Sponsoring Research in Appropriate Technology

Dr. Christopher Papadopoulos, University of Puerto Rico, Mayaguez Campus

Christopher Papadopoulos is an Assistant Professor in the Department of General Engineering at the University of Puerto Rico, Mayaguez (UPRM). He earned B.S. degrees in Civil Engineering and Mathematics from Carnegie Mellon University (1993) and a Ph.D. in Theoretical & Applied Mechanics at Cornell University (1999). Prior to coming to UPRM, Papadopoulos served on the faculty in the Department of Civil Engineering & Mechanics at the University of Wisconsin-Milwaukee (UWM).

Papadopoulos has diverse research and teaching interests in structural mechanics, biomechanics, engineering ethics, and engineering education. He is PI of two NSF sponsored research projects and is co-author of Lying by Approximation: The Truth about Finite Element Analysis. Papadopoulos is currently the Program Chair Elect of the ASEE Mechanics Division and serves on numerous committees at UPRM that relate to undergraduate and graduate education.

Dr. William Joseph Frey, Univ. Puerto Rico - Mayaguez

William J. Frey has taught research, business, engineering, and computer ethics at the University of Puerto Rico at Mayaguez since 1990. He is a member and former director of that university's Center for Ethics in the Professions. He and a team of ethicists have worked with different universities in the Latin American context on faculty development workshops for identifying issues in engineering ethics, developing course modules in this area, and designing curricular strategies for integrating ethics across the engineering curriculum. His publications cover moral psychology, moral pedagogy, and engineering ethics in Puerto Rico. Most recently, he has been working on the GREAT IDEA project, an NSF-funded project that explores research in appropriate technology and community development.

Marcel J. Castro-Sitiriche, Department of Electrical and Computer Engineering, University of Puerto Rico-Mayagüez

Marcel J. Castro-Sitiriche is a professor of Electrical Engineering at the University of Puerto Rico in the Mayagüez Campus (Recinto Universitario de Mayagüez). His research efforts contain academic, educational and service activities. Some of the research areas of interest include appropriate technology, engineering education, power electronics, computational intelligence, electric motor drives, and renewable energy systems. He is the co-coordinator of the Social, Ethical, and Global Issues in Engineering program at the College of Engineering in the University of Puerto Rico, Mayagüez. He is chair of the IEEE Engineering Education Western Puerto Rico chapter, and member of the International Network on Appropriate Technology. One of the current research projects combine most research interests and is based in the concept of appropriate technology. The project title is "Graduate Research and Education for Appropriate Technology: Inspiring Direct Engagement and Agency (GREAT IDEA)" and it is funded by the NSF (http://greatidea.uprm.edu/).

Joann M Rodriguez, University of Puerto Rico, Mayaguez Campus

Joann M. Rodriguez is currently a second year graduate student in Environmental Engineering at the University of Puerto Rico at Mayaguez (UPRM). Her research is focused on the biological mechanisms in the biosand filter technology. Previously, in 2012, she completed a Bachelor Degree in Chemical Engineering and a certificate in Environmental Engineering at the UPRM. She is interested in water quality testing and in water treatment systems appropriate for rural areas and developing countries.

Mr. Jeffrey Santiago
Mr. Tyrone Medina, University of Puerto Rico at Mayaguez

Tyrone Medina was accepted and enrolled to pursue his bachelor's degree in the University of Puerto Rico at Mayaguez in 2007. He earn his bachelor's degree in Electrical Engineering and graduated Magna

Cum Laude in 2013. During this time he gain interest in the fields of renewable energy, alternative power generation and appropriate technology. He also became a member of the Golden Key Honour Society and the Tau Beta Pi Engineering Honor Society where he is currently a member of the executive board as Vice President of Activities of the Puerto Rico Alpha Chapter and has also contributed to community service and the environment. Tyrone is currently pursuing his Master's degree in Electrical Engineering in the University of Puerto Rico at Mayagüez majoring in power electronics. His research and academic interests are in power electronics, renewable energy, and appropriate technology.

Ricardo Maldonado

Ricardo Maldonado was born and raised in Puerto Rico. He graduated from the University of Puerto Rico at Mayagüez where he obtained a Bachelor's degree in Electrical Engineering. During the summer of 2010, Ricardo interned at Argonne National Laboratory in Chicago, IL where he developed a wind energy assessment project for Puerto Rico. He is currently pursuing a Master's Degree in Power Electronics from the aforementioned university while working for an aerospace company (Raytheon Co.) in Arizona as an Electrical Engineer Circuit Designer. Ricardo has a couple of publications in the IEEE, his most recent publication, "Simulation, Design, Hardware Implementation, and Control of a 9-level Flying Capacitor Multilevel Inverter with Particle Swarm Optimization Algorithm", was presented in Japan at COMPEL 2012.

Cristina Rivera-Vélez, GREAT IDEA

Cristina Rivera-Velez is from Mayaguez, Puerto Rico. Holds a B.A, in Communications from the University of Sacred Heat, San Juan, P.R. Attended the University of Puerto Rico- Mayaguez, where she completed her Master of Business Administration (2013). As graduate student, she worked as a graduate research assistant with GREAT IDEA, where she assisted in the research regarding attitudes of engineers. Also a member of the GREAT IDEA, she organized two events for the academic community, an Alternative Job Fair and an Appropriate Technology Forum. During the Fall 2013 semester, served as the teaching assistant of the course INTD 6095 Responsible Research in Appropriate Technology- University of Puerto Rico- Mayaguez. Co-author: Bringing Responsible Research into Engineering Ethics: Responsible Research in Appropriate Technology. Her research interests include: media consumption trends, strategies for innovation and organizational change, appropriate technology and social entrepreneurship, strategies for the development of medium and small business.

Mr. Davis Chacon-Hurtado

Mr. Davis Chacon Hurtado just finished his Master of Science studies at the school of Civil Engineering and Surveying from the University of Puerto Rico, Mayaguez Campus. He is original from Cusco, Peru where he got his Bachelor degree in Civil Engineering from the University of San Antonio Abad. After graduation, Mr. Chacon worked in the development of transportation infrastructure projects in rural areas for about two years before stating his graduate studies. His currently starting his Ph.D. studies in which the focus of his research will be the development and promotion of sustainable transportation systems.

Mr. Pablo Jose Acevedo, UPRM

Pablo Jose Acevedo earned undergraduate degrees in civil engineering at University of Puerto Rico, Mayaguez (2011). Driven by his necessity to further inquire into alternative development processes and ecological sustainability, in the beginning of 2012 he traveled to Colombia to participate in an intensive training course called GIGa (Integral Management of Guadua angustifolia) offered by Technological University of Pereira, department of Risaralda. During a period of six months, Pablo work as sustainable management technician for a Bamboo construction company called Co2Bambu. In October of 2012 he participated in a combined workshop of Earth Bag Construction "Super Adobe " and Principles Design of Permaculture offered by Cal Earth (The California Institute of Earth Art and Architecture) in Hesperia, California. In the present Pablo is completing his master degree in structural engineer, conducting a thesis

project title ”Evaluation of Physical and Mechanical Properties and Effectiveness of Preservative Solutions of Tropical Bamboos with Structural Applications Cultivated in Puerto Rico”. Pablo is a professional fully committed to promote and develop sustainable development on underserved communities.

