Convergence

Frugal Engineering
Research
Sustainability
Social Entrepreneurship
Service Learning in Engineering
Humanitarian Engineering
Interdisciplinary
Reflection
Frugal Innovation

Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs

Edited By: Thomas H. Colledge, PhD, PE

International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)

ISBN 978-0-615-60997-3
90000>
9 780615 609973

Convergence

Frugal Engineering

Research

Sustainability

Social Entrepreneurship

Service Learning in Engineering

Humanitarian Engineering

Interdisciplinary

Reflection

Frugal Innovation

Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs

Edited By: Thomas H. Colledge, PhD, PE

Rice University students engaging members of the 'Next Generation of Humanitarian Engineers and Social Entrepreneurs' - Class of 2019*

*Beach, K.E., et al, Integrating Research, Undergraduate Education and Engineering Outreach, International Journal for Service Learning in Engineering, Vol. 2, No. 2, pp. 89-101, 2007

*"…..service learning 'should be viewed as among the most powerful of teaching procedures, if the teaching goal is lasting learning that can be used to shape student's lives around the world.'"**

*Kellogg Commission on the Future of State and Land-Grant Universities. Returning to our roots: The engaged institution. (Washington, DC: National Association for Higher Education, 1999).

Printed in the United States of America.

Published by *the International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)* and supported by the National Collegiate Inventors and Innovators Alliance (NCIIA) and the College of Engineering at The Pennsylvania State University.

ISBN 978-0-615-60997-3

Acknowledgements

The editors of the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)* sincerely appreciate the support received for the Journal and this book from the National Collegiate Inventors and Innovators Alliance (NCIIA), The Pennsylvania State University, and Queen's University. A special thanks to Bonnie Osif, Rachel Dzombak, Melanie Fedri, Bridget Dougher and Toral Zaveri for their critiquing and proofreading efforts on the book.

From the Editor:

Over the years, there have been many innovative and daring souls from around the world; faculty members, researchers, practitioners, and students, who have sought to nurture a spirit within the engineering and entrepreneurship communities; a spirit which encourages the assumption of leadership and use of academic skills to tackle some of the most pressing problems of marginalized peoples around the world – while implementing pedagogies and engaging in projects which produce a better educated student and citizen.

Recognizing the need for a 'convergence' of interdisciplinary collaboration, academic rigor, cultural awareness, sustainability, entrepreneurial skills, and applied research, these pioneers have begun to coalesce around the notion that by collaboratively employing their skills, they may in fact achieve both goals. These efforts have been undertaken under many names: service learning in engineering, humanitarian engineering, social entrepreneurship, frugal engineering, and others. In the process, a sense of community has begun to be forged.

In an effort to facilitate this movement, the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)* was founded in 2006 to provide an outlet for the scholarly work of this emergent community. The Journal seeks to nurture such efforts as a distinct body of knowledge.

IJSLE is proud to have worked with the various contributing authors of this book to provide background and context to those who may wish to learn more about what we feel is one of the most exciting pedagogical movements in higher education today – the enhancement of rigorous experiential learning opportunities for students while concurrently making a meaningful, sustainable difference in the lives of marginalized people around the world. On behalf of the editors of IJSLE, I encourage you to participate in this exciting academic arena and to consider disseminating your work through the IJSLE.

Thomas H. Colledge, PhD, PE
Editor-in-Chief, IJSLE

From the Sponsor:

Every generation has an emblematic educational innovation that over time becomes part of the 'normal' approach to training the next generation. The experiential, socially beneficial learning approaches that are the focus of this volume are no doubt such hallmark innovations. It is critical that the learning and practices of the pioneers in this field are documented and disseminated and for that reason, we at NCIIA are pleased to have been able to support the formation and emergence of the IJSLE and the creation of this volume.

The National Collegiate Inventors & Innovators Alliance (NCIIA) is a US educational non-profit focused on stimulating and supporting the next generation of inventors, innovators and entrepreneurs. With a membership of nearly 200 colleges and universities from all over the United States, the NCIIA engages more than 5,000 student and faculty innovators and entrepreneurs each year, helping them to bring their concepts to commercialization.

Through the support of this field we hope to catalyze new approaches to education that give rise to empathetic innovators equipped with the tools, experience and attitude to apply science and technology in an entrepreneurial way to make the world a better place. I thank you for your interest in engaging in this effort and welcome your participation in our emerging community.

Phil Weilerstein
Executive Director
NCIIA

Contributing Authors

Dr. Manuel C. Belino, Dean, School of Mechanical Engineering, Mapúa Institute of Technology, Manila, Philippines, mcbelino@mapua.edu.ph

Dr. Angela Bielefeldt, PE, Associate Professor of Civil Engineering, University of Colorado, Angela.Bielefeldt@Colorado.edu

Debbi Brock, Assistant Professor of Entrepreneurship, Anderson University, ddbrock@anderson.edu

Dr. Nalini Chhetri, Professor, School of Sustainability, Arizona State University, nalini.chhetri@asu.edu

Dr. Thomas H. Colledge, PE, Assistant Professor, Engineering Design, Editor-in-Chief, *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE),* Penn State University, thc100@psu.edu

Dr. Mark Henderson, Professor, Department of Engineering, College of Technology Innovation, ASU Polytechnic, mark.henderson@asu.edu

Dr. Martina Jordaan, Senior Lecturer, Community Based Project Module, Department of Informatics, University of Pretoria, martina.jordaan@up.ac.za

Dr. Lois A. Jordan, PE, Visiting Professor, Department of Management, The University of Tampa, ljordan@ut.edu

Khanjan Mehta, Director, Humanitarian Engineering and Social Entrepreneurship (HESE), Penn State University, krm209@psu.edu

Dr. Carl Mitcham, Professor, Liberal Arts and International Studies Division, Director of the Hennebach Program for the Humanities, Colorado School of Mines, cmitcham@mines.edu

Dr. David R. Muñoz, Associate Professor, Engineering Division, Director, Humanitarian Engineering Minor Program, Colorado School of Mines, dmunoz@mines.edu

Usman Mushtaq, Civil Engineering, Queen's University, usman.mushtaq@queensu.ca

Dr. William Oakes, Associate Professor, Engineering Education, Director, EPICS, Purdue University, oakes@purdue.edu

Dan O'Neill, Director, Venture Acceleration, ASU Venture Catalyst, Arizona State University, dan.oneill@asu.edu

Dr. Carlos R. Paredes, Dean, College of Engineering, University of the Valley of Guatemala, cparedes@uvg.edu.gt

Dr. Joshua M. Pearce, Associate Professor, Department of Materials Science and Engineering and Department of Electrical and Computing Engineering, Michigan Technological University, pearce@mtu.edu

Dr. Bradley Rogers, Associate Professor, Department of Engineering Technology, College of Technology Innovation, ASU Polytechnic, BRogers@asu.edu

Dr. Susan D. Steiner, CPA, Associate Professor, Chair, Department of Management, The University of Tampa, ssteiner@ut.edu

Dr. John Takamura, Assistant Professor, Herberger Institute for Design and the Arts, Arizona State University, John.Takamura@asu.edu

Table of Contents

Acknowledgments		*v*
Editors: International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship		*viii*
Contributing Authors		*ix*
Introduction	by: Thomas H. Colledge	2
Chapter 1:	**Rationale** by: Thomas H. Colledge	6
Chapter 2:	**Service Learning in Engineering** by: Angela Bielefeldt and Joshua Pearce	24
Chapter 3:	**Humanitarian Engineering** by: David R. Muñoz and Carl Mitcham	54
Chapter 4:	**Using the Social Entrepreneurship Model to Teach Engineering Students How to Create Lasting Social Change** by: Debbi Brock, Susan Steiner, Lois Jordan	80
Chapter 5:	**Frugal Innovation** by: Dan O'Neill, John Takamura, Nalini Chhetri, Mark Henderson, Bradley Rogers	96
Chapter 6:	**The Philosophy and Praxis of Convergence to Shape an Emergent High-Impact Learning Through Service Program** by: Khanjan Mehta	114
Chapter 7:	**Learning Through Service: Best Practices** by: William Oakes	146
Chapter 8:	**International Perspectives on Service Learning** by: Manuel C. Belino, Martina Jordaan, Carlos R. Paredes	178
Chapter 9:	**Open Access Scholarly Knowledge: a Common Wealth** by: Usman Mustaq	204
Chapter 10:	**Stakeholders**	214

Students from the University of Virginia discuss their water treatment design with community leaders in Venda, South Africa…….

….and share the task of transporting sand for use in construction of the filters.

"A dreamer is one who can only find his way by moonlight, and his punishment is that he sees the dawn before the rest of the world."

— Oscar Wilde

INTRODUCTION

Thomas H. Colledge, PhD, PE
The Pennsylvania State University

The editors of the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)* are pleased and proud to have collaborated with faculty from around the world to provide you with this book. This effort would not have been possible without the support and assistance from the National Collegiate Inventors and Innovators Alliance (NCIIA) as well as the American Society of Mechanical Engineers (ASME) and the Institute of Electrical and Electronics Engineers (IEEE).

The intent of the book is to detail a number of academic programs and pedagogies being implemented at various universities around the world which seek to 'do good' (through collaboration with people in marginalized communities to alleviate pressing problems they experience) while 'doing well' (for students in terms of enhancing their academic and 'real world' learning). We also wanted to pass along some suggested best practices should you choose to develop your own similar program. A final goal in producing the book is to encourage those engaged in such efforts to disseminate the results of their work in the IJSLE.

IJSLE publishes the original work of practitioners and researchers who have a specific focus on projects, programs, research and pedagogy that involve Humanitarian Engineering, Social Entrepreneurship, Frugal Engineering and Service Learning in Engineering. The primary purpose of the journal is to foster inquiry into rigorous engineering design, research and entrepreneurship efforts which are directed toward solving problems of marginalized communities. The journal seeks to nurture Humanitarian Engineering, Social Entrepreneurship, Frugal Engineering and Service Learning in Engineering as a distinct body of knowledge.

Given the growing interest in such programs across the country (and indeed the world), as well as the variety of names and titles which describe such efforts, the editors felt it worthwhile to provide a primer for faculty, administrators, community leaders, and other interested parties which might assist them in better understanding the differences and similarities amongst the various programs. It is also hoped that this book might serve as a source of information and context for the existing community of practitioners at universities, those dreamers, who have set their hearts and passionate aspirations on using their academic training and skills to address the problems of those around the world who lack the resources and/or wherewithal to do so for themselves.

Primary constituents of this intended audience are engineering and entrepreneurship faculty and their students. It is recognized, however, that to be successful, many other disciplines critical to such ventures must be drawn from, including: business, education, agriculture, science, human development and liberal arts among others. As such, another key objective of this book is to encourage and facilitate multidisciplinary collaboration when addressing the problems of marginalized communities.

This book, then, is intended to serve as a resource book for those who wish to learn more about what we feel is one of the most exciting pedagogical movements in higher education today – the enhancement of collaborative learning by those involved in such efforts (students, faculty, practicing engineers and other professionals, community members) while concurrently making a meaningful, sustainable difference in the lives of marginalized people around the world.

In the following chapters, a number of educational programs and approaches will be discussed along with tools to facilitate such inter-disciplinary, collaborative efforts. These programs and their definitions, as provided by the authors of the respective chapters, are as follows:

- **Humanitarian Engineering:** The artful drawing upon of science to direct the resources of nature with active compassion to meet the basic needs of all—especially the economically poor, or otherwise marginalized, always seeking a balance of listening and learning from the traditional people while humbly sharing appropriate engineering knowledge.

- **Social Entrepreneurship:** The creation of social impact by developing and implementing a sustainable business model which draws on innovative solutions that benefit the disadvantaged and, ultimately, society at large.

- **Frugal Engineering:** The complete rethinking and rebuilding of the product/process development process in order to design, develop and deliver innovative solutions to customers at the Base-of-the-Pyramid (BOP).

- **Service Learning in Engineering:** A form of experiential education which combines community service and academic instruction with critical, reflective thinking and civic responsibility.

These program types often overlap in purpose, activities, and methods, but all seek to engage students in meaningful, transformative, real life adventures and educational experiences while simultaneously making a difference in the lives of others who lack the means to improve their own lives.

It is hoped that the information contained in the book will provide greater insight and motivation for those who may be considering 'doing good while doing well' to not only improve the lives of those in the world who lack the means to do so themselves, but also to have their students benefit from the active learning environments which are inherent in such efforts.

Mapúa Institute of Technology students testing their hydroturbine-generator

The result: The first night ever with electricity in Sitio Henalong, Philippines

"And let it be noted that there is no more delicate matter to take in hand, nor more dangerous to conduct, nor more doubtful in its success, than to set up as the leader in the introduction of changes. For he who innovates will have for his enemies all those who are well off under the existing order of things, and only lukewarm supporters in those who might be better off under the new."

— Niccolò Machiavelli
The Prince

CHAPTER 1
Rationale

Thomas H. Colledge, PhD, PE
The Pennsylvania State University

Historically, the undertaking of service projects – engaging marginalized individuals or communities in improving some facet of their lives - has been viewed by many as simply doing 'nice things for poor people'. Student 'service learning' efforts often include projects such as painting orphanages, repairing roofs, reading to children, and so on. It is recognized that such altruistic efforts certainly have value as students gain cultural awareness, civic responsibility, and develop critical leadership skills while simultaneously satisfying a real need experienced by the partnering community. The literature details the benefits of a variety of forms of service learning experiences. Showing 'solidarity with the poor' and making a human connection are necessary to sustain hope and thus affect change, and are powerful and essential elements in 'making the world a better place'.

However, more often than not, the types of service projects being undertaken were such that the marginalized communities could very well have accomplished all they needed to do simply by having the funds to undertake the projects themselves. Engagement, resulting in high value addition, empowerment, and sustainability of efforts, was not commonly achieved through this form of service learning. This may help to explain the knee-jerk reaction by many to the notion of service learning projects as being merely educational 'fluff'; that is, the engagement in projects as 'service' being without rigorous academic value and the sustainable value addition for marginalized communities was minimal.

