the acquisition of income generation skills.* Major challenges arose in the initial testing stage, from the formidable physical and cultural distances that separate the design engineer/teacher from their intended customers in developing nations, to the lack of "ground truth" information to guide the design process. For this reason, over the past two years E105:, *Product Design for the Developing World,* a Development Engineering course at Caltech, has evolved to include e-Teams as an integral element in its curriculum. The e-Teams bring together students from the US and industrial design and agricultural students from a developing nation. The US engineering students contribute their fast prototyping and analytical problem solving skills while the foreign students contribute their familiarity with poorly defined markets and add cultural sensitivity to the e-Team designs. The students deal with strong constraints on product costs and pricing, evaluate the availability of local materials and the lack of manufacturing and product standards. The e-Team members work together through a variety of electronic communication technologies: Video-conferencing, video streaming, Instant Messaging, Internet telephony, e-mail and web-groups. These electronic tools, which play a role at various levels in the design process, are briefly discussed.

1.0 Introduction

A new effort to find solutions to extreme poverty around the world is taking place at various academic institutions around the United States. A new discipline is emerging, which we will refer here as "Development Engineering". In some instances, such as at Caltech, it is the students who initiated the effort to create relevant curricula. These efforts have been channeled towards the creation of a new course, E105, Product Design for the Developing World, at Caltech over the last three years. The course gives engineering and design students the opportunity to be creative and to take active leadership roles, exposing them to social, ethical, and political issues that will prepare them to be industrial and community leaders in a world increasingly influenced by issues raised by globalization.

Similar efforts are taking place at MIT [3-6], while at other institutions, such as Georgia Tech, these efforts take a complementary approach in what we now know as "Sustainable Engineering". Sustainable Engineering emphasis is on conservation and balance of problems brought about in a post-industrial society, problems such as pollution, unmanageable urban sprawl, natural resource conservation, and etcetera. Sustainability seeks to create "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs..." [8]. Examples of sustainability include solid waste management and recycling, water saving landscaping, green technologies, and product reuse

among others. On the other hand, Development Engineering seeks to "assist local innovation to create income generating goods and services as the essential means to alleviate extreme and moderate poverty in a pre-industrial, mostly rural, developing community". In broad terms one might say that both emerging disciplines "light the same candle from different ends", one seeking solutions to the uncontrolled use of resources brought about by modern consumerism, the other the establishment of viable micro-industries that can help prevent the destruction of natural resources and biodiversity caused by extreme poverty which drives human encroachment into naturally sensitive habitats.

E105 Product Design has evolved over the past 3 years to focus on products appropriate for the developing world. E105 seeks to harness the creativity of engineering and design students to make products the developing world wants and can profit from. The class combines lectures on product design methodologies combined with a special emphasis on the cultural context of the target customers- the over two billion people who subsist on less than $2/day. The students not only study the standard issues of product design -market, manufacturability, cost, usability, safety, and environment- but are also engaged in understanding how the product can be made sustainable in a business context, i.e that the productivity gain to the user must be high and the cost must be so low that a small business can be created to quickly repay the user for the cost of the product and to invest in future sales. An outside guest lecture series is held in parallel to the class through the auspices of the Caltech Chapter of "Engineers for a Sustainable World" (ESW).

1.1 e-Team Rationale

It has been long established that a major component for success in product design is a close contact with the intended customer. This is true even when the designer and the customer share a common culture and are close together physically. A major challenge thus arises from the distance of the locations we are trying to serve from Caltech and the formidable cultural differences.

Most approaches on this subject rely on the creation of "proxy" customers, idealized forms of third-world subjects with data gathered from public sources. These approaches are less than ideal because developing products for the developing world requires attention to a multitude of factors not sufficiently taken into account in this "proxy" customer model. These include:

- Cultural, religion, ethnicity and gender differences
- Lack of infrastructure and/or communications: transportation, power availability
- Government interference and corruption
- Ethics of previous projects, a history of exploitation
- Business partners of variable reliability
- Lack of a large well established middle class
- Business sustainability and access to capital
- Lack of Social Organization
- Appropriate profit/tax system
- Distance between developers and users
- Differences in product cycle time

Thus, the engineering student teams need the necessary field data and the proper market research to create realistic product specifications that take these issues into account.