Sponsoring Research and Education in Appropriate Technology

1. Abstract

In this paper we describe the initiative to sponsor graduate level research and education in the field known as "Appropriate Technology" at the University of Puerto Rico, Mayagüez (UPRM). These efforts are sponsored by the project "Graduate Research and Education for Appropriate Technology: Inspiring Direct Engagement and Agency (GREAT IDEA)", which is funded by NSF. We first provide a brief background on the concept of Appropriate Technology, including our interpretation. We then describe specific thesis research projects and coursework that are sponsored by our project. Finally, we outline new ramifications of Appropriate Technology in Research Ethics, and describe how we address these in courses that we have created for our students.

2. Schumacher's Intermediate Technology as the Precursor to Appropriate Technology

Appropriate technology is widely credited as an outgrowth of the ideas expressed by the "radical economist"[1] Ernst Friedrich "Fritz" Schumacher in his book *Small is Beautiful: A Study of Economics as if People Mattered*[2], which is a compilation and synthesis of his writings and work from the 1940s through 1960s in which he developed the concept of "Intermediate Technology". The origins of Intermediate Technology reside in Schumacher's criticism of conventional development practices, which assumed that the problems of the developing world could be solved by the transfer of capital-intensive, large-scale technologies from the industrialized world to the developing world. Kelvin Willoughby, scholar of Schumacher and author of *Technology Choice: A Critique of the Appropriate Technology Movement*[3], writes

> The most conspicuous of the immediate origins of Intermediate Technology occurred in the context of the economic development difficulties of the South. It was the realization by people in both aid-giving and aid-receiving countries that the development aid of recent decades, and the associated attempts at accelerated industrialization through capital-intensive technology imported from the North, had largely failed as means of solving the basic problems of economic development in the South.[3(p. 60)]

Indeed, in the opening paragraph of *Small is Beautiful*, Schumacher writes:

> One of the most fateful errors of our age is the belief that 'the problem of production' has been solved. … For the rich countries, [the experts] say, the most important task now is 'education for leisure' and, for the poor countries, the 'transfer of technology'.[2(p. 13)]

A principal root of this problem, Schumacher argued, was a fundamental disregard for the limits of the earth's resources, in which mainstream economic policies (and, by extension, politics) erroneously accounted for natural resources as income rather than "liquidation"[2(p. 16)] of "natural capital"[2(p. 15)], leading to political arrogance and an ethic of over-consumption:

> The illusion of unlimited power, nourished by astonishing scientific and technological achievements, has produced the concurrent illusion of having solved the problem of production. The latter illusion is based on the failure to distinguish between income and capital where this distinction matters most. Every economist and businessman is familiar with the distinction, and applies it conscientiously and with considerable

> subtlety to all economic affairs - except where it really matters - namely, the irreplaceable capital which man had not made, but simply found, and without which he can do nothing.[2(p. 15)] …
>
> This illusion … is mainly due to our inability to recognise that the modern industrial system, with all its intellectual sophistication, consumes the very basis on which it has been erected.[2(p. 20)]

Schumacher further understood development problems in terms of the "dual economy and its twin evils of mass unemployment and mass migration into cities".[2(p. 167)]. This situation arises in poor countries as development efforts are concentrated in cities – a direct artifact of the attempts to rapidly transfer the industries and technologies of the industrialized countries – and relative poverty exists in rural areas. These conditions draw people from the rural areas to the cities in hope of finding work. However, because neither the industries nor the public infrastructure of these cities can accommodate rapid population influx, slums and poor labor conditions are created, the vital agricultural economies of the rural areas are depleted, and the country's overall economy becomes further dependent on the "aid-giving" nations and agencies.[cf. 2(p. 180)]

Schumacher saw these problems not only in material and economic terms, but also in terms of human spirituality and wellbeing. While working as a consultant to the Burmese government in 1955, Schumacher was immersed in Buddhist culture and realized that the Burmese people were very "lovable" and "much happier and nicer than we are" in the industrialized countries.[4(p. 243); from 3(p. 62)] He saw unbridled materialism as the root of the problem in industrialized countries:

> [M]odern industrial society, in spite of an incredible proliferation of labor-saving devices, has not given people more time to devote to their all-important spiritual tasks.[5(p. 25); from 6(p. 188)]

Keenly grasping the relationship between over-consumption and the high costs to human wellbeing, Schumacher wrote "since consumption is merely a means to human well-being the aim should be to obtain the maximum of well-being with the minimum of consumption".[2(p. 57)]

In his ambition to address these problems, Schumacher developed a framework for development alternatives that he called Intermediate Technology. Largely influenced and inspired by his study of Gandhi, Schumacher wrote (emphasis added)

> As Gandhi said, the poor of the world cannot be helped by mass production, only by production by the masses. The system of mass production, based on sophisticated, highly capital- intensive, high energy-input dependent, and human labour-saving technology, presupposes that you are already rich, for a great deal of capital investment is needed to establish one single workplace. The system of production by the masses mobilises the priceless resources which are possessed by all human beings, their clever brains and skilful hands, and supports them with first-class tools. The technology of mass production is inherently violent, ecologically damaging, self-defeating in terms of non-renewable resources, and stultifying for the human person. *The technology of production by the masses, making use of the best of modern knowledge and experience, is conducive to decentralisation, compatible with the laws of ecology, gentle in its use of scarce resources, and designed to serve the human person instead of making him the servant of machines. I have named it* ***intermediate technology*** *to signify that it is vastly superior to the primitive technology of bygone ages but at the same time much simpler, cheaper, and freer than the super-technology of the rich*. One can also call it self-help technology, or democratic or people's technology – a technology to which everybody can gain admittance and which is not reserved to those already rich and powerful.[2(pp. 153-154)]

In fact, Gandhi himself is often acknowledged as the "father of appropriate technology" or as the "first appropriate technologist"[7]. Indeed, a cornerstone of Gandhi's approach to achieving Indian independence was the development of rural village industry, epitomized both substantively and

symbolically by the Charkha, or spinning wheel, which can be seen to be compatible both technically and socially with Schumacher's ideas in the excerpt above.