More rigorous academic learning opportunities, particularly for engineers, which would directly and sustainably benefit the marginalized communities, were not commonly available. This was the case for a variety of reasons: no formal, technical mentoring was afforded students either through projects embedded in courses or by other means of formal mentoring, insufficient logistical support, poor communications, lack of funding, unsustainable collaborations and partnerships in place, and so on.

The hurdles to rigorous academic engagement were indeed high. The end result, however, was clear. Though not commonly undertaken as 'service', a need existed for significant, high-impact projects requiring technical proficiency, a deep understanding of communities' social and cultural contexts, and realistic assessments of customer and market needs, and sustainable implementation of designed solutions.

At the same time, there exists a persistent and growing need to address problems confronting a huge proportion of humanity - those at the Bottom of the Pyramid (BOP). This phrase, BOP, refers to the 2.5 billion people who live on less than $2.50 per day[1], as first defined in 1998 by Professors C.K. Prahalad and Stuart L. Hart. It was subsequently expanded upon by both in their books: The *Fortune at the Bottom of the Pyramid by Prahalad*[2] and *Capitalism at the Crossroads by Hart*[3]. These billions of people often lack access to basic necessities, such as: adequate housing, energy, water quantity and quality, wastewater treatment, efficient agricultural products/processes, as well as meaningful employment opportunities. Essential in addressing these issues, aside from technical expertise but equally important, are potential entrepreneurial solutions to ensure economic sustainability as well as social and cultural acceptance of such solutions.

Many of these problems might be best addressed by engineers in collaboration with other professionals. The nature of these vast needs often motivate many engineers, business men and woman, social scientists, and others to desire to make a difference, to engage in and address such problems. But altruism alone does not govern such actions by these practitioners. Practical benefits are derived from such participation, particularly for students. For example, future markets may lie precisely in these emerging areas. As such, cultural familiarity, technological competency, language and networking skills will be needed to successfully function in such markets. In addition, globalization dictates the need for engineers and others to be prepared to collaborate with colleagues around the world in addition to being familiar with such markets.

Engineers have a long track record of addressing the needs of people.

From the design and construction of bridges which facilitate the transport of food stuffs to market, to developing life-saving pharmaceuticals, to development of electrical devices which lighten life's burdens, and on and on. Engineering, as a discipline, has improved the lives of many billions of people around the world over time.

In spite of all the technological successes achieved by engineers over the centuries though, most engineering interventions have been directed to just a tiny fraction of the world's population. By some estimates, 90% of all engineering design impacts just 10% of the world's population. A great demand exists for engineering solutions which address problems of those least able to afford expertly designed systems. For many, this may be viewed as a moral issue, an imperative to act. But, unfortunately, economic constraints serve to prevent many from acting in this regard. There are no economic forces that drive participation by trained engineers to address the problems of most of the world. Given that 80% of the world makes less than $10 per day, one avenue which might attract such technical expertise to address the problems of the poor is to couch the problem in an entrepreneurial light – that is, to consider those 5.6 billion people as a potential market. If proper incentives are present, design of solutions will follow. And if entrepreneurial energy, creativity, and collaborative efforts are unleashed, real results might be achieved.

It is against this backdrop that programs such as Humanitarian Engineering, Social Entrepreneurship, Frugal Engineering and Service Learning in Engineering have evolved and subsequently found themselves confronting skeptics; both as to the academic value of such efforts, and in other quarters, the true value of the projects being implemented in the communities themselves.

Students, faculty and administrators often easily make the connection between the value of such programs and finding employment with organizations like the Peace Corp or various non-governmental organizations (NGOs). However, quite often they do not make the critical connection between these efforts and the needs of the next generation of engineers and entrepreneurs. It will be useful to briefly describe those objectives of engineering education as detailed by a) the National Academy of Engineering, b) the Accreditation Board for Engineering and Technology, and c) industry and see how such programs fit with these objectives and do not simply serve as a means to do 'nice things for poor people'. It will also be useful to elaborate upon the expectations, benefits and hurdles of such efforts by a variety of stakeholders including: universities, colleges, departments, faculty, students and communities.

National Academy of Engineering (NAE)

From a professional development standpoint, the National Academy of Engineering's report 'The Engineer of 2020'[4] laid out a vision of what skills and attributes engineers will need to be successful in the coming decades. The report suggests that engineering education should emphasize the development of students as **emerging professionals** and **educated citizens**, "equally at home with **societal concerns** as they are with **technical issues**." They stress the need for engineers to continue to possess **strong analytical skills**, but to expand the engineering design space such that the impacts of **social systems** and their associated constraints are afforded as much attention as **economic, legal, and political constraints** (e.g., resource management, standards, and accountability requirements). They foresee engineers needing to concentrate on **systemic** outcomes in the same ways that focused outcomes are considered.

An excellent example of an endeavor which addresses such goals would be that of the 'Mashavu: Networked Health Solutions' venture developed at Penn State. In the United States there are 390 people for every physician. In many parts of East Africa, that ratio is 50,000 people for every physician. Many people in these communities have especially high instances of communicable diseases and infection, in addition to malnutrition. Inadequate prevention and treatment of these

FIGURE 1.1 A COMMON EAST AFRICAN HOUSEHOLD

problems is directly related to the lack of available medical care. For individuals living on less than $2 a day, as is typical in rural Kenya, the transportation cost to reach a doctor amounts to two days' income. The cost of transportation, combined with the long lines that are typical at health clinics, lead many people to wait until they have a medical emergency before seeking any form of care. As an engineer, as part of a multidisciplinary team in programs such as the Humanitarian Engineering and Social Entrepreneurship (HESE) program at Penn State for example, students are asked to address such ill-defined problems – and actually implement sustainable solutions!

Clearly, the technical skills employed by students in disciplines such as electrical engineering, computer science, bioengineering, among others could be envisioned as critical to such an effort. Equally challenging, however, is requiring the students to collaborate in a multidisciplinary fashion taking into consideration the cultural, economic, legal and political constraints in the East African context. Intimate familiarity with the social context is inherent in the process.

The need for **practical ingenuity** by engineers will continue to be a mainstay in engineering education and in their professional careers. For example, issues related to climate change, the environment, and the intersections between technology and social/public policies are becoming increasingly important. **Creativity** (invention, innovation, thinking outside the box, art) is an indispensable quality for engineering. The creativity requisite for engineering will change only in the sense that the problems to be solved may require **synthesis** of a broader range of **interdisciplinary knowledge** and a greater focus on **systemic** constructs and outcomes.

FIGURE 1.2 MASHAVU MEDICAL TESTING

For the Mashavu system, engineering students have designed low-cost medical devices that gather vital information including: images, body temperature, lung capacity, height/weight, blood oxygen saturation, blood pressure, and stethoscope rhythms. They have additionally created a web-based portal that transmits the gathered information to medical personal anywhere in the world. Multidisciplinary design teams are assembled and perform as a team. Besides engineering students, students from medicine, law, international affairs, business, human development, geography, communications, and education among others take part on the teams. The synergies developed through such multi-year, multidisciplinary engagement provide fertile ground for creative and innovative design solutions while employing a systems approach.

As always, good engineering requires good **communication skills**. Engineering must engage multiple stakeholders—government, private industry, and the public. Parties that engineering ties together must involve **interdisciplinary teams, globally diverse team members, public officials, and a global customer base**.

Imagine the Mashavu teams, collaborating with their counterparts from East Africa via the internet, and developing solutions to address the health care problem by connecting medical professionals to rural communities in East Africa using modern technology and communications infrastructure. This is accomplished by ensuring that Web servers aggregate the information from various stations and provide it to medical professionals anywhere in the world through the online portal.

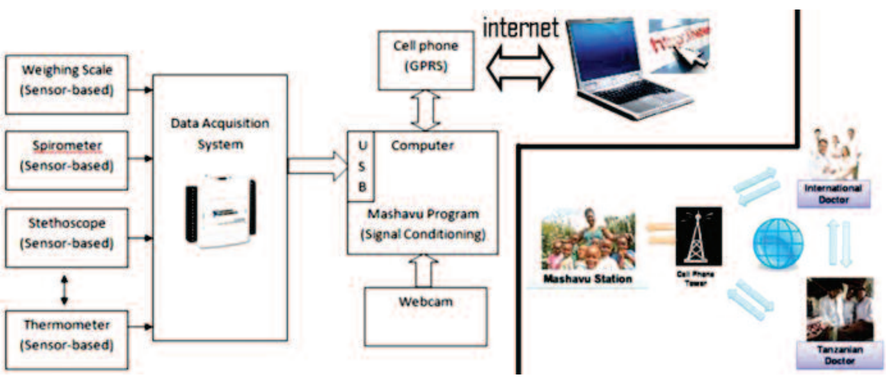


FIGURE 1.3 MASHAVU SYSTEM

With the growing interdependence between technology and the economic and social foundations of modern society, an increasing number of opportunities for engineers to exercise their potential as **leaders in business and management** must be provided, not only in business but also in the nonprofit and government sectors. **Policy decisions** in technological societies demand the attention of leaders who understand the strengths and limitations of science and technology.

In this regard, think of the practical aspects of developing business plans for the Mashavu venture. Plans that ensure that the medical professionals have incentives to supervise the health of the patients and provide medical feedback, as do the Mashavu kiosk operators who staff such systems. The business planning, supply chains, user-centered design needs, and the impact of employment for the local population all are of critical importance to the designer. Students interact with government regulators, policy makers and engage in discussions on altering how health care is delivered in such marginalized communities. These experiences directly lead to engineers understanding the principles of **leadership** and being able to practice them in growing proportions as their careers advance. How they must also acknowledge the significance and importance of **public service and its place in society**, stretching their traditional comfort zone and accepting the challenge of **bridging public policy and technology** well beyond the roles accepted in the past.

Complementary to the necessity for strong leadership ability on such projects is the need to also possess a working framework upon which **high ethical standards** and a strong sense of **professionalism** can be developed. These are supported by **boldness and courage**. Striving to succeed in a resource constrained environment, while directly impacting the lives of people, places the students in the front lines in terms of boldly leading such difficult efforts. The 'gray' choices to be made, balancing (for example) economic, social, environmental, and gender-related factors, with cost constraints provide the context for students to benefit through a sense of purpose and clarity.

The novel solutions arrived at by the Mashavu team demonstrates the success of efforts in terms the students employing the **dynamism, agility, resilience**, and **flexibility** required to make 'it' happen. Not only is technology changing quickly, but the social-political-economic world in which engineers work changes continuously as well. In this context, it is not 'this or that' particular knowledge that engineers need, but rather, the **ability to think critically, learn new things quickly and the ability to apply knowledge to new problems and new contexts**. Being able to adapt, to solve problems on the ground, with time constraints, in East Africa surely works to facilitate these particular identified educational goals for the students.

NAE stresses that for students to be individually and personally successful, they need to learn continuously throughout their careers; and not just about engineering but also about history, politics, business, and social customs. Encompassed in this theme is the imperative for engineers to be **lifelong learners**. For Mashavu members, after returning from their travel to East Africa, they write scholarly papers for publication and dissemination as well as reflect on their achievements. Such activities allow the Mashavu team members to gain perspective as well as recognize the need for lifelong learning.

The exciting and highly motivational opportunities to address nearly every one of the skills to be developed in engineering students, as identified by NAE, are addressed by the students participating in such projects, AND, the community benefits through its implementation.

Accreditation Board for Engineering and Technology (ABET)

Similar objectives are reflected in the Accreditation Board for Engineering and Technology (ABET)'s Engineering Criteria Outcomes 3a-3k. It is suggested that students be immersed in engineering design and practice, incorporating societal, economic, and cultural concerns in the design process, as early and as pervasively as possible. In an effort to highlight the movement toward emphasizing these 'soft skills', the ABET EC 2000, Criterion 3, a-k processing skills are categorized as follows:

'Technical' engineering goals within ABET goals:

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(e) an ability to identify, formulate, and solve engineering problems
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

More ‘holistic, but engineering-related’ goals within ABET goals:
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as **economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability**
(h) the broad education necessary to **understand the impact of engineering solutions in a global, economic, environmental, and societal context**

‘Broad, common’ educational goals contained within ABET goals:
(d) **an ability to function on multi-disciplinary teams**
(f) **an understanding of professional and ethical responsibility**
(g) **an ability to communicate effectively**
(i) **a recognition of the need for, and an ability to engage in, life-long learning**
(j) **a knowledge of contemporary issues**

Note how the last seven of the eleven criteria listed lend themselves directly to the real life contexts such as the HESE projects at Penn State offer. Indeed, such projects may be easily adapted to address all eleven of the criteria by requiring rigorous technical components to the project(s).

Industry

A number of ‘transferable skills’ for graduates have been identified and sought by industry, government and business, as well as higher education. These skills have been identified in the U.S. Department of Labor’s SCANS 2 Report[5] which elaborated the actions and outcomes required of educational institutions in preparing students for the workplace; The Center for Improved Engineering and Science Education report entitled Edu-Trends[6] elaborated the actions and outcomes required of educational institutions; and the Boeing Corporation and its list of what it considers to be the desired attributes of an engineer[7]. The American Society for Engineering Education (ASEE) has also advocated reshaping engineering education including: more emphasis on teamwork in the engineering curriculum, to stress the global context in which engineering is practiced today, and diversity in the engineering field. A synthesis of these various 'transferable skills' is summarized in Table 1.1.

TABLE 1.1 TRANSFERABLE SKILLS

Citizenship/Social Responsibility	Problem Solving
Adaptable & Flexible	Creativity
Ethics	Critical
Lifelong Learning	Communication Skills
Application (Context) to the Real World (including business, history, economics, etc.)	Manage Complexity in a Systems Environment
Information and Technology Literacy	Leadership
Teamwork	Self Actualization
Multidisciplinary	Curiosity

Many of these 'transferable skills' listed are actually learning processes – meaning; you do not merely memorize, apply, analyze, synthesize or evaluate in classroom lectures and homework problems. Rather, these skills are acquired through application and practice. The major types of learning processes that are sought in the engineering classroom are: learning how to think (metacognitive skills); how to solve problems, how to think creatively, and how to think critically. Providing an underlying theoretical foundation for such concepts is valuable, but just as important is the opportunity to engage in the practice of such skills to nurture them and develop them. The question becomes how best to incorporate such learning processes into an already crowded curriculum?