After the first year we simplified the problem to some extent by concentrating on rural Guatemala and using US based intermediaries with experience in this area. The consensus was that the class benefited from this focus, especially since some students had some familiarity with the region and the mentors were extremely helpful in vetting the ideas that the students generated. It has always been recognized, however, that direct in-country contacts would improve the interaction and enhance the learning experience. Attempts to set up these contacts were unsuccessful.

In summary, our intention was to use the e-Team approach to speed up the product development process and increase the success rate by shortening the iteration cycle time for improvements through rapid testing with customers ("ground truth"). This allows fast concept modifications followed by deployment, the creation of "in situ" entrepreneurship, and also builds a model that can be replicated by other institutions. Finally, it was hoped that the concept would enable students to develop a global awareness and reinforce the importance of considering cultural differences in the design process. Together, the e-Teams learn how to work with poorly defined markets, add cultural sensitivity to their designs, deal with strong constraints on product costs and pricing, and consider the availability of local materials as well as the lack of manufacturing and product standards. It also raises awareness among privilege university student in developing nations to consider their own country context and needs.

1.2 Product Design Engineering Rationale

A pressing ethical question must be addressed: Do global economies need clients from the Third World? The majority of the world's design engineers are currently employed creating products for the wealthiest third. This opens an opportunity for the creation of viable businesses which create products that are more affordable and appropriate for use in the developing world. However, such business designs must avoid

1) Products which require a high initial investment and several months of foregone income
2) Complex products which are expensive to operate and maintain, and are insufficiently rugged
3) Feature-rich products requiring a sizeable training burden with complex manuals in a foreign or poorly translated language, to say nothing of the possibility of an illiterate user

Because the productivity, quality, and volume improvements required by developing economies are not as high as those forced presently by world markets in the global economy, it is possible to design products that are affordable, utilize local materials and are easy to service and use. The design and sale of these products can form the basis for the creation of income generating activities in the developing world. Because of the strong emphasis on remaining affordable at the local level, strong competition from developed nations in this niche market may be averted.

1.3 Entrepreneurship Rationale

We believe that the key to lasting development is to increase the income generating power of the poor, rather than to give away free goods and services. Humanitarian relief aid is a singular event driven process, typically made of assistance programs for human caused or natural disaster. Humanitarian aid fills a short term gap, but lacks the staying power required for a more permanent solution to poverty. In addition, international loans, combined with internal political corruption, has significantly increased the external debt of developing nations and often resulted in currency devaluations that greatly affected the living standards of the poorest of the poor. Some aid now goes towards implementing policies to improve governance and fight corruption.

Other forms of economic aid take the form of loans used to start new businesses and to acquire "productivity" products that are commonly beyond the purchase power of the poor.

The approach taken in E105 is to create new businesses around products the developing world wants and can profit from. In doing so we intend to teach the context for launching new businesses, with an emphasis on creating a viable business plan to teach basic skills in market research, accounting, customer service, human resource allocation, sales promotion and marketing.

2.0 "Proxy Engineering" (Fall 2005)

We began the process by developing methodologies to harness the ingenuity of US students to design products for a developing nation. For E105 2005 class, the chosen nation was Guatemala. One goal is to harness this creative effort in a reproducible way. Although the core curriculum emphasis was on learning the Product Design process, additional benefits for the education of these students include the teaching of:

- Social awareness
- Social responsibility
- Maintaining an open yet critical mind in the face of huge constraints
- Environmental responsibility including sustainable development
- Cultural diversity in the world college student population

In the era of globalization these elements are required for a more complete education of future generations of engineers. Engineering Design and Research challenges include:

- Early identification of solvable problems with the potential for significant, measurable impact
- Poorly defined markets
- Cultural sensitivity
- Strong constraints on product costs and pricing
- Availability of local materials
- Lack of manufacturing and product standards
- Customer's lack of familiarity to deal with technical problems

Various steps were undertaken to solve some of these particular constraints: an outside guest lecture series was organized by ESW-CIT, and in-class participation and advice was provided by

a Guatemalan anthropologist as well as by members of the Guatemalan business and academic community in Los Angeles. Examples of products that were developed in 2005 include:

- eFarming: a website for agricultural information systems and trading platform
- Agua Cristal: a water purification system
- MasMaiz: a hand held corn sheller
- 18 Graos: a premium pomegranate brandy

The first two in this list have been turned into start-up businesses. In addition, one student and former class TA has been accepted into the Peace Corps, a second has been awarded a Thomas Watson Fellowship to study water issues in Africa and a third has traveled to India to study Entrepreneurship.