With Gandhi's movement likely in mind, as well as his own imperative to reverse the trend of the dual economy, Schumacher emphasized the need to develop the rural economy as "Help to Those Who Need it Most":

> It is necessary, therefore, that at least an important part of the development effort should by-pass big cities and be directly concerned with the creation of an agro-industrial structure' in the rural and small-town areas. In this connection it is necessary to emphasise that the primary need is workplaces, literally millions of workplaces.[2(p. 173)]

He went on to argue that in contrast to conventional development approaches that emphasize centralized industries with high output per worker, the emphasis should be on employing as many people as possible: "It is therefore more important that everybody should produce something than that a few people should each produce a great deal".[2(p. 174)]

With the goal to develop strong rural economies, Schumacher envisioned Intermediate Technology as "immensely more productive than the indigenous technology (which is often in a condition of decay), but … immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry".[2(p. 180)] From an economic perspective, he proposed as a guideline that the capitalization cost per new workplace should approximately equal the order of the annual salary of an ambitious or entrepreneurial member of the local community.[2(p. 180)] Describing qualities of such technologies, Schumacher wrote:

> The intermediate technology would also fit much more smoothly into the relatively unsophisticated environment in which it is to be utilised. The equipment would be fairly simple and therefore understandable, suitable for maintenance and repair on the spot. Simple equipment is normally far less dependent on raw materials of great purity or exact specifications and much more adaptable to market fluctuations than highly sophisticated equipment. Men are more easily trained: supervision, control, and organisation are simpler; and there is far less vulnerability to un- foreseen difficulties.[2(p. 181)]

Behind Schumacher's idea of Intermediate Technology was a conviction that development must occur gradually and smoothly, and in proportionality with the people's skills and capabilities; it cannot come about through sudden changes, jumps, or fiats from the outside (emphasis added):

> If aid is given to introduce certain new economic activities, these will be beneficial and viable only if they can be sustained by the already existing educational level of fairly broad groups of people, and they will be truly valuable only if they promote and spread advances in education, organisation, and discipline. *There can be a process of stretching – never a process of jumping*. If new economic activities are introduced which depend on special education, special organisation, and special discipline, such as are in no way inherent in the recipient society, the activity will not promote healthy development but will be more likely to hinder it. It will remain a foreign body that cannot be integrated and will further exacerbate the problems of the dual economy.[2(p. 169)]

Schumacher justified this empirically, noting that "In every 'developing country' one can find industrial estates set up in rural areas, where high-grade modern equipment is standing idle most of the time because of a lack of organisation finance, raw material sup- plies, transport, marketing facilities, and the like".[2(p. 178)]

3. The Emergence of Appropriate Technology

In the early 1960s, Schumacher began publishing many of these ideas in a series of articles in the *Observer* (London). One of these articles, "How to Help them Help Themselves"[8], resulted in a particularly strong reader-led grassroots call for action and led Schumacher to found the Intermediate Technology Development Group (ITDG) in 1966[1]. ITDG survives today under the name Practical Action and is very active worldwide contributing to poor people's wellbeing by building capabilities of poor men and women with a focus on technology justice.

ITDG had three primary aims: (1) Promoting the systematic assembly and documentation of all data relating to intermediate techniques and technologies; (2) Drawing attention to [these] by publishing information about them and promoting the concept of Intermediate Technology, and advertising the group's services; and (3) Offering advice and assistance to overseas projects in order to demonstrate the practical use of intermediate technologies in helping poor people to help themselves.[1; cf. 3(p. 70)]

According to Akubue, the term "Appropriate Technology" emerged as a result of the *Conference on the Further Development in the United Kingdom of Appropriate Technologies for, and their Communication to, Developing Countries*, held at Oxford 1968 and co-sponsored by ITDG, at which it was suggested that the term "Intermediate Technology" connoted inferior technology and/or implied a separation of social and political factors from proposed technological solutions[7]. Within a few years, the development economists Jéquier and Blanc offered the following description that echoed many of the qualities articulated by Schumacher, and also served to encompass the aims of a growing movement:

> Appropriate technology (AT) is now recognized as the generic term for a wide range of technologies characterized by any one or several of the following features: low investment cost per work-piece, low capital investment per unit of output, organizational simplicity, high adaptability to a particular society or cultural environment, sparing use of natural resources, low cost of final product, or high potential for employment.[9(p. 10)]

During the 1980's, when the National Science Foundation sponsored a program dedicated to research in Appropriate Technology, the definition in the program solicitation was similar, though somewhat less prescriptive:

> Appropriate Technologies are defined as those which possess many of the following qualities: they are decentralized, require low capital investment, are amenable to management by their users, result in solutions that conserve natural resources, are in harmony with the environment, are small or intermediate scale, and are more labor- than capital-intensive.[10]

Several other definitions with similar criteria abound in the literature, several of which are summarized by Akubue.[7]

Willoughby, who cautioned against defining Appropriate Technology in terms of "specific characteristics"[3(pp. 20-21)], proposes two definitions (distinguished by the use of lower-case and upper-case letters), to avoid prescribing AT too narrowly and to illuminate the distinction between "appropriate" *artefacts* and the "appropriate" *practice*:

> **appropriate technology:** Artefacts which have been tailored to function as relatively efficient means and to fit the psychosocial and biophysical context prevailing in a particular location and period (i.e., technology which is compatible with its context).[3(p. 44)]
>
> **Appropriate Technology**: A mode of technology-practice aimed at ensuring that technology is compatible with its psychosocial and biophysical context. The term may also be used to denote the general concept, social movement or innovation strategy associated with this mode of technology-practice.[3(p. 44)]

In this article, we follow Willoughby to maintain distinction between "appropriate technology" and "Appropriate Technology", although we use both terms somewhat more informally.

Recent significant contributions to Appropriate Technology include the work focused on Sustainable Living by Robert Wicklein[11], conference papers directly focused on Appropriate Technology[12], and a recent doctoral thesis that provides a "philosophical exploration of how the Capabilities Approach can be brought to bear on technology" for development[13]. Lastly, every other year since 2004, the International Conference on Appropriate Technology (ICAT) has gathered international scholars and local practitioners in four different cities across the African Continent. The ICATs have been organized by the International Network on Appropriate Technology and the proceedings of the conferences can be accessed freely online[14].

Historically, Appropriate Technology, as follows from Schumacher's synthesis, is rooted in the imperative to improve practices for development of poor countries. Although this remains an important and major aspect of Appropriate Technology, the general concepts and commonly cited characteristics can be applied, in many cases, to industrialized societies.

4. GREAT IDEA and its Sponsored Projects in Appropriate Technology

Nearly four years ago, we set out to establish a program at our institution that would, among other goals, encourage graduate students to pursue their thesis research in Appropriate Technology. The resulting project, "Graduate Research and Education for Appropriate Technology: Inspiring Direct Engagement and Agency", or "GREAT IDEA", was funded by the Ethics Education in Science and Engineering (EESE) Program at NSF (Grant #1033028). A primary reason for emphasizing graduate study was to move beyond the excellent but often-short lived undergraduate projects that might be of a voluntary nature to inspire work that is more centrally tied to career ambitions. A complete overview of the project's activities, publications, personnel, and partners can be found at http://greatidea.uprm.edu.[15]

We broadly speak of research in Appropriate Technology as *research that is responsive to a specific community or social context*. The coursework and seminars that we offer enable students to learn skills to conduct research in this context, particularly when their research involves interaction with a community. Implicitly, such work is interdisciplinary, requiring not only the usual scientific and technical training, but also techniques (or at least awareness of such) from other relevant fields of inquiry, such as philosophy, sociology, anthropology, and economics. This has had the wonderful consequence of involving several of our colleagues as research associates and co-advisors of our students. Through these interactions, we are building a strong institutional network of "Appropriate Technologists" and expanding the sphere of those who choose to undertake work in Appropriate Technology.