Stakeholders: Expectations, Benefits and Hurdles

In order to incorporate such programs into the curriculum in a formal educational setting, there must be perceived benefits for multiple stakeholders. These include the university, colleges and departments, faculty, students and the community partners themselves.

The University

The mission statement of Penn State University, for example, states that the institution "educates students from Pennsylvania, the nation and the world, and improves the well being and health of individuals and communities through integrated programs of teaching, research, and service"[8]. This is precisely one definition of service learning. The mission statement goes on to say that the University "engages in collaborative activities…….with partners here and abroad to generate, disseminate, integrate, and apply knowledge that is valuable to society." Clearly the university has an interest in engaging students and faculty to apply their academic talents to address problems of communities.

HESE ventures at Penn State allow the University to be visibly responsive to society's needs. "Often this enhances the public image of the university and can positively impact the curriculum, student recruitment and retention, alumni relations, sense of community on campus, and the success of fund-raising efforts. HESE-type ventures provide good public relations and allows the University to be seen as a good member of the global community as opposed to an isolated 'ivy tower[9].'"

To achieve these benefits it is incumbent upon the University to promote and elevate HESE-type programs as one of the integral, core goals of its mission – in addition to research and teaching. The benefits of this service component can only be attained if there is an intentional emphasis placed on it in the form of institutional rewards and incentives. This may include examining promotion and tenure procedures, providing administrative support and curricular opportunities to facilitate such emphasis on service learning for all stakeholders: the University, students, faculty, colleges and departments, and communities at large.

Colleges and Departments

Globalization has been a process that has increased the interconnectedness between nations and peoples of the world. It has put increased pressure on educational institutions, specifically the universities, colleges, and departments, to prepare students for life in an increasingly connected and borderless world. One of the main functions of an internationalized curriculum is the 'formation of the skills….required to operate in the global environment itself'[10]. Thus internationalization of the curriculum is clearly linked to globalization, and relates to 'those processes by which the peoples of the world are incorporated into a single world society, a global society'[11].

Students face a future in which they will need more than just a discipline-specific background to be successful. In setting the goals for any project or task they may be asked to undertake, students will be expected to interact effectively with people of widely varying social, cultural and educational backgrounds. They will then be expected to work with people from many different disciplines to achieve these goals. The concept of HESE-type programs and student engagement with communities directly addresses these issues. They need educational experiences that help them develop these skills through integrating and partnering with existing programs. Such programs have proven to be successful not only in broadening the education of students, but in the recruitment and retention of high quality students. This is in addition to ensuring the students emerge as well-rounded and informed citizens.

Multidisciplinary teamwork is deemed useful[12]. Real life problems and contexts are viewed as intrinsically motivating and useful for students. Engaging in such projects allows departments and colleges to market and promote themselves. The value of such programs is not in question. However, how to undertake these efforts and institutionalize them is an issue for discussion. To successfully implement a program to attain the learning outcomes listed above, inter-collegiate and inter-departmental cooperation and collaboration is required.

Faculty

By engaging in HESE-type projects, the faculty role in the classroom is expanded from a provider of knowledge to a facilitator of critical synthesis and learning. As educational leaders at an institution of research and higher education, such projects allow faculty to enhance the learning and instruction accomplished within the classroom on a real-life, practical level. Students are attracted to courses that allow for the application of learned material in unique and realistic settings. By definition, it promotes awareness of current societal issues as they relate to academic areas of interest and enriches and enlivens teaching. Such projects also provide authentic assessment opportunities and identify new areas for research and publication. In addition, many professional academic associations now include sessions on HESE-type efforts and community engagement at national and regional conferences. Indeed, the American Society for Engineering Education (ASEE) is initiating a new division entitled 'Community Engagement and Engineering Education'. Special issues of professional journals such as the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)* now feature such efforts as topics of inquiry. Involvement in HESE-type projects can augment and redirect one's professional research interests, especially when a strong partnership is created with a community organization. Most faculty who participate in HESE activities come away re-energized and invigorated with renewed energy for their careers.

Students

Elbert Hubbard, a popular early 20th century homespun philosopher, had some words of wisdom still applicable in the 21st century: "A school should not be a preparation for life," Hubbard observed. "It should be life." A growing body of research shows that meaningful engagement with the community interwoven with high quality classroom instruction benefits students in four different areas. It greatly enhances students' academic skills, fosters a lifelong commitment to civic participation, significantly sharpens their intercommunication skills, and, perhaps most importantly for our nation, prepares youth to enter and mesh with what almost surely is the most diversified work force in history[13].

These benefits may be well documented, but the practical concerns of students and potential implementation hurdles are numerous. In order to engage in pertinent, real life projects in service, students report concern over: How does this 'fit' with their graduation requirements? Do they obtain credit for the activity? How much time is involved? What travel support is available? Is there adequate faculty oversight and mentoring in order to make a real difference in the project? How best to work in multidisciplinary teams? How best to engage with a learning community and experience the associated benefits of such organizations. What skill training will enable them to actually be able to implement their proposed solutions in the community itself?

Partners

Engagement in HESE-type ventures frequently builds lasting ties between universities and the communities with whom they partner. Such communities highly value the involvement of college students, not only for their enthusiasm, but because they are eager to explore the intersection of theory and practice and act as catalysts for improvements and change. Any relationship with partners must be equitable and mutually beneficial to all parties. The partnerships might also be diverse in kind and established in diverse ways, e.g. partners should not be limited to institutions of higher education. It is essential to offer the partners (hosts) something of value, which may include a sustainable benefit to them, as well as be mindful of working to empower partners through the projects carried out (even if this only includes greater, reciprocal understanding), since sometimes local hosts, perhaps issuing out of cultural norms, agree to partner in ways that further burden them, resource-wise, and are more harmful to them than helpful. There is a danger in such partnerships in terms of building expectations and not following through on projects. There are significant opportunities for student-led projects to actually impede projects in communities. Oversight and communication are essential.

Diversity

The impact of HESE-type opportunities cannot be underestimated on the retention of women and minorities. Richardson et al[14] emphasized that projects can serve as a powerful tool for attracting students to and retaining them in engineering programs by demonstrating the diversity of skills needed to practice engineering. Two student organizations that engage in such learning activities incorporating design, research and outreach have seen remarkable outcomes. Engineers Without Borders (EWB) and Engineers for a Sustainable World (ESW) are two organizations that have similar missions. Both were developed to provide students with opportunities to engage in design and research of problems found in developing communities. They directly engage students in hands-on activities – including travel to implement their design and research. These groups both have disproportionately high numbers of women and minority participants who self-select into the groups. Nationally, in the U.S., 20% of undergraduate engineering students are female. In the workforce, it is about 11% who are women[15]. Many Engineers Without Borders chapters report that approximately 50% of project participants are women and/or minorities. These results are duplicated with ESW.

Given the preceding discussion detailing the benefits of HESE efforts at Penn State, the remaining chapters in this text will elaborate upon the description and background of various types of programs that exist for students which not only enhance their learning and better prepare them for their careers, but also concurrently make a real difference in the lives of others.

Acknowledgements

Efforts to develop a formal engineering service learning program at Penn State have been ongoing since 1997. These persistent efforts recently bore fruit as Humanitarian Engineering and Social Entrepreneurship (HESE) was approved as a formal program in the College of Engineering in 2011. The International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE) was borne as part of this effort in 2006. I would like to express my heartfelt gratitude to Khanjan Mehta. Since joining the effort in 2004, he has elevated the entire program through his tireless quest to integrate social entrepreneurship into the program as an integral component. In addition, many students and colleagues from Penn State, too numerous to mention here, were instrumental in developing the program over the years and their contributions have been greatly appreciated.

REFERENCES

[1] World Bank Development Indicators, 2008

[2] Prahalad, C.K., *Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits.* 2004. Pearson Prentice Hall

[3] Hart, Stuart L., *Capitalism at the Crossroads: The Unlimited Business Opportunities in Solving the World's Most Difficult Problems.* 2005. Pearson Prentice Hall.

[4] National Academy of Engineering, Educating the Engineer of 2020. 2005. *National Academies Press*

[5] A Scans Report For America 2000, The Secretary's Commission On Achieving Necessary Skills,U.S. Department Of Labor, June 1991

[6] Edu-Trends, *Trends in K-12 Education and their Predicted Impact on Worker Competencies in 2005-2010,* September 30, 2001, Joshua Baron, Edward A. Friedman, Beth McGrath, Stevens Institute of Technology, Center for Improved Engineering and Science Education

[7] http://www.boeing.com/educationrelations/attributes.html

[8] http://www.psu.edu/ur/about/mission.html

[9] Adapted from Otterbein College's "Center for Community Engagement" and Pfeiffer University's "Faculty Service-Learning Handbook and Resource Guide."

[10] Marginson, S., 1999, After globalization: emerging politics of education. *Journal of Educational Policy,* 14(1), 19–31.

[11] Albrow, M., 1990, Introduction, in A. Albrow and E. King (eds.), *Globalization, Knowledge and Society.* Sage, London, pp. 3–13.

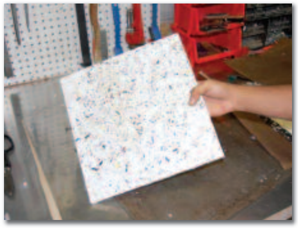
[12] Karlsson, Jan, Anderberg, Elsie, Booth, Shirley; Odenrick, Per; Christmansson, Marita. Reaching beyond Disciplines through Collaboration: Academics' Learning in a National Multidisciplinary Research Programme. *Journal of Workplace Learning,* v20 n2 p98-113 2008

[13] Adapted from Truman College's Service-Learning Website.

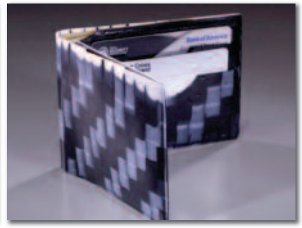
[14] Richardson, J., Corleto, C., Froyd, J., Imbrie, P. K., Parker, J., Roedel, R., "Freshman design projects in the Foundation Coalition," *Proceedings of the 1998 28th Annual Frontiers in Education Conference,* November 4 - 7, 1998, Tempe, AZ, USA, 50-59, 1998.

[15] Women, Minorities, and Persons with Disabilities in Science and Engineering: www.nsf.gov/statistics/wmpd/.

Student working press at RISD



Completed waste plastic composite tile



Student designed wallet produced from waste by Cooperativa Nueva Mente in Buenos Aires

Queen's University, the Centro Experimental de la Produccion in Argentina, the Rhode Island School of Design, Smith College, the University of Western Australia and ‘Waste for Life’ (a loosely joined network that develops poverty-reducing solutions to specific ecological problems) collaborate to develop means of production for smaller cooperatives in communities in Argentina and Lesotho. An example of open source appropriate technology shown above, allows the user to produce a value-added composite tile out of waste plastic and fiber.

“The working knowledge of professionals is almost universally considered intrinsically informal, hence unteachable except by experience. If we express working knowledge formally……we can manipulate it, reflect on it, and transmit it more effectively.”

— Harold Abelson and
Gerald Jay Sussman, MIT

CHAPTER 2
Service Learning in Engineering

Angela R. Bielefeldt, PhD, PE
University of Colorado Boulder

Joshua M. Pearce, PhD
Michigan Technological University

Introduction

Demands by industry, and by society as a whole, for the knowledge, skills, and abilities of engineers continue to expand and deepen[1]. Educating engineers who can best address those demands is our challenge. The National Academy of Engineering's report 'The Engineer of 2020' forecasts that engineers of the future must not only be trained to be technically competent, they must also possess a certain business savvy, be culturally aware, able to manage complexity, and possess leadership and communication skills. However, it has become increasingly difficult to meet these needs within traditional curricula given constraints such as: limited time, student credit loads, and course content requirements.

It has been known for some time that for the student, "experience-based education creates a powerful learning environment, which results in new educational outcomes" (pg. 121).[2] As a form of experiential education, service-learning (SL) provides a potential vehicle for achieving a diverse range and greater depth of learning outcomes and presents opportunities to address the goals cited above. Service-learning has been defined by Bringle and Hatcher as: "a course-based, credit-bearing, educational experience in which students (a) participate in an organized service activity that meets identified community needs and (b) reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility."[3] Service-learning has been documented as a pedagogy since the 1960s, with roots dating to the early 1900s[4]. However, the implementation of SL within engineering and with proper emphasis on the various dimensions has only been documented since the 1990s. Significant learning outcomes may result outside of courses in extracurricular activities such as Engineers Without Borders (EWB) and Engineers for a Sustainable World (ESW). Therefore, Learning Through Service (LTS) has been used as an umbrella term to encompass both SL and extracurricular activities that yield educational outcomes[5,6].

This chapter will first more carefully define SL and related activities and outline the scope of such activities. Next, the underlying learning concepts which provide the theoretical foundations for service-learning are summarized. Third, examples of the applications within engineering are provided. Fourth, some of the documented learning outcomes and benefits of such activities within engineering are described. Finally, the chapter concludes with a discussion of the need for sustainable and appropriate technology which provides both an urgent impetus for LTS and a readily available opportunity to integrate SL in any engineering classroom.

Definition and Scope of Service Learning and Learning Through Service

Although Bringle and Hatcher's definition of service-learning is often cited, there is a range of learning environments that encompass elements beyond these defined limits or lack some of the cited aspects. Therefore, Learning Through Service (LTS) has been proposed as an umbrella term to include a broad array of activities. In some cases, the lines between learning environments may not be clear; for example, course-based (SL) versus extracurricular activities. Extracurricular activities can have explicit learning goals as well. For example, EWB was born with two primary goals (1) to help disadvantaged communities and (2) to educate students with the appropriate knowledge and attitudes to lead sustainable engineering projects. Similarly, the Institute of Electrical and Electronics Engineers (IEEE) in their Humanitarian Technology Challenge (HTC) and the American Society of Civil Engineer's (ASCE) Body of Knowledge (BOK2) recognize the important role of extracurricular activities in engineering education[7]. The group effort from the American Society of Mechanical Engineers (ASME), EWB, and IEEE to create Engineering for Change (E4C) also clearly supports such efforts. Thus, extracurricular learning that serves communities in need can be viewed as an appropriate dimension within LTS.