2.1 In Country Visits (Spring-Summer 2006)

In the summer of 2006 four of the authors (KP, MB, LMD, JK) traveled to Guatemala to cement new relationships, lecture to potential international students that will be part of the 2006 E105 Fall course and travel to rural Guatemala. We made contact with the Dean of Agriculture and Environmental Science Dr. Charles MacVean and others at Universidad Rafael Landivar (http://www.url.edu.gt) in Guatemala. Dr. Ivan Azurdia, Director of Fundacion Solar (http://www.fundacionsolar.org.gt), an NGO dedicated to rural development, provided staff and site availability for the TA of the course to travel and get acquainted with the local rural population in the Lake Atitlan and the Central Highland region. We found that in a separate program triggered by our E105 effort over 280 students are currently engaged in various Development Engineering courses at Caltech.

We feel that such country visits are part of the systematization of the experience. These visits may resolve the Educational and Research problems mentioned above. For example, we have collaborated with the Media Laboratories at Caltech and Universidad Rafael Landivar to resolve the critical technical and course scheduling problems. Through the use of streaming video and off-line teleconferencing we were able to lecture during the 2006 fall quarter even though the academic calendars at both institutions differ by a few weeks in their start date. The full course was made available on line for later viewing by the students in Guatemala with just a few days delay after the lecture was taught at Caltech.

2.2 Introducing e-Teams (Fall 2006)

From our 2005 experience with “proxy engineering”, it was clear we had to consider various issues:

- Cultural and Language barriers
- Differing University cultures driven by different objectives
- Differing roles and responsibilities for American and Guatemalan students
- Incompatible communication technologies
- Unsafe and difficult to reach rural areas
- Class scheduling across time zones
- Accreditations and class credits

- Different start and end dates for academic terms
- Varying degrees of student expectations and prior student knowledge
- Appropriate level of interaction between lecturers, students and TA's

Nevertheless, we decided to create these teams, relying on Guatemalan college students to be in contact with the real customer. Given the difficulty in understanding the cultural context of rural areas, it was imperative to have some in-country contacts that could work with the Guatemalan students. We partnered with grass roots organizations at the local community level and with a local NGO. This resulted in collaborations that helped facilitate a variety of programs and projects.

2.2 Other Related Methodologies: Choosing Projects

Through our one week visit to Guatemala prior to the beginning of the quarter, we vetted some 30+ potential products/businesses. With the collaboration of URL faculty and students, we agreed on ranking criteria for these projects. The object was to choose the best projects and to involve students from the developing country in the decision-making exercises. The students and faculty came up with the following ranking criteria:

1. Product/Business Impact
2. Customer Identified Needs
3. Economically Accessible (cheap)
4. Sustainable (economically long-lived)
5. Scalable (transferable as a business from region to region)
6. Simple (Transparent, maintainable, easy to use)
7. Culturally Sensitive
8. "Chilero" (local word for "cool" or exciting to be designed and built)

We considered and ranked several projects of interest. To give an example, we considered one class of projects we called, "Waste to Value"

1. A process for producing ethanol from waste fruit providing additional income and/or fuel
2. A method for extracting methane gas from landfills and dumps, building on a previous URL project
3. Corn Cob Fertilizer/Pesticide Carriers that use the absorptive properties of cobs to more efficiently deliver fertilizers and pesticides to crops
4. A process for making bio-diesel from crops which are grown in the Lake Atitlan region, such as the castor bean, to provide a low-cost alternative fuel for powering diesel generators developed by Fundacion Solar and local project participants
5. Methods for producing charcoal from agricultural waste to provide a clean burning fuel source and help to limit deforestation. This project would build on a technology developed at MIT and adapt it to the local conditions in Guatemala

From the long list 6 projects were chosen by the Guatemalan students. The Caltech students then "precipitated" in groups around these choices.

3.0 Project Examples

Two examples of final project presentations are provided as illustrations of the balance between Product Design emphasis and Business Development focus of these projects: "Bicienergia", a modular power supply for rural "off the grid" areas and "Montasilla" a wheelchair made from recycled bicycle parts. General guidelines for the final report included: a mission statement, results of marketing research (primary and secondary), summary of design for sustainability and manufacturing, product safety (manufacturing and usage), prototypes, drawings, detailed marketing including the four P's (product, pricing, promotion and placement), cost analysis. We selected sections of the final reports with the original narrative in place to provide the reader with a flavor for the final products design student reports in E105. In the interest of space we include only their Mission statements and Market research.