To provide a concrete grounding in this approach to research in Appropriate Technology, during the first year of the project a new course INTD 5095 titled "Appropriate Technology: Towards Sustainable Wellbeing" was created and delivered under the direction of Marcel Castro. The main goal of the course is to engage students in a critical examination of choices inherent in technological development and design, including study of alternative ways to define, measure, and consideration of *progress* and *wellbeing*. The course presents challenges and best practices related to the development of appropriate technologies, including an emphasis on involving community participation. To provide exposure to a broad interdisciplinary spectrum of approaches to these issues, 15 faculty members from several different departments presented lectures representing fields such as ethics, economics, technology innovation, social entrepreneurship, philosophy of technology, and participation action research, and applied to topics such as renewable energy, agriculture, water purification, and birthing. The course has been offered twice, reaching a total of 50 students (despite our focus on graduate education, about 40 of these students were upper division undergraduates), and is in the late stages of becoming a permanent course at UPRM. A summary of the overall course outcomes and assessment was published in 2012.[16]

To date GREAT IDEA is(has) sponsoring(ed) five Master's students and one exceptional undergraduate student to investigate diverse topics that relate to or instantiate Appropriate Technology. The PI's are also working in the rural village if Duchity, Haiti to plan development of power and water projects. We summarize each of these projects below in order to give a concrete idea of how Appropriate Technology can be approached in a substantive way at the graduate level. Further details of each project can be found at http://greatidea.uprm.edu/initiatives.html.[15]

Note: each description is followed by a *Characterization Remark*, which summarizes how the project fits into the overall Appropriate Technology framework, and in some cases a *Personal Remark*, which expresses some of the student's own experience in conducting his or her research in the context of Appropriate Technology.

- **Christopher Papadopoulos and Marcel Castro** made their first visit to Duchity, Haiti in March 2011. Duchity is a village located in the mountains of Haiti's southwest peninsula, roughly halfway between the cities of Les Cayes and Jérémie. The economy is primarily agrarian, though many villagers also earn a living by selling services such as cell phone minutes and battery charging. A major market twice per week draws people from the region and even from Port au Prince to buy and sell produce, baked or processed foods, clothing, and other household goods. Duchity is home to a national school and teacher's college, a Catholic Church, Evangelical Church, regional court, and an orphanage. Due to the presence of several NGO's, the village is also home to a health clinic, dental clinic, farmer's cooperative.

  As a result of speaking with many members from the community and listening to what they determined to be a major priority, the PI's are actively working with "the community" – which is primarily the village Electric Committee and local officials – to plan development of a sustainable supply of electricity. In particular, feasibility studies for a micro-hydroelectric plant and a solar array are underway. Although the PI's

provide some technical assistance, they are taking the broader role as members of an "external board" to support the village Electric Committee to take responsibility for managing key aspects of the project, such as (i) solicitation of bids from local engineering companies to do surveying, (ii) visit officials from government agencies, NGO's, and private development contractors to learn about other projects that are being planned in the region, and (iii) local discussions of what resources the community can contribute to the project. The principal partners in this effort are the Rotary Club of Metro New York City, St. Thomas Apostle Catholic Church (Naperville, IL), Youthaiti (Milwaukee, WI), and the Vermont Haiti Project.

The PI's are also involved to an extent with addressing water/sanitation, agricultural, building construction, and education and technical training. Further information regarding GREAT IDEA's partners and work in Duchity has previously been reported[17] and can be found at http://greatidea.uprm.edu.[15]

Characterization Remark: *this work led by the investigators in Duchity seeks to select and design specific appropriate technologies using the generic Appropriate Technology framework, particularly in its steadfastness to work closely with the community.*

- **Ricardo Maldonado** is a Master's student in Electrical Engineering at UPRM who is completing his thesis entitled "Empowerment of Underfunded Rural Communities using Appropriate Technology". His research is focused on the development of a simulation-based tool to select an appropriate Flying Capacitor Multilevel Inverter (FCMI) (for the conversion of DC to AC) that would be appropriate for the context of Bangladesh, in which 40% of the population does not have access to the national grid (nearly 90% of these people live in rural areas). A prototype design was built and tested[18] with through-hole components, and an improved prototype is being developed with surfaced mounted components; a comparison between through-hole and surface mounted technology will support the assessment for the most appropriate design. The design will be selected not only based on cost, but also on ability to maintain and repair the FCMI using locally available materials and labor. A life cycle analysis of the major components will also be considered. Whenever a new technology is brought to an ecosystem, it is essential to evaluate all possible consequences and environmental burdens associated with the implementation of the technology.

  Characterization Remark: *Ricardo's research seeks to design a specific appropriate technology by employing the generic Appropriate Technology framework, particularly in its effort to arrive at a technology that is cost effective and technically manageable in the context of Bangladesh.*

  Personal Remark by Ricardo Maldonado: *Appropriate Technology is one of the most complex topics I've encountered and, at the same time, one of the most intriguing I've worked with. My interest in this topic motivated me to use the Appropriate Technology framework as the main guideline for my Master's thesis. Appropriate Technology, for me, is a way to foster sustainability in poor, rural communities by facilitating technology that can suit their needs and be maintained locally. The implementation of a new technology*

in a community could carry negative consequences if its impact and effects technology are not carefully analyzed. Before introducing a technology into a community, there are many aspects that need to be taken into consideration. Designing a technology using the precepts of Appropriate Technology can offer a flexible tool that can empower the community in a manner that it deserves.

- **Davis Chacón** recently completed his Master's thesis *Sustainable Development and Transportation Decision Making: Embedding Community Preferences in Visualizations*[19] in the Transportation Engineering program in the Department of Civil Engineering at UPRM. In this work, Davis worked directly with the community of Dulces Labios (located in Mayagüez) where residents are concerned about several in issues in urban transportation in Puerto Rico. The community lacks reliable public transportation services, lack of access for pedestrians, bicycles, noise form traffic, among others. He designed and deployed a detailed survey to collect residents' preferences regarding the redesign of the main corridor that passes through the community with respect to criteria established in the sustainable transportation literature. He then interpreted these results by constructing several visual "fly through" design alternatives that represented subsets of the preferences, after which he returned to the community to solicit their reactions to the design alternatives. Thus, in contrast to typical development processes in which the community's input is usually sought as a reaction to alternatives prepared by an outside developer, in this approach, *the very first design alternatives that the community members see are based on their own expressed preferences*.

  Another outcome of Davis' research is that the community members' responses to the visual design alternatives are highly correlated with their originally expressed preferences, implying that systematic visualization of community preferences can be performed and used as an important tool to include public participation in the planning of transportation projects – a mandate of US federal policy. We are now implementing this methodology to develop visual design alternatives for the main street of Duchity, Haiti where GREAT IDEA is working to help the community plan the arrangement of solar arrays in public spaces.