Many criteria within Bringle & Hatcher's SL definition are not always rigorously evident in course-based or extracurricular LTS. For example, if a course does not explicitly evaluate whether students have an enhanced sense of civic responsibility after the activity, is it not actually SL? Some debate can be made between intended outcomes (teaching) versus realized outcomes (learning). This is even more challenging given the authentic and variable nature of student learning in the community. Therefore, rigorous distinction between learning environments is not the goal of this section, but rather to outline the range of learning activities that fall within the sphere of LTS.

First, it is helpful to include all of the commonly used terms that fall within the LTS arena; see Figure 2.1[6,8]. Some of these activities have distinguishing elements, but uninformed usage by practitioners means that there are many examples of perhaps erroneous use of each term which tends to blur the lines between these educational practices. Therefore, a spectrum of structures, student learning outcomes, student attitude outcomes, and community engagement lenses can be found in LTS practice. Mooney and Edwards identified six different community based learning (CBL) options which were defined based on six attributes: in community, service rendered, curricular credit, apply/acquire skills, structured reflection, and social action[9]. However, to fall under the LTS umbrella at least two criteria must be satisfied: a community partner is served and students acquire skills, knowledge, and/or affective outcomes.

Figure 2.1 Range Of Educational Methods That Fall Within The Sphere Of Learning Through Service

Four elements have been proposed that should be present in all SL activities, the four Rs: reciprocity, respect, relevance, and reflection[10]. The presence of each of these elements is also recommended in any LTS activity. Each of these elements is briefly summarized below.

From the reciprocity standpoint, both the students and the community should benefit from the activity. The community should have articulated its needs and goals for itself and then see if it can find an academic partner. A balanced partnership is a key component of a successful SL activity. The perspective of a partnership will help ensure that both sides respect one another. Any outsiders (i.e. students) entering a community should respect its traditions, culture, etc. And they should respect that each community possesses knowledge and skills that are of meaning and value. The lack of a mutually respectful relationship will be detrimental to both the community benefits that are realized and the students' cognitive and affective learning outcomes.

Relevance dictates that the service must be relevant to the learning objectives of the course. The service activity must apply, reinforce, and/or extend the key learning objectives of the course. If students are unable to clearly see this relevance, they may be openly skeptical or even hostile regarding the SL requirement. Engineering courses generally have well defined technical knowledge outcomes that are clear to students, but instructors sometimes are less rigorous in specifying the desired professional skills and attitude outcomes. Articulation of the full range of learning goals for each class improved significantly in many programs due to the outcomes-based engineering accreditation criteria of ABET starting in 2000[11].

Finally, the reflection element is requisite to SL in order to activate students' metacognition regarding the learning that has occurred. This is particularly necessary in service-placement type of activities where the learning objectives are not clearly manifest in the activity. However, within the typical project-based service learning (PBSL) applications in engineering, the learning outcomes are generally obvious in the activities being executed (i.e. design, team work, communication). Therefore, some engineering projects for community partners have not included required reflection activities, but have still generally been termed SL. Clearly, properly structured reflection can and should be executed to enhance student learning in these PBSL contexts.

More recently, a number of stages have been proposed by Root and Jesse[12] and endorsed by Learn and Serve America[13] as the standard process for ensuring the quality of a SL experience. The stages (abbreviated as IPARDC) are: (1) Investigation, (2) Planning and Preparation, (3) Action (engaging in the service experience), (4) Reflection, and (5) Demonstration / Celebration. Sustainability of the beneficial community impacts and the SL program itself should also be considered[114]. Although proposed for a K-12 context, the steps in this cycle also seem consistent with a college-level SL experience.

The typical initiation point of a SL activity is that an instructor has identified a learning goal that can be met via community service, and then seeks out an appropriate community partner. However, the Bringle & Hatcher SL definition implies that secondary benefits are derived from SL beyond the specific learning outcome desired, such that students will be endowed with an enhanced sense of civic responsibility and a broader perspective on their discipline. The extent to which all SL courses expect and evaluate students' civic responsibility and disciplinary perspectives to be enhanced is unclear, and frequently does not appear to be rigorously evaluated. This is perhaps driven by engineering educators' focus on assessment of accreditation-required outcomes and specific content-based technical elements. More information on the documented student outcomes from LTS will be discussed later in this chapter.

It is also important to note the range of potential "community" partners in the SL effort. Community partners in engineering are typically non-governmental organizations (NGOs), non-political governmental institutions, municipalities or towns, schools, hospitals or health clinics (typically within developing countries), individuals with disabilities, and for-profit micro-enterprises in developing countries. Student work for corporations and industrial partners is excluded from the definition of SL[4]. Although it should be noted that work with industry partners on projects that are defined by the needs of the community (e.g. energy efficiency and emission reductions in non-energy industries) have been used as SL projects successfully[13].

Theoretical Foundations for LTS

A number of learning theories have elements that seem to explain why LTS will be a powerful and particularly effective pedagogy. This section will highlight a few of the learning theories that are most relevant to the LTS experience. Understanding of these theories helps highlights attributes of an LTS experience that should optimize student learning. Readers are referred to a number of good articles that have discussed relevant educational theories that support the basis of SL in more depth[14,15,16].

John Dewey's theories (circa 1933, 1938) are often listed as a foundation for understanding the attributes of SL that make it a powerful teaching method[17,18]. Dewey's theories point to the power of experiential learning, of which SL is one form. LTS forms the situation where the student interacts with the community environment in a meaningful way from which the student learns and grows. LTS situates the learner in the community in a unique way which helps catalyze the learning process. Dewey postulates five phases of reflective thought[17], which can describe why critical reflection by the students is an important and indispensable part of the learning cycle. Project based learning through the engineering design process maps well to these learning phases, which can be summarized as:

1. A disturbance where an individual determines that routine approaches are insufficient to solve a problem.
2. Problem definition which requires exploration.
3. Analyzing potential methods and resources needed to solve the problem, developing hypotheses.
4. Reasoning which involves thinking through courses of action and hypotheses, to estimate likelihood of success
5. Action to solve the problem.

The added benefit of SL may be seen through Dewey's four criteria for "projects to be truly educative"[17]:

1. a service learning project often generates genuine interest among the students because it addresses a real problem;
2. SL projects are worthwhile because they have intent to create a real positive benefit for specific individuals;

3. SL projects often present problems that demand students' creativity and self-directed learning; and
4. most PBSL experiences generally span enough time (typically at least an entire semester) to allow genuine learning to occur.

SL projects in engineering meet the continuity requirement if students realize that they can build on their previous knowledge to solve the SL problems and also feel that they may reasonably be able to build on these learning experiences in the future[14,15].

Jean Piaget's educational theories are relevant to LTS through the assertion that learning and cognitive development occur when conflict or an uncomfortable situation triggers the active processes of assimilation, accommodation, and equilibrium[19]. Therefore, LTS may provide an unfamiliar experience, leading to discomfort or even personal mental conflict. This part of the learning process points to the importance of placing students in situations outside of their normal experience, whether it is working at a homeless shelter or serving an impoverished rural community in a foreign country via EWB. However, Piaget's theory postulates that learning and growth will not occur from the experience unless the student processes and works through these feelings and conflicts. This reinforces the importance of reflection that was also evident in Dewey's learning theories[16,20].

David Kolb's learning cycle (circa 1984) extends Dewey's concept of the importance of experiential learning[21]. Concrete experiences (stage 1) are followed by reflective observation (stage 2), which leads to assimilation into abstract conceptualization (stage 3), and then active testing and experimentation (stage 4). This testing and experimentation phase provides new experiences, which feeds into additional learning cycles. The cyclic engineering design process is somewhat reflective of this experiential learning cycle. This is particularly true in an authentic LTS project. Experiences with the partner community to understand their challenges are the spark, while the data gathering and structured reflection are also key ingredients in the learning cycle. Stage 3 requires the students to apply basic science and engineering fundamentals to address the problem. The active testing is the application of the design and the determination if changes are needed[15,16].

Paolo Freire has also been cited as posing theories about education that are particularly relevant to service learning[15,22,23]. His writings seem at first most relevant in describing the symbiotic partnership between our students and the community, where both entities can benefit and learn in a respectful environment. This transforms the framework of the learning from a "service" paradigm that seems to imply a power structure of the "server" (student, teacher) and the "served" (the community), to a more balanced relationship. In a similar fashion, the students and instructors involved in LTS tend to rebalance the traditional learning perspective of one-way transmission of knowledge to a student-driven learning cycle. Instructors often find LTS particularly appealing and rewarding as they find themselves learning and growing through the process of facilitating these experiences and partnerships with communities. However, many engineering educators are likely to find Freire's focus on the ideological purpose of education less relevant to their concept of the role of engineering education, and may therefore discount his theories on learning.

Additional educational theories have been described as relevant to SL[24,25]. In all cases, these theories highlight different aspects of LTS that create a powerful environment for student learning. Viewing LTS through these different lenses of educational theory can highlight elements of the learning structure which faculty should build into the LTS experience in order to produce optimal learning. Explicit discussion of SL pedagogy with engineering students may be help alleviate some negative pushback from students as they initially enter this generally unfamiliar mode of learning and are perhaps uncomfortable with some aspects, in particular the requirement for critical reflection.

Applications of LTS within Engineering

There are a number of examples of the application of LTS within engineering. Because LTS often begins at a grass-roots level with a single professor adding SL into a single course, an exhaustive list of LTS efforts in engineering is not possible. However, there are three common types of engineering classes where SL has been implemented: design (any level from first year to capstone design), experimental lab courses, and analysis-based engineering science (i.e. thermodynamics, fluid mechanics). Integration into design courses appears the most common. There are also organizations that facilitate LTS which are very popular with students (i.e. Engineers for a Sustainable World (ESW)).

There are many examples of SL in first year introduction and/or projects courses, such as at the University of South Alabama[26], University of San Diego[26], Virginia Commonwealth University[27], and the University of Colorado[28]. In many of these courses, SL projects are among many choices available to students or selected as the topic for a particular section of the course. Often these courses are very large, which poses coordination challenges. The first-year course at the University of Toronto has over 1000 students in the fall semester, and includes required SL projects[29].

There are also many examples of SL projects in capstone design courses[30]. Civil and environmental engineering programs seem particularly well-suited to community based SL projects due to the traditional nature of projects in these disciplines, with well-documented examples at the University of Colorado Boulder, South Dakota State University, the University of Vermont, and Michigan Technological University[30,31]. Mechanical and biomedical engineering programs often include assistive technology devices in capstone design courses. Examples include Duke University[30] and the University of Massachusetts Amherst[32].

Laboratory courses can provide an opportunity to provide data to communities that they find useful for a variety of purposes. Examples of laboratory courses that include SL are: a transportation course in civil engineering at University of Hartford[33], a surveying course at Union College[34], a materials lab at University of Dayton[35], and an environmental engineering lab at the University of Massachusetts Lowell[36].

Examples of service integration into core engineering courses have been less commonly published. There are a number of examples from the Service Learning Integrated throughout the College of Engineering (SLICE) program at the University of Massachusetts Lowell, including statics, dynamics, thermodynamics, fluid mechanics, heat transfer, and materials courses across five different engineering majors[36,37]. The SLICE program is an example of how a coordinated effort can ease the burden on faculty and lead to widespread incorporation of SL. Their success indicates that SL may be appropriate for any course. Another example is a heat transfer course at Grand Valley State University[38]. However, studies have found that many engineering faculty do not believe that SL is appropriate to core engineering science courses. A survey at MIT found that while 94% of the mechanical engineering faculty mentioned The Product Engineering Process as a course suitable for SL; for Thermal-Fluid Engineering and Mechanics and Materials only 25% and 15% of faculty noted these courses, respectively, as suitable for SL[39].

Beyond specific, individual courses, there are broader curricular efforts (many originally sponsored by the National Science Foundation (NSF)), programs, certificates, and extracurricular organizations that embrace LTS. A few of these programs are listed below. The list is not intended to be exhaustive, but merely to provide some concrete examples. Also note that some programs offer a mixture of courses and extracurricular activities, so the specific examples are only loosely arrayed under each specific category.

<u>Example Curricular Efforts and Initiatives:</u>

1. Engineers in Technical, Humanitarian Opportunities of Service-Learning (ETHOS) at the University of Dayton (http://www.udayton.edu/engineering/ethos/)
2. Service-Learning Integrated throughout the College of Engineering (SLICE) at the University of Massachusetts - Lowell (http://www.slice.uml.edu/)
3. Massachusetts Institute of Technology (MIT) Edgerton Center, Public Service Center and D-Lab: Introduction to Development (http://web.mit.edu/Edgerton/www/ServiceLearning.html (http://web.mit.edu/servicelearning/index.shtml) and (http://web.mit.edu/d-lab/)
4. Entrepreneurial Design for Extreme Affordability at Stanford University (http://soe.stanford.edu/publicservice/courses0607.php)
5. Humanitarian Engineering and Social Entrepreneurship (HESE) at Penn State University (www.hese.psu.edu)
6. Global Resolve at Arizona State University (http://globalresolve.asu.edu/)

7. University of Vermont, Civil and Environmental Engineering, http://www.uvm.edu/~sysedcee/?Page=service/default.php&SM=service/_servicemenu.html

Example Certificates and Programs:

1. Engineering Projects in Community Service (EPICS) started in 1995; members at 20 universities in the U.S. and abroad, and even high school efforts (http://epics.ecn.purdue.edu/)
2. Community Service Engineering Certificate Program (Michigan Technological) (http://www.d80.mtu.edu/Certificate.html)
3. (Humanitarian) Engineering and Community Engagement Certificate Program (Penn State) (www.hese.psu.edu)
4. Master's Degree in Engineering for Developing Communities and Peace Corps (Michigan Technological) (http://www.cee.mtu.edu/peacecorps/index.html)
5. Engineering for Developing Communities (University of Colorado) (http://www.edc-cu.org/index.htm); graduate certificate
6. Ohio State University, Engineers in Community Service (ECOS) (http://ecos.osu.edu/)

Example Extracurricular Student Organizations:

1. Engineers Without Borders (EWB) (http://www.ewb-international.org/)
2. Engineers for a Sustainable World (ESW) (http://www.esustainableworld.org/)
3. Engineering World Health (EWH) at Duke University (http://www.ewh.org/about/index.php); becoming an NGO

It is important to note that the student activities associated with extracurricular student organizations have often crossed into course-based settings. At Rice University, the Civil and Environmental Engineering Department created three courses to complement their EWB activities: project management, sustainable technologies, and a senior-level special problems design course[40]. At the University of Wisconsin – Madison the EWB activities reportedly led to the creation of a course on sustainability[41]. At some universities, EWB projects have formed the basis for senior design projects within the capstone design course (i.e. University of Colorado Boulder, Lafayette College, University of Arizona)[30].