3.1 Example 1: Bicienergía, A Rural Modular Power Supply

Mission: To develop an affordable and user-friendly electricity-generation and storage device to enable rural inhabitants to power portable devices such as cell phones and batteries for radios and flashlights.

Market Research: Research focused on Bichemal, one of the villages surrounding Chajul, Quiche, in Guatemala. Villagers from Bichemal walk between 2-5 hours in the mountain to get to a power grid to charge portable devices such as cell phones and rechargeable radio and flash light batteries. Cell phones are very common since most villagers have one or relatives working in the USA who send these devices and pay the monthly bills, to keep in touch with their families. Eighteen families live in Bichemal. Their main source of income is the production of natural fiber baskets. The villagers travel to Chajul every 15 days to buy basic goods and to deliver their baskets. They spend around Q. 20.00 (US$ 2.50, 1 Quetzal=$0.13), in lightning products like candles and charcoal, and another Q.22.00 (US$ 2.55), in batteries for their portable radios per month. That is Q. 42.00 (US$ 5.00) per month, almost 30% of their total monthly income.

3.2 Example 2: Independence through Mobility, An Affordable Wheelchair

Mission: To provide alternative, inexpensive means of transportation for poor, disabled people in Guatemala and later, other developing countries.

Market Research: Generally, it is estimated that over 20 million people in developing countries suffer from disabilities that severely limit their mobility, independent of assistive mechanisms. In the case of Guatemala, the major causes of handicap include the aftermath of a fairly recent civil war, disease, and vehicular accidents. We project the number of disabled Guatemalans is around 92,000, with some approximate assumptions contributed by our Guatemalan contacts. Since the wheelchair is a common and acceptable means of assistance, we have decided to tap into this market. One correspondent mentioned that he and his family were saving money to purchase a wheelchair for a relative, which cost nearly $400 and would take years to save that much. Given that the biggest contributor to the modern Guatemalan economy is the influx of money sent back from the US, a separate target market of considerable size and viability exists here within the US.

2.4 e-Team Performance Incentives

Excellence in engineering design and vigorous efforts were recognized by what we have come to call The Developing World Challenge Award. The award consists in a $1,000 grant for the members of the winning team to pursue the business plan presented as part of their project. A separate incentive for the international students and their mentors consisted of a one-week invitation, including round plane tickets, to visit the host university and be present for the final presentation session and closing ceremonies.

3.0 On line archive

The integrated results of the two years E105 has been taught can be viewed on line at http://www.its.Caltech.edu/~e105/index_files/Page462.htm

4.0 Student Feedback

By targeting problems our students would not normally encounter in the USA, at least at the price point required for success in the developing world, we are among the ones breaking new ground. By imbedding the objective that solutions to these addressed problems be viable (in a business context), American students will be more effective in understanding an increasingly global economy and have better abilities to open up new markets. But in a very real sense the skills gained through participation in this endeavor will be of significant value in the student's education independent of their specific career choice after graduation. At the closing ceremony of 2006 class, some data was gathered in the form of student testimonials, like the following:

-"This class has been a changing experience that will surely impact my whole career"
- " To be able to interact with students from another country has opened my eyes to the needs of the poor that were not visible for me before"
- " To be able to interact with students from another country has open my eyes to the roles played by stereotypes and prefix judgments"
- " Thanks to this class, I have discovered my future profession"
- "The motivation gathered through this class has inspired me to travel to the third world"

The closing ceremony was also used to identify the biggest problems to be addressed in the next iteration of the course, including:

1. Team misunderstandings of expectations within the groups. Poor communication was the most often mentioned issue in need of improvement.
2. Very short time for this course (approx 10 weeks of class time, 30 hours of lectures)
3. The combination of engineering, business and developing world materials makes the course somewhat unwieldy, especially in view of the short time frame.
4. Syllabus not always followed due to changes necessitated by evolving conceptions of what "needed to be learned".