Acknowledgement: *The authors recognize the work of Dr. Alberto Figueroa in the Department of Civil Engineering who directed Davis' research as the President of his Master's thesis committee.*

Characterization Remark: *Davis' research seeks to develop a particular Appropriate Technology method in the field of Transportation Engineering and Planning by employing the generic Appropriate Technology approach, particularly by intimately integrating community participation in technical decision making. As such it represents an advance in "Context Sensitive Design" (alternatively referred to as "Context Sensitive Solutions") which is promoted by the Federal Highway Administration, the Institute of Transportation Engineers, and other leading transportation organizations.*

Personal Remark from Davis Chacón: *From my perspective, Appropriate Technology and related concepts are essential guidelines in engineering practice that will enable the*

achievement of the ultimate goal of any engineering project, which is to enhance social welfare. I believe that professionals must: first, be aware of the high impact role they play in society and second, learn to derive professional satisfaction from practicing Appropriate Technology. During the development of my thesis, the assimilation of these concepts was not easy because I had not been exposed to this in my previous experience with as an engineer with a more "traditional" role. But now, my experience with the project helped me to choose a research area for my upcoming Ph.D. studies and it is definitely influencing my current and professional development goals.

- **Joann Rodríguez** is a Master's student in Environmental Engineering in the Department of Civil Engineering at UPRM and is completing her thesis entitled "Assessment of Pathogen Reduction Mechanisms Throughout and Intermittent Biosand Filter". Her research is focused on understanding the biological mechanisms that enable intermittent biosand filters (IBSF) to purify water. The IBSF's are unpowered, concrete box columns, filled with sand and gravel, that purify water as the water passes through and stands on an intermittent basis (i.e., as the filter is replenished periodically by the user). This filtration method emerges as an appropriate technology for the removal of turbidity and pathogens from raw water, due to its low cost and operational simplicity. The first stage of this research involved developing a specially designed bench scale model, with the same operational height and filtration rate of a conventional IBSF, to enable the sampling of water from different levels through the sides of the filter[20]. The designed and built bench scale model is presented in Figure 1.

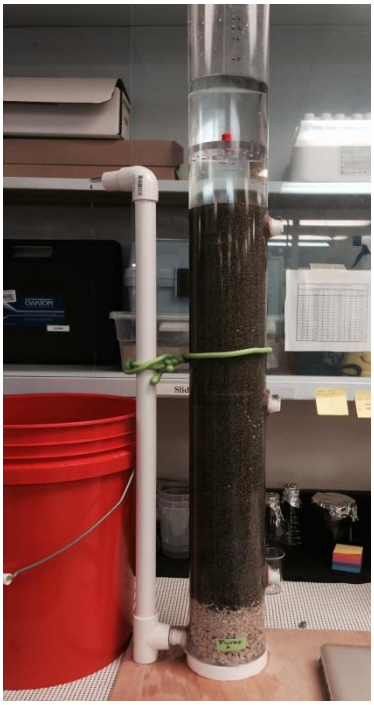

Figure 1. Bench-scale model IBSF.

In the second stage, samples taken using this apparatus will be used to infer the profiles of dissolved oxygen and bacteriological populations as functions of depth and time. Also, as part of the research objectives a short survey will be conducted to the IBSF users in Duchity. The broader goal is to use the newly discovered scientific knowledge to identify future improvements to the filter design in order to address the users' needs, particularly to optimize the materials used and the functioning of the IBSF in order to shorten the preparation time of the filter (IBSF currently must be flushed for approximately 15 to 30 days prior to use).

In conjunction with her research, Joann has contributed extensively to outreach, education, and training of others. She established a water quality testing facility in the health clinic in Duchity, and trained two local young men to take water samples and test them for the presence of coliform bacteria. She has also given several presentations in Puerto Rico about general principles and practices of water purification.

Acknowledgement: *The authors recognize the work of Dr. Pedro Tarafa in the Department of Civil Engineering who is directing Joann's research as the President of her Master's thesis committee.*

Characterization Remark: *Joann's research seeks a scientific basis that can provide a rationale to design a specific appropriate technology. The generic Appropriate Technology approach is invoked, particularly through the effort to arrive at a technology that is cost effective and technically manageable in the context of rural Haiti, and also through the related efforts to provide technical education and training to community members (capacity building).*

Personal Remark from Joann Rodríguez: *My work with the GREAT IDEA project is the best professional and personal opportunity of my life. We, as engineering students, need courses and research experiences focused in the development of skills to work with and for the community. Engineers should work to solve problems in the simplest way and always keep in mind what the user really needs, rather than the creation of new products to make the user depend on it. For example, with the IBSF, the basic need of safe water can be provided without sophisticated technology and power, even though the scientific basis of its operation is highly technical. As part of my work with GREAT IDEA, I had been exposed to meetings in where the engineers discuss the ideas with the community. From this experience I learned that for the project to succeed, engineers have to understand what the community needs and how they want it, but also the community needs to trust the engineers because they have the required knowledge for design. In a community project, engineers need to develop effective communication skills with the community people and include as part of the work, the evaluation of the social impact of the project in the community. Because of my experience in GREAT IDEA, now I know that I have more career alternatives than just the industry.*

- **Pablo Acevedo** is a Master's student in Structural Engineering in the Department of Civil Engineering at UPRM. His thesis project is titled "Evaluation of Physical and Mechanical Properties and Effectiveness of Preservative Solutions of Tropical Bamboos with Structural Applications Cultivated in Puerto Rico". This project is focused on the development of a catalog of information which will allow comparisons of the mechanical and physical development of structural bamboos cultivated in Puerto Rico with their corresponding properties developed in their native regions. Although bamboo construction is well established in some countries, and its properties have been studied before, it is an underutilized resource in many countries where it can be cultivated. This thesis will represent the first systematic study of the physical and mechanical properties of bamboos cultivated in Puerto Rico, where bamboo has not yet emerged as a major construction material.

  As a part of this work, samples of structural bamboos from 7 different geographical regions of Puerto Rico will be tested for stiffness and ultimate strength in compression, tension, shear and flexion. Also, the samples will be subjected to different alternative (nontoxic) preservative solutions to contrast their effectiveness against insect attacks with the traditional preservation. An immediate objective of this project is to provide the initial data needed to adapt existing bamboo construction codes to conditions in Puerto

Rico. A broader goal is to establish the necessary information and sustainable procedures that will foster the birth of a new industry focused on sustainable management and use of bamboo in Puerto Rico.

Characterization Remark: *Pablo's research employs the generic Appropriate Technology approach to produce the scientific knowledge necessary to develop a resource that will enable a series of specific appropriate technologies and related industries to emerge within the intersecting fields of construction and sustainable environmental management.*

Personal Remark from Pablo Acevedo: *It's indispensable for our generation to seek decentralized solutions to confront our present and impending global threats. I believe that most of the solutions lie in the fusion of ancestral knowledge and wisdom with efficient and clean technologies. As a civil engineer (or any other professional), I believe that the most powerful tool is the conscience, which guides the application of technical knowledge to serve the common wellbeing. Essentially the Appropriate Technology approach gives us the route to empower communities to invest in their self-management.*

- **Tyrone Medina** is a Master's student in Electrical Engineering at UPRM. His research is focused on the planning and design of sustainable smart micro-grids in the context of underserved remote rural communities and assessing the potential impact (economical, cultural, educational, etc.) that these micro-grids may have on these communities. This research is in its early stages and will focus on micro-grids sourced by with a variety of renewable energy resources such as hydropower, wind, solar, and biomass. Because of the great differences between regions, geographically and in terms of the different resource available, tools and/or procedures to help in the planning and design process of these micro-grids will be developed. Other important aspects of the planning and design of these micro-grids are the coordination with regulatory government entities, and community's participation throughout this process which is crucial to make these emerging technologies appropriate to the surrounding social context.