Student Learning Outcomes from LTS

Although there should be a balance between community and students in the learning partnership, the outcomes for students have been much more widely documented than outcomes for the partner communities. Therefore, this section focuses on the documented cognitive and affective (interest, attitudes, and values) outcomes from student LTS participants. In addition, the potential diversity impacts, particularly in regards to recruiting and retention, will be explored.

There is a substantial and yet rapidly expanding body of literature showing that service learning outcomes have been positive for students, faculty, educational institutions, and community partners[13,42,43,44,45,46,47,48,49]. Service learning has proved so overwhelmingly successful that the Kellogg Commission concluded that service learning "should be viewed as among the most powerful of teaching procedures, if the teaching goal is lasting learning that can be used to shape student's lives around the world."[50]. Research into service learning pedagogy has been maturing quickly. It is now well established that service learning has a positive impact on students' academic learning, moral development, improves students' ability to apply what they have learned in the "real world", and improves academic outcomes as demonstrated complexity of understanding, problem analysis, critical thinking, and cognitive development[51,52,53,54,55]. The largest benefactors of an experiential education or service learning approach are thus students, who are more motivated, work harder (and longer), learn more, and experience lasting benefits from their experience[56,57,58,59,60,61].

Bielefeldt et al.[30, 62] summarized a wide range of student learning outcomes that have been achieved in engineering using LTS methods. This included all of the ABET a-k outcomes[63], many of the additional ASCE Body of Knowledge 2nd edition outcomes[7], and additional attributes. Jaeger and LaRochelle mapped EWB activities with all of the ABET a-k outcomes[64]. Faculty who have incorporated SL into courses have direct evidence of student learning via students' performance on traditional graded assessments, such as homework, lab reports, and exams. There also is interest in evaluating whether SL provides additional learning benefits over other teaching methods. This information is less widely available because it would require a controlled study where some students do not participate in SL activities. The data on the benefits of LTS toward student learning includes primarily indirect evidence that is self-reported by students. There are also anecdotal reports from many engineering professors. There has been less data presented from direct methods used to assess student performance such as graded exams, projects scored using detailed rubrics, standardized tests, or concept inventories. For example, some researchers are exploring whether PBSL provides differential learning outcomes compared to PBL[65]. The sections below highlight some examples of outcomes assessment information; readers are referred to Bielefeldt et al.[66] for additional examples.

Knowledge and Skills Learning Outcomes

First, SL can provide an effective method to teach academic subject matter in core engineering areas such as thermodynamics, fluid mechanics, heat transfer, circuits, and dynamics. For the SLICE program at University of Massachusetts–Lowell, Duffy reported positive results of indirect measures of subject matter comprehension measured by increased grades[37]. Students self-reported being more motivated to learn course subject matter, which is a key ingredient in learning. Students also stated that they voluntarily spent more time on SL tasks. Faculty agreed with the statement that students learn course subject matter better with SL. Holtzclaw reported that EWB students had self-reported increases in confidence levels in basic civil/environmental engineering concepts and principles; however, statistical evaluation of the data was not presented[67].

The widespread implementation of service learning in design courses, has shown documented success in teaching students engineering design[30]. Ariely[68] described the outcomes from a capstone design course in mechanical engineering where there were a combination of service and non-service projects. Student self-evaluations were indicative that the real clients for the SL projects helped students better understand the design process although the statistical difference was only $p=0.09$. Students who worked on the SL projects did have a significantly higher self-reported appreciation for the ability to help communities as engineers ($p < 0.02$). In addition, it was found that under-represented minorities (URM) students expressed significantly more interest in community service and in using engineering to solve social problems[68]. The SL experience also differentially impacted URM students' belief in engineers' social responsibility[68].

Other common outcomes reported from SL seem to largely result from the team environment and project communication requirements. Blomstrom and Tam[69] looked for significant differences in self-reported gains in content, organization, delivery, team skills, and personal skills in a first-year speech communication course taken by engineering majors. For the 5-factors combined, differences between SL and non-SL were not statistically significant. The service learning group, however, might have a stronger treatment effect based on the changes of the means. The changes in the means were higher in the service-learning subset for each of the five factors. Likewise, the partial eta-squared calculations for each of the five factors were also higher in the service-learning group, indicating that the course had stronger effect on the overall outcome than the non-service learning students. SLICE also found self-reported student gains in teamwork and communication skills as a result of SL[37]. Students in the Purdue EPICS program reported that the most valuable things that they learned from the SL experience were teamwork and communication[70]. Similarly, a survey of EWB members also found self-reported gains in the appreciation of the importance of teamwork[64].

Leadership was posited as a learning outcome from LTS by Ejiwale and Posey[71] but they present no concrete data to support this claim. A specific course "Leadership and Teamwork from Within" for Honors Students at the University of Cincinnati included SL as one of many components (seminars, PBL, a leadership camp). The leadership-related learning objectives were reportedly achieved[72]. Meanwhile, "increased student understanding of and commitment to leadership" was reported as one among many outcomes from an integrated first-year experience that included SL[73]. Leadership was also taught in a first-year engineering projects course via a SL project at the University of California Berkeley[74].

Students self-reported improvement in their engineering skills at the end of the course, including leadership and management skills. In these various examples it was difficult to attribute the leadership gains uniquely to the SL experience as distinct from PBL or other teaching methods.

In a large study of approximately 800 students participating in multidisciplinary projects, Huyck et al.[75] found that service learning projects compared to non-SL projects did not appear to differentially increase the students' self-perceptions of their own competence in communication, teamwork, ethical awareness, or project management. In addition, the researchers found no difference between the students who completed the three structured reflective writing exercises and those students who did not. This provides further support for the difficulty in identifying potential differential benefits of PBSL over other PBL experiences. Although, obviously the PBSL projects had the potential to–and often did–benefit the community partners, the PBL projects had no such capacity.

Thus, the true power of LTS may be its ability to achieve a wide array of learning outcomes in an efficient manner that is equally as effective as other methods that are more targeted. For example, a PBSL experience in a heat transfer course may teach heat transfer principles equally as well as traditional textbook problems. But in addition, the PBSL experience benefits students' understanding of the impacts of engineering on society, contemporary issues, modern engineering tools, communication, and teamwork skills. Beyond these skills, the service learning experience may impact students' attitudes about community service, the professional responsibilities of engineers, and their motivation to remain in engineering. Finally, SL courses have been shown to make a positive material difference in the real world. These ideas of motivation to persist in engineering and the impact of SL to benefit global society are elaborated on in the next section.

Diversity Recruiting and Retention

There has been speculation in the literature that engineering which focuses on benefits to communities and individuals might be more attractive to groups traditionally under-represented in engineering, specifically female and URM students. Support for this notion has been provided by statistics which indicate that women are over-represented by a significant percentage in optional LTS activities such as EPICS and EWB[70,76,77].

In a study of recruiting and retention associated with the SLICE program at the University of Massachusetts Lowell (UML), it was reported that the number of entering students increased 50% in the four years SLICE was in existence[37]. Twenty-three percent of the incoming students reported that SL was one of their reasons for their choosing UML. Although female student enrollment in engineering did not increase, the number of Hispanic students enrolled increased 50%. UML students also indicated that SL increased the likelihood they would remain in engineering. Females and URM students at UML indicated a significantly more positive impact of SL on retention in engineering. Monroe and Lima[78] found that female retention increased significantly at Louisiana State University after a first year course focused on service learning was added into the curriculum; an increase to 86% retention into the second year compared to 50% prior to SL.

The Benefits of Service Learning to Communities

The Need For Just Sustainable Development

Although the sections above have shown the clear benefits from an educational perspective for SL, this does not mean that the assistance engineering students can provide to both local communites and the global community should be ignored. Service learning provides an ideal vehicle for students to apply their academic skills toward this end through engagement and collaboration with marginalized communities.

The need for development is as great as it has ever been, but future development in such marginalized communities cannot simply follow past models of economic activity, which tended to waste resources and produce prodigious pollution[79,80,81,82,83]. For the future, the entire world population needs ways to achieve economic, social, and environmental objectives simultaneously. There is thus a need for just sustainability, which is “the egalitarian conception of sustainable development”(pg. 32)[84]. It generates an improved definition for sustainable development so that it is “the need to ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems" (pg.5)[85]. This new form of sustainable development prioritizes justice and equity, while maintaining the importance of the environment and the global life support system. In order to meet this goal, international co-operation to overcome technical problems is necessary to eliminate poverty and help all the world's people develop as we move towards a just global society.

The present global picture is sobering and demonstrates how far we are from a just, sustainable world: Around 1.2 billion people live on less than $1 a day and 2.8 billion people live on less than $2 a day[86].

- Ingestion of unsafe water, inadequate availability of water for hygiene, and lack of access to sanitation contribute to about 1.5 million child deaths and around 88% of deaths from diarrhea every year[87,88].
- Overall 10.8 million children under the age of five die each year from preventable causes – equivalent to about 30,000/day[89].

The well known environmental ethicist, Holmes Rolston III, puts the current state of affairs in context[90]:

> *As a result of human failings, nature is more at peril than at any time in the last two-and-a-half billion years. The sun will rise tomorrow because it rose yesterday and the day before, but nature may no longer be there. Unless in the next millennium, indeed in the next century, we regulate and control the escalating human devastation of our planet, we may face the end of nature as it has hitherto been known. Several billion years worth of creative toil, several million species of teeming life, have now been handed over to the care of the late-coming species in which mind has flowered and morals have emerged. Science has revealed to us this glorious natural history and religion invites us to be stewards of it. That could be a glorious future story. But the sole moral and allegedly wise species has so far been able to do little more than use this science to convert whatever we can into resources for our own self-interested and escalating consumption, and we have done even that with great inequity between persons.*

This enormous challenge to our generation is growing – the world's population will probably increase to over 9 billion people by 2050[91]. How do we engineer our future development so that all people, both in developed and developing communities, have basic human needs met and a clean, healthy, and safe world in which to grow and prosper? This is the challenge of creating a just sustainable world for all.

The global community has recognized that we must face the challenge of sustainable development immediately and do so with education. The United Nations has labeled this the "Decade of Education for Sustainable Development" (2005-2014). **Teaching sustainability has become the most important goal in education in this century.** Yet science and engineering education has not even begun to meet the global needs. For example, Al-Khafaji and Morse in their recent international survey of engineering students, found widespread and startling knowledge gaps about many core aspects of sustainable development[92].

Despite this lack of universal sustainable engineering knowledge, there is also a growing list of examples of engineering service learning to teach sustainable design principles, most notably discussed at the American Society for Engineering Education Conferences and the Annual Conferences on Frontiers in Education. Also, although global conditions continue to reflect a marked underinvestment in sustainable development, a growing body of university student work has been shown to solve environmental and developmental problems on a small scale using service learning projects[93,94,95,96,97,98,99,100].

Similarly, although a body of academic work devoted to sustainable development has begun to amass, much of the research conducted at universities is not specifically designed to help resolve the developing world's problems. The vast majority of resources, both mental and economic, are concentrated on scientific and technological research focused on quantifying sustainability indicators and the frontiers of science and social theories – pushing the envelope on large and complex problems. However, the less grand questions of how to actually implement sustainable practices across a range of contexts, particularly for small-scale appropriate technologies, or applications, in developing nations is often apportioned significantly less resources for inquiry[101].

Service Learning and Appropriate Technology

Appropriate technology is technology that is most suitable to the specific location where it is employed. It can be defined as any object, process, idea, or practice that enhances human fulfillment through satisfaction of human needs[102]. In the context of the developing world, appropriate technologies must be able to be economically constructed using locally available materials, energy resources, and tools or processes maintained and operationally controlled by the local population. Appropriate technologies must meet environmental, cultural, economic, and educational resource constraints of the localized community.

For example, Weiss, George, and Walker describe the process of redesign for a manual shredding machine used to harvest breadfruit in the Republic of Haiti[103]. Their methodology examined each function of the shredder assembly to determine if parts could be eliminated or combined and if there were simpler ways to meet the performance criteria without sacrificing quality. This work resulted in a machine that was easier to build in a developing country, used materials that were more commonly available, had a reduced number of parts, was more robust, was easier to clean and keep sanitary, and cost less to make!

It should be noted here that in some cases the most appropriate solution to a community's challenges may involve some components outside of the scope of local production[104]. For example, Ros, et al. describe the establishment of a computer laboratory to provide an education resource to encourage learning and creativity for a children's center in Guatemala[105]. They utilized the appropriate technology of the open source Linux operating system, a free and technically superior alternative to commercial software. Design and implementation of the project covered not only technical areas but also social aspects of computer technology. Although some research has been done on a number of appropriate technologies, the diffusion of these innovations has greatly lagged the demand in the developing world.

Unfortunately for many institutions, the expense of sending large cohorts of students on international service learning trips is prohibitive. Yet, students remain enthusiastic and well equipped to assist in sustainable development. One opportunity to conduct engineering service learning that attempts to overcome this challenge has been developed enabling students to provide solutions to sustainable development problems. This is accomplished using on online tool titled Appropedia.org. Appropedia is the site for collaborative solutions in sustainability, poverty reduction, and international development through the use of sound principles and appropriate technology and the sharing of wisdom and project information. It is a wiki, a type of website which allows anyone to add, remove, or edit content. This method of virtual service learning has been demonstrated in the past to benefit from some of the positive outcomes of service learning, while avoiding the challenges of finding appropriate community partners for every specific learning goal[106].