4.1 Future Plans

In order to better bond the teams, we are considering flying at least one US member of each team to Guatemala prior to the start of classes to meet and get to know their Guatemalan partners as well as to visit the NGOs and, most importantly, the rural people who are our customers. This will help to extend the time for the course. In addition Summer Undergraduate Research Fellowships (SURF) are being offered to allow the students who wish to take their projects to Guatemala and work towards implementation. The syllabus will undergo another scrub with a more extensive use of supplementary readings and greater focus on the essentials for the lectures.

In addition, as a mechanism to catalyze research and development in this area, we are in the process of co-founding an annual MIT/ Caltech Affordable Design World Summit. This summit will bring together, from all over the world, students, faculty, rural community leaders and field practitioners interested in design for development. The International Development Design Summit will be a month long design fest, celebrated at MIT and at Caltech, alternating location each year to disseminate the methods. Unlike traditional conferences, participants will not present papers, but rather, they will work in teams to create designs, build prototypes and develop business models for the implementation of low-cost technologies that target the needs of the rural poor populations. Participants will come from universities and organizations in the developing world as well as US institutions with papers, ideas, and projects at a sufficient level of development, to be presented as candidate products to be given more input during the Summit's work. Over the course of three weeks, in addition to the design activities, there will be two-day workshops in areas such as curriculum development, market feasibility studies and project evaluation where participants will be creating materials to enhance the activities of their organizations.

5.0 Conclusions

We embarked on an effort to test the hypothesis that through the creation of multi-national teams of engineering students it is possible to improve the design of products that can generate income for the third-world poor. The products to be deployed can be identified, designed, and built in a single academic term in collaboration with international partners. Some amount of preparatory (in country visits) work is required to establish these collaborations. The results of this teaming methodology were compared with our "proxy" methodology applied the previous year. The participation of local students greatly enhanced the final choice of products, product design, and marketing plans.

6.0 Acknowledgements

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Team LaTreeN: Jenny Liang, Anna Olsen, Atabel Pineda, Cecilia Yu. **Coffee Depulping Waste Water Management:** Natalie Becerra, Alireza Ghaffari

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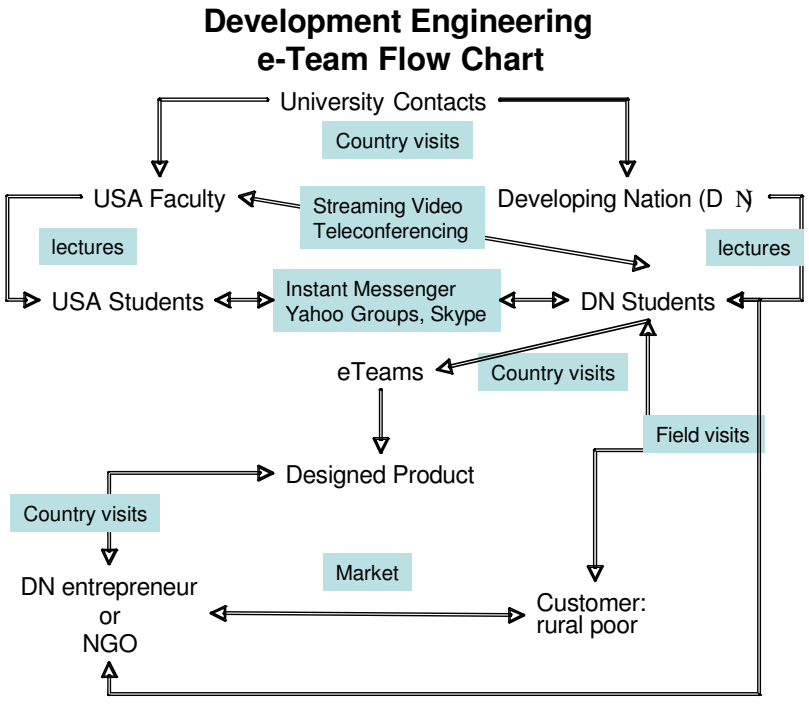

Figure 1. Information flow for "e-Team" based development engineering. Traditional lectures are combined with information technologies (streaming video, teleconferencing, internet telephony, instant messenger, web-based groups) to strengthen the communication channels at each required level. Near the beginning and end of the design process site visits might be required in the original establishment of these collaborations.

Figure 2. Diagram of the pedal powered generator. Left, solid rendering of entire pedal assembly. Right top, 12 V battery and circuit housing. Bottom right, stand and generator assembly.

Figure 3. Solid rendering of how the bicycle parts, ingredients for mobility, are harvested to construct the wheelchair prototype.