  Characterization Remark: *Tyrone's research invokes the generic Appropriate Technology framework to design specific appropriate technologies for electrical power generation. Moreover, owing to its planning component, the research also seeks to develop an Appropriate Technology methodology for developing rural electrification projects.*

- **Jeffrey Santiago** is an undergraduate student in Mechanical Engineering at UPRM. He participated in a workshop last year led by Mike Hatfield from the Aprovecho Research Center (Cottage Grove, OR), which is an internationally recognized organization that builds efficient and clean-burning cookstoves. He was so fascinated by these stoves that for his project in the class *Creative Design*, he built a model stove using concentric tin cans, with a layer of soil in between for insulation (to hold heat). Impressed with his initiative, the project investigators decided to send him to an intensive one-week workshop at Aprovecho last summer (2013).

Jeffrey returned to UPRM with a knowledge of the two main types of clean wood-burning stoves, the Rocket stove and Top-Lit Up-Draft (TLUD) Stove (Figure 2). The Rocket stove is composed of a combustion chamber where the burning of wood takes place. Because the chamber is well designed, nearly all of the gases and pollution that are produced by the combustion process are burned by the flame, resulting in clean air that is less harmful to people and the environment. The "TLUD" stove has two combustion chambers, an inner and outer. The combination of the two combustion chambers provokes primary and secondary air flow, serving to reduce pollution and toxins, resulting in cleaner air and biocharcoal. Jeffrey won a prize at the workshop for one of the most efficient designs of the TLUD stove designed by Dr. Paul Anderson and improved by Mr. Mick Black and Jeffrey Santiago.

Figure 2. TLUD and Rocket Stoves.

Characterization Remark: *Jeffrey's studies take place within the generic Appropriate Technology approach to scientifically understand and design a specific appropriate technology, particularly as evidenced by its holistic approach to interpreting social needs as technical design requirements.*

Personal remark from Jeffrey Santiago: *Thanks to the opportunity that the GREAT IDEA project gave me to go to the Workshop at the Aprovecho Research Center, I was able to grow as an engineer and as a person. In the process of creating a stove I was involved in design, testing, data analysis, product innovation. This helped me become a better engineer by applying all my knowledge in mechanical engineering to a real life situation. I now grasp how the stove designs relate to theoretical principles of Thermodynamics and Fluid Mechanics, and more generally how to gather the opinions of people from different professions and unify them to create a solution to a problem. In stove research, there are many people with different professions from nearly every country of the world, and they are studying, designing and realizing innovations to clean-burning stoves. I plan to continue study efficient cookstoves as part of his continued education in Mechanical Engineering.*

This experience also made me more mature as a person because I was able to understand that the main goal of an engineer is not only to make fancy artifacts that will innovate the world, but that it is also to use my knowledge to find the most simple solution to help people of any part of the world, especially to help poor people be able to live a happier life. For me, this cannot be done by visualizing engineering as a profession that is only focused on math and physics, but also biology, chemistry, business administration, art, and the humanities. All the professions in the world form a line that is the circumference of a circle and the profession of engineering is the center of this circle; as the radius is traced it connects with every point of the circumference.

- **Cristina Rivera-Vélez** recently completed her Master's of Business Administration at UPRM. Her thesis, *Corporate Social Responsibility in the Media*,[21] explores the portrayal of individuals of social groups in the media, and the relationship between the influences of the postage message and the cultural and social implications that may result from it, (e.g., the reinforcement of gender stereotypes, individual identity and the integration of and participation in social processes). This research proposed a model that evaluated these practices through policies of corporate social responsibility. The analysis was conducted through Cultivation Theory and Social Learning Theory in the specific context defined as sports journalism in the United States. The research explored how the sports broadcasting industry has filtered and structured social content to distort the identity of and block the participation of women. Through an ethical framework analysis (Justice, Rights and Utilitarianism), she cites considerable evidence to document bias and distortion in the sports broadcasting media and points the way toward future research into more appropriate media technologies that would free women from identity-limiting stereotypes and open avenues of greater and qualitatively-enhanced participation.

  Alongside her research, Cristina worked as a graduate research assistant with GREAT IDEA. In this capacity she organized two events, an *Alternative Job Fair* and an *Appropriate Technology Forum* and also assisted the PI's with research regarding attitudes of engineers. During the Fall 2013 semester, Cristina further served as the teaching assistant of the course INTD 6095 Responsible Research in Appropriate Technology which is described further in Section 5.

  The Alternative Job Fair (September 27, 2012) provided a forum for faculty, graduate students, and undergraduates to outline the concept of Appropriate Technology and how this might lead to alternative career opportunities. Representatives from Jesuit Relief Services (Washington DC) and the Aprovecho Research Center (Cottage Grove, OR) joined via webcast to describe the opportunities offered by their organizations. The target audience consisted of both undergraduates and graduate students. In the Appropriate Technology Forum (September 17, 2013) the PI's gave a brief overview of GREAT IDEA and then each student supported by the project presented a brief summary of their research projects. A closing panel consisting of students enrolled in INTD 6095 provided perspectives on the concept of Appropriate Technology and its relation to Research Ethics. An auxiliary presentation in condensed from was presented to the UPRM Graduate School Council for the purpose of demonstrating the potential of GREAT IDEA to provide general education in research ethics and to present the viability of research in

Appropriate Technology.

Characterization Remark: *Cristina's research is provides an evaluation of the effect of media technologies that is commensurate with providing an analysis with respect to the generic Appropriate Technology framework, particularly in uncovering undesired social consequences that are biased against women by sports journalism practices. The analysis could point the way toward developing specific appropriate technologies or Appropriate Technology practices within sports journalism.*

Personal Remark from Cristina Rivera: *Personally, I believe that Appropriate Technology and GREAT IDEA's main objectives represent a REAL economic and social approach, applicable in any professional field. From a business perspective, it promotes social responsibility and ethical compliance, and it enables the efficient and sustainable fulfillment of the purpose of any organization and industry in general. My work with GREAT IDEA represents one of the most significant experiences in my academic and professional career. This experience has helped me realize many different career paths and also made me aware of the importance of the analysis and proposals of alternatives (strategies, initiatives) that assess the social realities of diverse groups with diverse opinions and needs.*

5. Relation to Ethics Education

Research in Appropriate Technology (henceforth abbreviated as "AT" when used in the broad sense of Appropriate Technology practice) raises ethical challenges, first because it is action-oriented and, second, because the call for action arises out of a normative assessment of a specific socio-technical-natural system. Indeed, research in AT requires the researcher to make an intentional choice of topic and application as related to a social situation. This is not necessarily the case with research that is characterized as pure or theoretical (as opposed to practical).