IJSLE and Opportunities for Students

The creation of the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE)* in 2006 provided opportunities for students to contribute directly to sustainable development and have their work published in a peer-reviewed journal and disseminated internationally. A quarter of a century has now passed since Logan suggested science could play a major role in sustainable development by contributing to the interdisciplinary field of appropriate technology[107]. Yet, the majority of appropriate technology research has been accomplished by time-consuming trial and error methods in the field by individuals without technical backgrounds. The ability of undergraduate students to solve such real-world problems is generally neglected[108]. Yet university students are both capable and enthusiastic real-world problem solvers if they are freed to undertake structured self-directed assignments[109]. Recent examples include: appropriate wheelchairs[110], wind powered LED lighting[111], and corrugated fiberboard cartons for produce[112]. The operations of many of these appropriate technologies are governed by physical laws taught in introductory physics and engineering classes. In addition to a solid foundation in the scientific method and engineering principles, students have access to the scientific literature in the university libraries, which is often not available to developmental agents in the field. The students also have access to some relatively sophisticated scientific equipment (e.g. computer-integrated thermocouples), fully equipped machine shops, which can be used for both prototype and controlled studies of appropriate technologies. Finally, most engineering students have access to very sophisticated design and simulation software tools (e.g. ANSYS for FEA; FLUENT for CFD; Solid Works and Solid Edge for 3D CAD; TRNSYS for transient systems simulation, Cambridge Engineering Selector (CES) technology for engineering materials selection, etc.). However, it should be noted that in order for local populations to have the best access to the designs, open source engineering software should be used and further developed[113]. By studying appropriate technologies students can perform the basic research necessary to optimize such devices, while gaining a better understanding of physical principles and engineering practice.

IJSLE assists in the growth of this burgeoning field by providing a platform for members of the academic community to help harness the knowledge and skills of university students, faculty, researchers, and practitioners to enhance global sustainable development. IJSLE includes examples of work undertaken by service learning organizations, curriculum, and programs.

A Way Forward

Appropriate technologies have a central role in the alleviation of poverty in the developing world. However, research and development of these technologies are generally apportioned relatively modest support by the world's institutions in part because the operation of many of these appropriate technologies is dependent on relatively well-understood science and engineering concepts accessible even to undergraduate university students.

The International Journal for Service Learning in Engineering: Humanitarian Enginnering and Social Entrepreneurship provides an outlet for university students that undertake project-based service learning assignments, and their mentors, to publish their work. Professors at all the world's institutions can capitalize on this opportunity to assist students to learn engineering more effectively by offering them a chance to make concrete contributions to the optimization of appropriate technologies for just sustainable development.

The next few chapters focus on specific types of service learning approaches which address both the educational goals for students, the scholarship activities of faculty, the implementation of design solutions by practitioners, and the enhancement of the lives of those living in marginalized communities. These approaches include: humanitarian engineering, social entrepreneurship, and frugal innovation.

REFERENCES

[1] National Academy of Engineering (NAE). 2004. The Engineer of 2020: Visions of Engineering in the New Century, 118 pp., *National Academies Press,* 2004.

[2] J.W. Peeples, "Why I want to be an Engineer"36th ASEE-IEEE- Frontiers in Education Conference, M1E1 (2006).

[3] Bringle, R. and J. Hatcher. 1995. A service learning curriculum for faculty. *Michigan Journal of Community Service Learning,* 2, 112-122.

[4] Barrington, L. and J. Duffy. 2010. Maximizing Benefits of Service-Learning in Engineering. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2010-2149. 20 pp.

[5] McPherson, K. 1991. Learning Through Service. The Learning Revolution: Education Innovations for Global Citizens, In Context #27, pg. 50.

[6] Swan, C., J. Duffy, O. Pierrakos, K. Paterson, A. Bielefeldt. 2011. The EFELTS Project – Engineering Faculty Engagement in Learning Through Service." *American Society for Engineering Education (ASEE) Conference and Exposition.* Paper AC 2011-1324. June 26-29, Vancouver, BC Canada.

[7] American Society of Civil Engineers (ASCE). 2008. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future,* 2nd edition, 191 pp., ASCE, 2008. www.asce.org.

[8] Sigmon, R. L. 1994. Serving to Learn, Learning to Serve: Linking Service with Learning, Council of Independent Colleges, Washington D.C.

[9] Mooney, L.A. and B. Edwards. 2001. Experiential Learning in Sociology: Service Learning and Other Community-Based Learning Initiatives. *Teaching Sociology,* 29 (2), 181-194.

[10] Butin, D.W. 2003. Of What Use Is It? Multiple Conceptualizations of Service Learning Within Education. *Teachers College Record.* 105 (9), 1674-1692.

[11] ABET (2010). Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2011-2012 Accreditation Cycle, 26 pp., *ABET Engineering Accreditation Commission.* www.abet.org

[12] Billig, S., Root, S., Jesse, D. The Impact of Participation in Service Learning on High School Students' Civic Engagement. Circle Working Paper, 33. RMC Research. http://www.civicyouth.org/PopUps/WorkingPapers/WP33Billig.pdf

[13] Branker, K. Pearce, J., McCorbett, J., and J. Webster, "Hybird Virtual–and Field Worked–Based Service Learning with Green Information Technology and Systems Projects." *International Journal for Service Learning in Engineering* 5(2), pp. 44-59 (2010) http://library.queensu.ca/ojs/index.php/ijsle/article/view/3166

[14] Giles, D.E., J. Eyler. 1994. The Theoretical Roots of Service-Learning in John Dewey: Toward a Theory of Service-Learning. *Michigan Journal of Community Service Learning.* 1 (1): 77-85.

[15] Cone, D., & Harris, S. 1996. Service learning practice: Developing a theoretical framework. *Michigan Journal of Community Service Learning.* Fall, 31-43. http://www.servicelearning.org/library/resource/1972

[16] McCormick, M., C. Swan, D. Matson. 2008. Reading between the Lines: Evaluating Self-Assessments of Skills Acquired During and International Service-Learning Project. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2008-1937.

[17] Dewey, J. 1933. How We Think. A restatement of the relation of reflective thinking to the educative process (Revised edn.), Boston: D. C. Heath.

[18] Dewey, J. 1938. *Experience and Education,* Collier Books, New York.

[19] Piaget, J. 1977. The development of thought: Equilibration of cognitive structures, *Viking Press,* New York.

[20] Duckworth, E. 1996. Either we're too early and they can't learn it, or we're too late and they know it already: The dilemma of 'applying Piaget', in The having of wonderful ideas and other essays on teaching and learning, 2nd. Ed., *Teachers College Press,* New York, pp. 31-49.

[21] Kolb, D.A. 1984. Experiential Learning: Experience as the Source of Learning and Development. Prentice Hall, Englewood Cliffs, N.J.

[22] Deans, T. 1999. Service-Learning in Two Keys: Paulo Freire's Critical Pedagogy in Relation to John Dewey's Pragnatism. *Michigan Journal of Community Service Learning,* 6, 15-29.

[23] Freire, P. 1994. Pedagogy of Hope. NY: Continuum.

[24] Kohlberg, L. 1975. The cognitive development approach to moral education, Phi Delta Kappan, 56, 670-677.

[25] Vygotsky, L.S. (1978). Interaction between learning and development, in L.S. Vygotsky, Mind and Society: The development of higher psychological processes, *Harvard University Press,* Cambridge, MA, pp 70-91.

[26] Duffy, J., E. Tsang, S. Lord. 2000. Service-Learning in Engineering: What, Why, and How? American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2006-3630.

[27] Hobson, R.S. 2000. Service-Learning as an Educational Tool in an Introduction to Engineering Course. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2000-session 3253. 10 pp.

[28] Zarske, M.S., D.T. Reamon, D. Knight. 2011. Altruistic Engineering Projects: Do project-based service learning designs impact attitudes in first-year engineering students? American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2011-968.

[29] McCahan, S. 2007. Team Teaching a Service Learning Course for a Large Class. Society for Teaching and Learning in Higher Education, The Alam Blizzard Award. http://www.stlhe.ca/wp-content/uploads/2011/06/2007-Blizzard-Paper.pdf

[30] Bielefeldt, A.R., M.M. Dewoolkar, K.M. Caves, B.W. Berdanier, and K.G. Paterson. 2011. Diverse Models for Incorporating Service Projects into Engineering Capstone Design Courses. *International Journal of Engineering Education,* 27(6) 1206-1220.

[31] Dewoolkar, M. M., George, L. A., Hayden, N. J., and Rizzo, D. M. (2009), "Vertical integration of service-learning into civil and environmental engineering curricula", *International Journal of Engineering Education* 56(6), 1257-1269.

[32] Terpenny, J., R. Gao, J. Ritter, D. Fisher, and S. Krishnamurty. 2001. Senior Design Projects to Air the Disabled. American Society for Engineering Education (ASEE) Annual Conference. Paper Session 2325, 11 pp.

[33] Fang, C. 2009. Community-based Service Project Learning in Civil Engineering Courses. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2009-1643.

[34] Wolfe, F.A. Integrating Service Projects into CER-021 Elementary Surveying. American Society for Engineering Education (ASEE) Annual Conference. Paper Session 2315.

[35] Zoghi, M. and M. Pinnell. 2005. Service-Learning Opportunities at the University of Dayton. American Society for Engineering Education (ASEE) Annual Conference.

[36] Duffy, J., C. Barry, L. Barrington, D. Kazmer, W. Moeller, C. West. 2008. Service-learning projects in 35 core undergraduate engineering courses. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2008-1525. 20 pp.

[37] Duffy, J., L. Barrington, M. Heredia. 2009. Recruitment, retention, and service learning in engineering. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2009-2138. 27 pp.

[38] Flieschmann, S.T. 2001. ABET 2000 and Community Service Projects for Engineering Students. American Society for Engineering Education (ASEE) Annual Conference. Paper Session 2793.

[39] Banzaert, A., S. Ariely, D. Wallace, B. Masi. 2005. Faculty Views of Service Learning in Mechanical Engineering. American Society for Engineering Education (ASEE) Annual Conference. 12 pp.

[40] Gordon, R., A. Gordon, and P. Bedient. 2006. Rice University Engineers Without Borders: An Exercise in International Service Learning. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2006-1111.

[41] Bosscher, P.J., J.S. Russell, and W.B. Stouffer. 2005. The Sustainable Classroom: Teaching Sustainability to Tomorrow's Engineers. American Society for Engineering Education (ASEE) Annual Conference Proceedings. Portland, OR, June 12-15.

[42] R. G. Bringle & J. A. Hatcher. "Implementing service learning in higher education". *Journal of Higher Education,* 67, (1996) 221-39.

[43] A.Driscoll, Holland, B., Gelmon, S. & Kerrigan, S. "An assessment for service learning: Comprehensive case studies of impact on faculty, students, community and institution" *Michigan Journal of Community Service Learning,* 3, (1996) 66-71.

[44] D. Panini, & Lasky. K. "Service learning's foothold in communication scholarship". *Journalism & Mass Communication Educator,* 57(2), (2002), 113-125.

[45] S.M. Gallini & Moely, B.E. "Service-Learning and Engagement, Academic Challenge, and Retention", *Michigan Journal of Community Service Learning,* 10(1), (2003) 5-14.

[46] D. Riley & Bloomgarden, A. H. "Learning and Service in Engineering and Global Development". *International Journal for Service Learning in Engineering* 2(1), (2006), 48-59.

[47] C. George, & Shams, A. "Challenge of Including Customer Satisfaction Into the Assessment Criteria of Overseas Service-Learning Projects", *International Journal for Service Learning in Engineering,* 2(2), (2007), 64-75.

[48] C. Keen & Hall, K. "Post-Graduation Service and Civic Outcomes for High Financial Need Students of a Multi-Campus, Co-Curricular Service-Learning College Program". *Journal of College and Character,* 10(2), Article 2. (2008). DOI: 10.2202/1940-1639.1066

[49] J.M. Pearce & ter Horst, E. "Service Learning for Sustainable Development in Languages", in Filho, W.L. Editor, *Sustainability at Universities: Opportunities, Challenges and Trends,* (Peter Lang Scientific Publishers: New York, 2009) 73-85.

[50] Kellogg Commission on the Future of State and Land-Grant Universities. *Returning to our roots: The engaged institution.* (Washington, DC: National Association for Higher Education, 1999).

[51] J. Eyler and D.E. Giles, *Where's the Learning in Service Learning?* (San Francisco, CA: Jossey-Bass: 1999).

[52] J.A. Boss, "The Effects of Community Service Work on the Moral Development of College Ethics Students", *Journal of Moral Education* 23, (1994), 183-198.

[53] J. Eyler, S. Root, and D.E. Giles, "Service Learning and the Development of Expert Citizens: Service Learning and Cognitive Science", In R. Bringle and D. Duffy (eds.) *With Service in Mind* (Washington, D.C.: American Association of Higher Education, 1998).

[54] J. Cohen and D. Kinsey, "Doing Good and Scholarship: A Service Learning Study," *Journalism Educator* 4, (1994) 14.

[55] J. Miller, "Linking Traditional and Service Learning Courses: Outcome Evaluations Utilizing Two Pedagogically Distinct Models," *Michigan Journal of Community Service Learning* 1, no. 1 (1994), 29-36.

[56] A.W. Astin & Sax, L.J. Long Term Effects of Volunteerism During the Undergraduate Years. *The Review of Higher Education,* 22(2), (1999) 187-202.

[57] J. Cohen and D. Kinsey, "Doing Good and Scholarship: A Service Learning Study," *Journalism Educator* 4, (1994) 14.

[58] D. E. Giles & J. Eyler, "The theoretical roots of service learning in John Dewey: Toward a theory of service learning". *Michigan Journal of Community Service,* 1(1), (1994), 77-85.

[59] S.M. Gallini & Moely, B.E. "Service-Learning and Engagement, Academic Challenge, and Retention", *Michigan Journal of Community Service Learning,* 10(1), (2003) 5-14.

[60] J. M. Pearce & Russill, C. Interdisciplinary Environmental Education: Communicating and Applying Energy Efficiency for Sustainability. *Applied Environmental Education and Communication,* 4(1), (2005), 65-72.