But Appropriate Technology research and practice also share ethical issues with more traditional, theoretically-oriented research in science and engineering. Outlining exhaustively where traditional research ethics (e.g., Responsible Conduct of Research, or "RCR") and Appropriate Technology research ethics converge and diverge is beyond the scope of this paper, and this is further complicated by the fact that there does not seem to be a uniformly accepted taxonomy of traditional research ethics issues.[22(pp. 4-5)] Nevertheless, some pertinent comments can be made on how our project has addressed the ethical and normative challenges raised by AT research and practice.

One way to identify ethical issues in engineering and scientific research is to deploy a "double axiological axis".[23(p. 491)] Research practices that promote or detract from the truth can be located around an **axis of truth**. Thus, fabrication, falsification, and plagiarism are proscribed because they interfere with the pursuit and dissemination of truth. Other issues, such as those centering on the treatment of animals and humans as experimental subjects, can be located around an **axis of social responsibility**. For example, the Belmont Report's injunction to create

Institutional Review Boards that review research based on respect for persons, beneficence, and justice highlights key elements of socially responsible research involving human subjects.

Research in AT shares many issues with traditional research ethics but others can be characterized as "new species of traditional moral issues".[24(pp. 16-19)] A good example is informed consent. Our students debate a case where scientists ponder how to facilitate informed consent from the inhabitants of a small isolated village in New Guinea from whom they wish to draw blood samples for a rather advanced study. Consent obviously includes comprehension but this may be particularly challenging when dealing with indigenous populations who lack analogies or experiences upon which to build common understandings.[25] In this way, AT and community development require "stretching" moral concepts to cover new situations.

Another way in which our project researchers have sought to extend traditional RCR to AT and community development is to add a third axiological axis, **social justice**. World hunger, poverty (and "poverty traps"), and political oppression fall unfairly upon undeserving peoples. This distribution does not come from out of the blue. Hunger arises as industrialized agricultural practices crowd out subsistence farming.[26] Poverty arises when unfair worldwide financial practices impoverish innocent peoples[27] while lack of access to education and inadequate insurance create poverty traps from which many victims vainly struggle to escape.[28(p. 11)] Research addressed toward identifying such injustices and then developing remedial technologies and practices should be framed under the rubric of social justice.

These points can be put more directly: AT research raises ethical challenges because it is designed to bring about social, political, and economic change. The ethical challenge is to recognize when it is necessary (and feasible) to address social injustices and how to empower agency and initiate value-positive change to bring about such remediation. Closely associated with social justice are a series of practical, normative, and ethical challenges. For example, how does one expand capabilities rather than create dependencies? How does one plan and implement means for bringing about value-positive, moral change given the difficulties with technology control and predictive accuracy? Thus, the normative, ethical and practical challenges raised by AT research and practice more than justify adding this third axiological axis of social justice.

A new course, INTD 6095 "Responsible Research in Appropriate Technology", was created and delivered by William Frey to address the new species of traditional concepts raised by research in AT and to outline the third axiological axis of social justice. It was taught for the first time in the Fall 2013 semester and is still undergoing development. In its current form, it addresses traditional issues in research ethics, IRB issues (respect for persons, beneficence, justice), responsible technological choice, techno-socio sensitivity,[29] and the specific ethical issues that arise in the research of the graduate students taking the class. The content and activities of this class have been published in an online platform called *Connexions*®.[30] The following summarizes assessment results that have been reported on in more detail elsewhere.[31] In particular, the class projects of Joann Rodriguez[32] and Pablo Acevedo[33] are published in Connexions, and relate to their research as described in Section 3.

1. Modules profiling rights and social justice helped broadened student awareness in the third axiological axis, social justice. Students were provided with a framework for examining and justifying rights claims and were able to demonstrate through responses to essay questions and through presentations that they understood these concepts and could apply them in situations arising in the application of AT research and practice. Students also were able to use different frameworks in social justice to help them recognize these issues in *their* research. For example, one student discussed different patterns in distributive justice for allocating the burden of cleaning up local waterways among those contributing to non-point source pollution.

2. Students identified a gap in the first course offering that needs to be addressed when the course is reoffered. More discussion of what Werhane et al. term "profitable partnerships" is required to help students move from research to practice.[34] The interdisciplinary backgrounds represented by students in the course helped them experiment with interdisciplinary "mixes" to respond to real world problems. Could for-profit companies partner with government agencies and NGOs to tackle problems of community development and social injustice? Could recent business innovations like micro-financing help to better instantiate AT into social-technical-natural systems where they could contribute to value-positive change? Assessment activities revealed that preliminary thought experiments along these lines helped students. It also dramatized the need for future instantiations of this course to address these issues in more detail.

- The interdisciplinary mix in the first offering of this course produced, perhaps, the most positive outcome. Four different backgrounds were represented by six students: environmental engineering, civil engineering, marine sciences, and business administration. This diversity challenged them at the beginning of the semester to understand work carried out by their peers in different areas. But different frameworks presented during the semester such as rights justification and responsible technology choice frameworks helped students build a common vocabulary and identify areas for interdisciplinary comparison. (The technology choice framework had students search for the analogue of a technical artifact in their area of research.) These shared frameworks encouraged students to draw comparisons between their own work and that of their peers. This "critical mass" will be difficult to duplicate, perhaps, in future offerings. It relied heavily on students who were at an advanced stage of their graduate research, and who were unusually interested in the research being carried out by their peers. But a happy finding of this first instantiation of the course was that research ethics in AT provides frameworks that have the additional benefit of stimulating interdisciplinary conversations.

Further remarks from Cristina Rivera regarding her perspective of INTD 6095 as the course TA: *I believe that the main objectives of GREAT IDEA materialized as its elements and values were integrated into the research projects presented and discussed during class. An interesting dynamic resulted from the analysis of students from diverse educational backgrounds and research approaches. Common ground was achieved mainly because the course provided students with the resources to integrate ethics frameworks into their research projects. Through the semester it was evident how*

participants evolved to recognize and understand the effect that technology has in every aspect of society and within a community, e.g., awareness of the "triple bottom line". Students also integrated the "zooming in - zooming out" process in which they looked at the specific details of their work, say as a technological artefact, to be congruent with the relevant social and environmental aspects from the first stage of research though the design and implementation stages. In general this course provided the students the resources to successfully approach effective research in within the Appropriate Technology framework, particularly with respect to considering social justice and social responsibility.

6. Conclusions

We have provided a background on the meaning of "Appropriate Technology" and described how we sponsor graduate student research in this topic at our institution. The topics that our students have selected are widely varied, but each corresponds to our broad, somewhat informal definition that the research is "responsive to a specific community or societal context". Moreover, each project represents a concrete example of how usual research methods and technical rigor apply to these topics. In conducting research in AT, the usual questions of research ethics arise, of course, but new variants of these traditional issues also arise. To prepare our students to work over this spectrum, two courses have been created that address both the traditional and expanded senses of RCR in the context of research in AT.