[61] C. Keen & Hall, K. "Post-Graduation Service and Civic Outcomes for High Financial Need Students of a Multi-Campus, Co-Curricular Service-Learning College Program". *Journal of College and Character,* 10(2), Article 2. (2008). DOI: 10.2202/1940-1639.1066

[62] Bielefeldt, A.R., M.M. Dewoolkar, K.M. Caves, B.W. Berdanier, and K.G. Paterson. 2011. Diverse Models for Incorporating Service Projects into Engineering Capstone Design Courses. *International Journal of Engineering Education,* 27(6) 1206-1220.

[63] ABET (2010). Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2011-2012 Accreditation Cycle, 26 pp., ABET Engineering Accreditation Commission. www.abet.org

[64] Jaeger, B. and E. LaRochelle. 2009. EWB^2 – Engineers Without Borders: Educationally, a World of Benefits. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2009-740.

[65] Bielefeldt, A., C. Swan, and K. Paterson. 2009. Measuring the Impacts of Project-Based Service Learning. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2009-1972. 15 pp.

[66] Bielefeldt, A.R., K.G. Paterson, and C.W. Swan. 2010. Measuring the Value Added from Service Learning in Project-Based Engineering Education. *The International Journal of Engineering Education.* 26 (3): 535-546.

[67] Holtzclaw, D., G. Zornes, P. Alvarez. 2007. Assessing Community Impact and Student Learning & Development from an Engineers Without Borders Project. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2007-2450. 2 pp.

[68] Ariely, S., A. Banzaert, D. Wallace. 2005. Mechanisms for Implementing Service Learning: Analysis of Efforts in a Senior Product Design Class in Mechanical Engineering. American Society for Engineering Education (ASEE) Annual Conference Proceedings. 11 pp.

[69] Blomstrom, S. and H. Tam. 2009. How and To What Extent Does a Service-Learning Pedagogy Enhance Communication and Collaborative Skill learning Among First-Year Students? American Society for Engineering Education (ASEE) Annual Conference, Paper AC 2009-408, 16 pp.

[70] Coyle, E.J., L.H. Jamieson, and W.C. Oakes, 2005. EPICS: Engineering Projects in Community Service. *Int. J. Engrg. Ed.* 21 (1): 139-150.

[71] Ejiwale, J., D. Posey. 2008. Enahncing leadership skills through service learning. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2008-2457. 6 pp.

[72] Suckarieh, Gl, J. Krupar. 2005. Leadership and Teamwork Education for Engineering and Technology Students: An Experiential Learning and Community Service Approach. American Society for Engineering Education (ASEE) Annual Conference.

[73] Mehta, S., K. Enger. 2004. Transforming First Year College Experience Through a Unique Learning Community. American Society for Engineering Education (ASEE) Annual Conference. Paper Session 1793.

[74] Pruitt, L.A. 2011. Introduction to Engineering Design for Freshman: Implementation of Leadership and Service Learning for Broadening Engineering Ingenuity. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2011-300.

[75] Huyck, M., K. Bryant, D. Ferguson. 2009. The Impact of Reflections in Service Learning and Other Undergraduate Team Project Learning. American Society for Engineering Education (ASEE) Annual Conference. Paper AC 2009-1032. 11 pp.

[76] Bielefeldt, A.R. 2006. Attracting Women to Engineering that Serves Developing Communities. American Society for Engineering Education (ASEE) Annual Conference. June 19-21, Chicago, IL.

[77] Amadei, B. and R. Sandekian. 2010. Model of Integrating Humanitarian Development into Engineering Education. *Journal of Professional Issues in Engineering Education and Practice.* 136 (2), 84-92.

[78] Monroe, W.T., M. Mailander, and M. Lima. 2006. Focus on Experiential Education: A Freshman Engineering Program in Biological Engineering. *Int. J. Engng.* Ed. 22 (6), 1129-1138.

[79] D.H. Meadows, Meadows DL, Randers J, Behrens III WW. *The limits to growth.* New York: Universe Books; (1972).

[80] D.H. Meadows, Meadows DL, Randers J. *Limits to growth: the 30-year update.* Chelsea Green Publishing; (2004).

[81] United Nations Environmental Programme. *Global environmental outlook IV.* Available at: http://www.unep.org/geo (2007).

[82] World Watch Institute. *State of the world 2009: into a warming world.* Available at: http://www.world watch.org/sow09 (2009).

[83] United Nations Development Programme. Human development report 2007/2008, fighting climate change: human solidarity in a divided world. Available at: http://hdr.undp.org/en/reports/global/hdr2007-2008 (2007).

[84] M. Jacobs, “Sustainable Development as a Contested Concept,” in A. Dobson, Fairness and *Futurity: Essays on Environmental Sustainability and Social Justice* (Oxford, UK: Oxford University Press, 1999).

[85] J. Agyeman, Bullard, R. D., and Evans, B. eds., *Just Sustainabilities: Development in an Unequal World* (London: Earthscan/MIT Press, 2003).

[86] United Nations Development Programme, "Human Development Report 2001: Making new technologies work for human development" (Oxford: Oxford University Press, 2001), Available: http://hdr.undp.org/reports/global/2001/en/

[87] World Health Organization. *The world health report 2002: reducing risks, promoting healthy life.* (Geneva: World Health Organization, 2002).

[88] M. Ezzati, A.D. Lopez, A. Rodgers, S. Vander Hoorn, C.J.L. Murray, and the Comparative Risk Assessment Collaborating Group. "Selected major risk factors and global and regional burden of disease". *The Lancet* 360 (2002), 1347–60.

[89] R.E. Black, S.S. Morris, and J. Bryce. "Where and why are 10 million children dying every year?" *The Lancet* 361 (2003), 2226–34.

[90] H. Rolston, Science, religion, and the future. In *Religion and Science: History, Method, and Dialogue,* edited by W. M. Richardson and W. J. Wildman. (New York: Routledge, 1996) 61-82.

[91] United Nations. *World Population Prospect: The 2004 revision volume III analytical report.* Department of Economic and Social Affairs: Population Division. (New York: United Nations, 2006).

[92] K. Al-Khafaji & M. Catherine Morse, "Learning Sustainable Design through Service", *International Journal for Service Learning in Engineering,* 1(1) (2006), 1-10.

[93] C. Keen & E. Baldwin. "Students Promoting Economic Development and Environmental Sustainability: An Analysis of the Impact of Involvement in a Community-Based Research and Service-Learning Program", *International Journal of Sustainability in Higher Education,* 5 (4), (2004) 384–94.

[94] A.S. Weinberg, "The University and the Hamlets: Revitalizing Low-Income Communities through University Outreach and Community Visioning Exercises', *American Behavioral Scientist,* 42 (5), (1999) 800–13.

[95] J.R. Mihelcic, L.D. Phillips and D.W. Watkins. "Integrating a Global Perspective into Education and Research: Engineering International Sustainable Development", *Environmental Engineering Science,* 23 (3), (2006) 426–38.

[96] J.M. Pearce, "Teaching Science by Encouraging Innovation in Appropriate Technologies for Sustainable Development", *Proceedings of the 11th Annual National Collegiate Inventors and Innovators Alliance Conference,* (2007) 159–67.

[97] J.J. Domask, "Achieving Goals in Higher Education: An Experiential Approach to Sustainability Studies", *International Journal of Sustainability in Higher Education,* 8 (1), (2007) 53–68.

[98] T. Endreny, "Storm Water Management for Society and Nature via Service Learning, Ecological Engineering and Ecohydrology", *International Journal of Water Resources Development,* 20 (3), (2004) 445–62.

[99] J.M. Pearce, "Teaching Physics Using Appropriate Technology Projects", *The Physics Teacher,* 45 (3), (2007) 164–67.

100 R. Sandekian, B. Amadei and M. Pinnell. "A Summary of the Workshop on Integrating Appropriate-Sustainable Technology and Service-Learning in Engineering Education', Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education (2005).

101 C. Pursell, "The Rise and Fall of the Appropriate Technology Movement in the United States, 1965 - 1985" *Technology and Culture,* Vol 34, No. 3: 629-637 (July 1993).

102 A. Conteh, "Culture and Transfer of Technology", in B. Hazeltine and C. Bull (Eds.) *Field Guide to Appropriate Technology,* Academic Press:London (2003).

103 J. Weiss, George, C., & Walker, J. " Redesigning an Appropriate Technology Shredder for Manufacture in a Developing Country". *International Journal For Service Learning In Engineering,* 1(1). (2006) 11-26.

104 F. Vanek, "Design Philosophies for Appropriate Technology", in B. Hazeltine and C. Bull (Eds.) *Field Guide to Appropriate Technology,* Academic Press: London (2003).

105 Ros, J., Lee, C., Bruce, M., Fan, C., Quan, R., & Pai, H. "A Portable and Sustainable Computer Education Project for Developing Countries-Phase 1". *International Journal For Service Learning In Engineering,* 1(1) (2006) 27-47.

106 Pearce, J.M. (2009). Appropedia as a Tool for Service Learning in Sustainable Development. *Journal of Education for Sustainable Development,* 3(1), 47-55.

107 P. F. Logan, "Physics in Appropriate Technology", *Phys. Technol.* 11, (1980)

108 J. M. Pearce and C. Russill, "Student Inquiries Into Neglected Research For A Sustainable Society: Communication and Application," *Bul. of Sci. Tech. & Soc.* 23 no. 4, (2003), 311-320.

109 J. M. Pearce, "The Use of Self-Directed Learning to Promote Active Citizenship in Science, Technology and Society Classes", *Bul. of Sci. Tech. & Soc.* 21 no. 4, (2001), 312-321.

110 V. A. Winter, "Assessment of Wheelchair Technology in Tanzania". *International Journal For Service Learning In Engineering,* 1(2). (2006). http://library.queensu.ca/ojs/index.php/ijsle/article/view/2085

111 B. Thomas, "A Wing Powered, White LED Lighting System for the Kibera Slum of Nairobi". *International Journal For Service Learning In Engineering,* 2(1). (2007). http://library.queensu.ca/ojs/index.php/ijsle/article/view/2089

112 G. Sharan, , Srivastav, S., Rawale, K., & Dave, U. Development of Corrugated Fiber Board Cartons for Long Distance Transport of Tomatoes in India. *International Journal For Service Learning In Engineering,* 4(1). (2009). http://library.queensu.ca/ojs/index.php/ijsle/article/view/2225

113 See a list of open source engineering software tools here: http://www.appropedia.org/Open_source_engineering_software

114 http://www.servicelearning.org/topic/quality-components-standards

Dr. David Munoz examining a borehole water well in Makondo, Uganda.

"The scientist merely explores that which exists, The engineer creates what has never existed before ... ...While the humanitarian engineer collaborates, innovates and sustains that which must be."

— Theodore VonKármán (modified)

CHAPTER 3
Humanitarian Engineering

David R. Muñoz, PhD
Colorado School of Mines

Carl Mitcham, PhD
Colorado School of Mines, Golden

INTRODUCTION

Engineers have long been focused on meeting the needs of humanity. However, during the past century, the acceleration in technological development has resulted in an increased gulf between the developed and developing world, and the engineer's occupation with the former. Though we have been to the Moon, sent robots to Mars, and done marvelous things on the mega and nano scales, the fact remains that on our unique planet 1.4 billion people live on less than $1.25USD per day, over 1 billion people lack access to clean water and 11 million children under the age of five die every year from malnutrition and disease[1]. Indeed, when we analyze our significant infrastructure constructed within the "developed" world during the last century, we see many things that must change to allow for a sustainable future. Energy and water consumption, food production, and the way in which we lead our everyday lives in the "developed" world must change to accommodate a habitable world for our descendents, while also providing an appropriate example for, as well as learning from, the developing world. In reality, we are all "developing" as we seek a sustainable path for our communities. There are better words to describe the earth's inhabitants. Miguel Karian (1996) introduced the word affluent to refer to the "developed" countries and traditional for the "developing" countries. Hereafter we will use these words to better capture the true meaning. The following definitions apply.

Affluent countries – countries in which the majority of the population have above average global resource consumption patterns; typically known as developed, Northern, Western or first-world countries.

Traditional countries – countries in which the cultural norms remain heavily based upon old-world traditions; typically known as developing, Southern, third-world, less-developed or underdeveloped countries[2].

Engineering graduates must understand the global (physical, social, political, cultural, environmental, legal and economic) constraints that they face and how to use the available tools as they consider the long view, while working to meet the needs of local people – the essence of Humanitarian Engineering.

THE ROLE OF ENGINEERING IN SOCIETY

Development of engineering as a discipline has been an evolutionary process. The forerunners of engineers, practical artists and craftsmen, proceeded mainly by trial and error. Yet tinkering combined with imagination produced many marvelous devices. Many ancient monuments around the world incite admiration that is embodied in the name “engineer” itself. In the west the word originated in the eleventh century from the Latin ingeniator, meaning one with ingenium, or the ingenious one. The name, used for builders of ingenious fortifications or makers of ingenious devices, was closely related to the notion of ingenuity, which was captured in the old meaning of “engine” until the word was taken over by steam engines and the like[3].

In general, the classical and medieval engineers did not have a quantified, scientific basis for their designs. There were exceptions such as the case of five simple machines – lever, wheel, pulley, wedge, and screw. Mathematical analysis of these machines had begun to take shape among the Greeks of the fourth century BC. However, their results were by no means wholly theoretical.

Development of an ‘engineering discipline’ was confronted by a myriad of impediments; for example (but certainly not limited to):

a. the difficulties of making calculations without the place-number and decimal systems,
b. the fact that engineers and master craftsmen were often illiterate (at least in the sense that they could not read the languages in which the theoretical treatises were written),

c. the fact that engineers have to apply themselves to whatever the concerns of their patrons are at any given time. Versatility was normal, but it was also essential. Specialization was a relatively new concept.
d. the fact that with so many problems in engineering their solution demands the use of differential or integral calculus, which was not invented until the seventeenth century.