As we institutionalize our efforts, we will keep track of the eventual research products and career trajectories of our sponsored students. We have established an identity at our campus and we expect to continue to attract further students to conduct research in AT, while at the same time providing a general service of providing education in RCR to all interested graduate students. In addition, we expect that in the future, some students will conduct research in AT with faculty advisors who were not investigators of our project, but who are enthusiastic to advise research in AT, particularly as interdisciplinary committees are required for such research.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1033028. The authors gratefully acknowledge this support. The authors thank Dr. Kelvin Willoughby for providing overall feedback and suggestions on how to develop the "Characterization Remarks". The authors also thank Dr. Héctor Huyke for providing a general review of the manuscript.

References

1. Practical Action. Website: http://practicalaction.org/history. Queried January 5, 2014.
2. Schumacher, E.F. *Small is Beautiful: A Study of Economics as if People Mattered*. Blond & Briggs, 1973.
3. Willoughby, K. *Technology Choice: A Critique of the Appropriate Technology Movement*. Westview Press, 1990.
4. Wood, B. *Alias Papa: A Life of Fritz Schumacher*. Jonathan Cape, London, 1984.

5. Schumacher, E.F. *Good Work*. Harper & Row, New York, 1979.
6. Weidel, Timothy, *Beyond Utility, Rights, and Care: An Alternative Approach to Global Poverty*. PhD Dissertation, Loyola University Chicago, 2012. Paper 403. http://ecommons.luc.edu/luc_diss/403
7. Akubue, A. "Appropriate Technology for Socioeconomic Development in Third-World Countries. *The Journal of Technology Studies: an E-Journal*. Vol. 26, No. 1, Winter/Spring, 2000.
8. Schumacher, E.F. "How to Help Them Help Themselves". *Observer*, London, August 29, 1965.
9. Jéquier, N. and G. Blanc. *The World of Appropriate Technology*. Organization for Economic Cooperation and Development (OECD), Paris, 1983.
10. National Science Foundation. "NSF Continues Appropriate Technology Research Program". *Anthropology News*, Volume 21, Issue 9, page 7, December 1980.
11. Wicklein, R. (2001). *Appropriate Technology for Sustainable Living* edited by Robert C. Wicklein Accessed January 2014: http://wickone.myweb.uga.edu/Appropriate.html
12. Sianipar, C.P.M., Yudoko, G., Adhiutama, A., and Dowaki, K. (2013). "Community empowerment through appropriate technology: Sustaining the sustainable development". *Procedia Environmental Sciences* 17, 1007-1016.
13. Oosterlaken, I. (2013). *Taking a Capability Approach to Technology and Its Design: A Philosophical Exploration.* 3TU. Center for Ethics and Technology. (Dissertation published through 3TU.Center for Ethics and Technology, Technische Universiteit Delft.
14. International Network on Appropriate Technology, INAT. (2014). *International Conference on Appropriate Technology Proceedings*. Accessed January 2014: http://www.appropriatetech.net/?q=content/icat-downloads
15. GREAT IDEA Project Webpage: www.greatidea.uprm.edu
16. Castro-Sitiriche, M., C. Papadopoulos, W. Frey, and H. Huyke. "Sustainable Wellbeing Education in Engineering", 2012 IEEE International Symposium on Sustainable Systems and Technology, DOI 10.1109/ISSST.2012.6228005, 16-18 May 2012.
17. Frey, W., C. Papadopoulos, M. Castro-Sitiriche, F. Zevallos, and D. Echevarría. "On Integrating Appropriate Technology Responsive to Community Capabilities: A Case Study from Haiti", Proceedings of the ASEE Annual Conference and Exposition, San Antonio, TX, June 2012.
18. Maldonado, R., C. Gomez, and M. Castro-Sitiriche. "Simulation, design, hardware implementation, and control of a 9-level Flying Capacitor Multilevel Inverter with Particle Swarm Optimization algorithm". IEEE 13th Workshop on Control and Modeling for Power Electronics (COMPEL), pp.1-6, June 2012.
19. D. Chacon. *Sustainable Development and Transportation Decision Making: Embedding Community Preferences in Visualizations*. Master's Thesis, University of Puerto Rico, Mayagüez, December 2013.
20. J. Rodríguez, B. Hernandez, P. Tarafa, and C. Papadopoulos. "Development of a Procedure and Apparatus to Quantify Pathogen Reduction Throughout an Intermittent Biosand Filter". International Perspective on Water Resources and the Environment. Quito, Ecuador, January 2014.
21. C. Rivera Vélez. Corporate Social Responsibility in the Media. Master's Thesis, University of Puerto Rico, Mayagüez, December 2013.
22. Comstock, G. (2013). *Research Ethics: A philosophical guide to the responsible conduct of research.* Cambridge, UK: Cambridge University Press, pp. 4-5.
23. Ferrer, Jorge José. (2007). *Deber Y Deliberación: Una Invitación a la Bioética*. Mayagüez, PR: Centro de Publicaciones Académicas Facultad de Artes y Ciencias UPR-RUM, p. 491.
24. Johnson, D. (2001). *Computer Ethics, 3rd Edition.* New Jersey, Prentice-Hall, pp. 16-19)
25. Informed Consent and the Collection of Biological Samples from Indigenous Populations. (1998) *Graduate Research Ethics: Cases and Commentaries – Volume 2.* Brian Schrag, ed.
26. *World Hunger and Morality*: 2nd Ed. (1996). Aiken, W. & LaFollette, H., eds. Upper Saddle River, NJ.: Prentice Hall.
27. Stiglitz, J. (2003). *Globalization and its Discontents*. New York: W.W. Norton and Company.
28. Smith, S. (2008). *Ending Global Poverty: A Guide to What Works*. Macmillan, p. 11.
29. Harris, CE. (2008). The Good Engineer: giving virtue its due in engineering ethics. *Science and Engineering Ethics*, 14(2), pp. 153-164.
30. Frey, W., & Rivera, C. (2014, February 17). Responsible Research in Appropriate Technology. Retrieved from the Connexions Web site: http://cnx.org/content/col11556/1.5/
31. Frey, W., & Rivera, C. (2014). Bringing Responsible Research into Engineering Ethics: Responsible Research in Appropriate Technology. *Proceedings*: *2014 International Symposium on Ethics in Engineering, Science, and Technology*.

32. Rodriguez, J. (2013, December 15). *Biofiltro Intermitente de Arena: Alternativa para tratar el agua en casa Caso de Estudio: Duchity, Haití*. Retrieved from the Connexions Web site: http://cnx.org/content/m48209/1.2/
33. Acevedo, P. (2014, February 6). *Bambú Tropical como Material Alternativo Para Construcción de Estructuras, Elaboración de Herramientas y Artesanía.* Retrieved from the Connexions Web site: http://cnx.org/content/m48977/1.1/
34. P. Werhane, S.P. Kelley, L.P. Hartman, and D.J. Moberg, Alleviating Poverty through Profitable Partnerships: Globalization, Markets and Economic Well-Being. NY: Routledge, 2010, pp. 91-95.