Of all the scholars whose names have come down to us, only al-Jazari[4] (late twelfth century, encyclopedia.com, 2008) seems to have devoted his entire life to engineering. Many others began their careers in a variety of occupations: Ctesibius (285 - 222 BC), according to Vitruvius (~80 – 15 BC)[5], was the son of a barber and developed many inventions as a result of his intense curiosity; Guido da Vigevano (14th century) was trained in medicine, Mariano Taccola (15th century) was an artist and sculptor. Al-Biruni (973-1048 AD), probably the greatest scientist of medieval Islam, made astronomical instruments and studied mining technology[6]. No doubt there was an element of prestige in having learned men attached to one's court, but, much like engineers working in today's world, they were expected to earn their keep as physicians, astronomers, teachers, architects, and engineers.

Engineers have claimed a history that goes back to the builders of medieval cathedrals, Roman aqueducts, and Egyptian pyramids. But these contexts and constraints were so different from those of the modern period that the only support for such a claim is to conceive of engineering in quite abstract terms. Using a sufficiently abstract description, almost everything human does some form of engineering. This is the argument, for instance, of the engineer philosopher B. V. Koen, (2003)[7], when he identifies engineering with heuristic decision making. Engineering is a socially constructed profession with a contextualizing and constraining history continuous with the present. Engineering arose in the late medieval or early modern period, initially in a military context.

The first institutions of engineering education were created by national governments and closely linked with the military. One early example is the Academy of Military Engineering established at Moscow in 1698 by Czar Peter the Great. Engineers started to detach themselves from the military context during the Industrial Revolution in Great Britain. John Smeaton (1724-1792), a member of the Royal Society who began to use scientific methods to analyze construction projects, was the first to denominate himself as a "civil engineer". Smeaton founded the Society of Civil Engineers, which became the Institution of Civil Engineers (ICE) in 1818, the first officially recognized professional engineering society. Civil engineering was simply defined as all non-military engineering. The description clearly included both what would now be called civil engineering (the designing of roads, dams, and related infrastructures), mechanical engineering (working with power and machines), and hydraulic engineering (irrigation and drainage). Thus, it is perfectly reasonable to apply his definition of civil engineering to engineering in general[4].

For roughly the first hundred years, until the early 1900s, the engineering ability to re-design the world and its usefulness in increasing human productivity, in conjunction with industrial economic expansion, was always assumed, precisely because of such utility, to be good. When engineers began to formulate explicit codes of ethics they tended to emphasize collaboration with business and industrial interests. Primary examples were the codes of ethics of the American Institute of Electrical Engineers (AIEE, adopted 1912), the American Society of Mechanical Engineers (ASME) and the American Society of Civil Engineers (ASCE), both of which were adopted in 1914[4]. These early codes of ethics were intended to document existing standards of behavior rather than establish ideals toward which the engineer may strive[8].

Engineering may be thought of as the "art of directing the great sources of power in nature for the use and convenience of humans" (McGraw-Hill Encyclopedia of Science and Technology, 10th Ed. 2007)

Humanitarianism is another instance that indirectly invites engineers to self-examination and to consider alternative contexts to those for which their professional practices have commonly been pursued.

HUMANITARIANISM

Humanitarianism is defined as an ethic of kindness, benevolence and sympathy extended universally and impartially to all human beings. Humanitarianism has been an evolving concept historically but universality is a common element in its evolution. No distinction is to be made in the face of human suffering or abuse on grounds of gender, tribal, caste, religious, or national divisions.

The evolution of humanitarianism has been a complex phenomenon as well. The roots of humanitarian criticism, or of restricted forms of community and the promotion of equity or equality among humans, are many. One root, for instance, is the cosmopolitanism of Greek and Roman philosophy. Some ancient philosophers argued that the whole cosmos (Greek for physical universe) constituted a kind of polis, making all human beings members of a single community. Diogenes of Sinope (c.400s BCE), when asked his citizenship, is reported to have answered, "I am a citizen of the world" (kosmopolitêsin Greek)[4].

Another root is Christian missionary theology illustrated by St. Paul, who argued a supernatural version of universalism; insofar as all human beings are created by and equal in the sight of God, they are members of a common community with obligations to care for one another[4].

A third root is to be found in the moral principles of Enlightenment philosophy in both the empiricist and rationalist traditions. With regard to empiricism, Scottish philosopher David Hume (1711-1776) defended sympathy as the foundational moral sentiment. This sentiment, expressible as benevolence and concerned especially to secure such basic goods as food, shelter, and social relationships not just for ourselves but for all and thus structures human behavior. From the tradition of rationalism, the German philosopher Immanuel Kant (1724- 1804) argued for recognition of a categorical obligation to treat all humans as ends in themselves[4].

None of these historical influences, however, adopted the term "humanitarianism." Indeed, in its initial secular uses in the early 1800s the term was largely derogatory, as denoting excess in the promotion of humane principles over more realistic or patriotic ones. People more concerned about the poor in a foreign country than the welfare of their own families were sometimes disparaged as "humanitarians." In the late 1800s, however, the term began to take on positive connotations, as when the American sociologist Lester F. Ward described humanitarianism as aiming "at the reorganization of society, so that all shall possess equal advantages for gaining a livelihood and contributing to the [common] welfare"

(Ward, L., 1883, p. 450)[9]. Only after the fact were social movements grounded in the goal of meeting the basic needs of all persons irrespective of national or other distinctions—often with a special focus on health care, food, and shelter—interpreted as expressions of something called a humanitarian movement[4].

Evolution of the Humanitarian Movement

The first major movement of active compassion that would come to be called humanitarianism addressed the issue of slavery. The struggle for racial equality has been a key in anticipation of a more universal humanitarianism. A second major movement in the development of humanitarianism is associated with the promotion of child welfare and labor protection legislation, and involved as well a democratic extension of the voting franchise that in effect challenged class privilege and economic discriminations.

Phase One (1800's): Rise of the Humanitarian Movement Proper

The humanitarian movement is generally understood to have originated in the mid- to late 1800s. This origination is associated with the rise of the profession of nursing, as promoted in the work of Mary Seacole (1805-1881) and Florence Nightingale (1820-1910) in the Crimean War (1854-1856) and Clara Barton (1821-1912) in the U.S. Civil War (1861-1865). But the key event was the reaction of Swiss businessman Henri Dunant (1828-1910) to the Battle of Solferino (1859), which ended the Second Italian War of Independence. Dunant's vision led to the 1863 creation of the International Committee of the Red Cross/Red Crescent (ICRC), which currently defines itself as "an impartial, neutral and independent organization whose exclusively humanitarian mission is to protect the lives and dignity of victims of armed conflict and other situations of violence and to provide them with assistance."[4, 10]

Phase Two (Early 1900's): Humanitarianism Beyond the Battlefield

During a second phase, the first half of the 20th century saw the development of new forms of humanitarianism that expanded the movement beyond the limits of medical care directed toward military personnel. The ICRC became concerned with the plight of civilian non-combatants and for persons caught in natural disasters. New models of humanitarianism can be found in the work of Norwegian scientist and explorer Fridtjof Nansen (1861-1930) and of U.S. mining and civil engineer Herbert Hoover (1874-1962): Nansen in post-World War I work resettling refugees under the auspices of the League of Nations, and Hoover in relief work during and after the war as well as in response to the Great Mississippi Flood of 1927[4,10].

Phase Three (1950's-1960's): Humanitarianism as Free World Ideology

This period witnessed the emergence of humanitarian nongovernmental organizations (NGOs) other than the ICRC: e.g., Baptist World Aid (1905), American Friends Service Committee (1917), Catholic Medical Mission Board (1928), Save the Children (1932), OXFAM (1942), and CARE (Cooperative Action for American Relief Everywhere, 1945).Creation of the United Nations (1945) and the international adoption of the Universal Declaration of Human Rights (1948) provided a further basis for questioning the primacy of national sovereignty[4,10].

In this third phase, something like humanitarian development became a kind of free-world ideological alternative to Communism.

Insofar as it grew out of post-World War II relief and recovery efforts, this third phase in the historical development of humanitarian thinking also highlighted efforts that go beyond some immediate response to a crisis. Simple crisis intervention humanitarianism, it was increasingly recognized, needs to be complemented with crisis recovery humanitarianism.

Phase Four (1970's-1990's): Alternative Humanitarianisms

Beginning in the late 1960s, however, and indicative of a fourth phase, humanitarianism began to separate itself from its previous close association with anti-communism. One key event was the Nigerian Civil War in the break-away province of Biafra (1969), which also became the first televised international humanitarian crisis. Under such conditions, humanitarian aid workers began to challenge even more strongly than had been done after World War II, the principle of respect for national sovereignty. Aid workers began to want to openly criticize governments on both sides of the civil war and governments outside the conflict supporting one side or the other. The resulting crisis of conscience in the humanitarian community catalyzed the founding, of Médecins sans Frontieres (MSF, or Doctors without Borders) in 1971, by the French physician Bernard Kouchner. MSF, which has become the largest non-governmental relief agency in the world, grew out of dissatisfaction with the inability of the Red Cross/Crescent to react independently of national government controls, and its tendency to remain within safe boundaries; MSF refused to be limited by state sovereignty[4,10].

Phase Five (2000-PRESENT): Humanitarianism Globalized and Questioned

Finally, in the context of the end of the Cold War (early 1990s), a widely adopted sense of humanitarianism was adopted. This trajectory is best represented by the "United Nations Millennium Declaration" (2000), in which the member states recognized, "in addition to separate responsibilities to [their] individual societies,…a collective responsibility to uphold the principles of human dignity" and a duty "to all the world's people, especially the most vulnerable" (Section I, paragraph 2). In addition, only through broad and sustained efforts to create a shared future, based upon our common humanity in all its diversity, can globalization be made fully inclusive and equitable[4,10].

The "Millennium Declaration" was extended into the Millennium Project, commissioned by UN Secretary-General Kofi Anan in 2002 to develop a concrete action plan to eradicate the most extreme poverty by 2015. In this project humanitarian action came to focus not so much on crisis relief or even recovery but rather on crisis prevention humanitarianism.

Millennium Development Goals

The eight Millennium Development Goals (MDGs) constitute an effort to operationalize the United Nations Millennium Declaration (September 2000). The MDGs (adopted in 2001) are:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

HUMANITARIAN ENGINEERING

It is against this backdrop, the convergence of engineering and humanitarianism that the discipline of "humanitarian engineering" has emerged.

In general terms, engineering is the 'artful drawing on science to direct the resources of nature for the use and the convenience of humans'. Humanitarianism has been generalized as an 'active compassion directed toward meeting the basic needs of all — especially the powerless, poor, or otherwise marginalized'. Humanitarian engineering may thus be described as 'the artful drawing on science to direct the resources of nature with active compassion to meet the basic needs of all—especially the powerless, poor, or otherwise marginalized'. To some degree humanitarian engineering is related to what Mitcham (2003) has termed "idealistic activism" among scientists and engineers, as exemplified by organizations such as International Pugwash (founded 1957) and the Union of Concerned Scientists (founded 1969).

Peace Corps

Growing up during the Great Depression in Iowa, Maurice (Maury) Albertson (1918-2009) was strongly influenced by a family commitment to try to live out the Christian message of the Sermon on the Mount and by witnessing the impact of an extended drought on farmers and their communities. This led him to study water resource engineering and earn a doctorate from the University of Iowa. After graduation, in 1947 he joined the faculty at Colorado State University. He had been impressed with the way the Marshall Plan helped Europe recover after World War

II. As a result, Albertson's co-authored a report, expanded into book form, which became New Frontiers for American Youth: Perspective on the Peace Corps (Albertson et al., 1961). The book explicitly describes the Peace Corps as extending the reach of volunteer Christian international service organizations into the promotion of American political ideals and lists among its Principal Project Needs, "engineering (irrigation, community water supply, flood control, roads, surveying, bridges)" (Albertson et al., 1961, p. 39)[11]. As an upshot of his report, Albertson was asked by the late R. Sargent Shriver, the first director of the Peace Corps, to head a panel that would lay out many of the operational structures which, in short order, had over 10,000 volunteers serving in some 50 countries[4].

Medecins Sans Frontieres - Doctors Without Borders

Perhaps even more influential than any one individual has been the model of Doctors without Borders mentioned earlier. Nearly all individuals involved in humanitarian work fundamentally accepted, even when they were frustrated by, the notion of national sovereignty. The U.S. Peace Corps, with which Albertson was so involved, is actually an agency of a sovereign country. It thus tends to reinforce the whole concept of sovereignty or the idea that national governments have the final say over what goes on within their state boundaries. At the same time, from its beginnings, humanitarianism involved a questioning of the idea of sovereignty and associated ideas such as national patriotism and sacrifice. One of the fundamental tenants of MSF was to criticize and reject the primacy of national sovereignty as a final arbiter of boundaries for humanitarian action. MSF activists are committed to going where the problems are, even without the permissions of national governments, and to exposing the misbehaviors of governments toward their own peoples, insofar as these misbehaviors involve mistreating their citizens or depriving them of protection and care[4,10].

Stimulated by the ideals of MSF, the late 20th century also witnessed emergence of a host of other MSF-like NGOs for lawyers without borders, builders without borders, and so on. Yet one of the strongest parallel 'without-borders' organizational developments has been associated with some form of the name "Engineers without Borders," in which engineering students and their professors began independently to explore possibilities of humanitarian engineering in diverse localities: Ingénieurs sans Frontiers (France, 1982), Ingénieurs Assistance Internationale (Belgium, c.1987), Ingeniería sin Fronteras (Spain, 1990), Ingeniererunden Graenser (Denmark, c.1992), Ingenjöreroch Naturvetareutan Gräser-Sverige (Sweden, c.1995), Engineers without Borders (UK, 2001), Engineers without Borders (Australia, 2003), Ingenieureohne Grenzen (Germany, 2003), Ingeneríasenza Frontiere (Italy, c.2005), and others. In 2003 a number of these groups organized "Engineers without Borders — International" as a network to promote "humanitarian engineering…for a better world," now constituted by more than 41 national member organizations[4].

Complementing such interests among engineers, humanitarians have increasingly come to see engineering and technology as having increasingly crucial roles to play in the world of humanitarian action. There is a lot of potential for adapting and creating technologies for humanitarian ends, but new technologies will not automatically be put to humane uses without the political will and the economic means to do so. This necessitates building upon and furthering the trend of enlargement of humanitarian concern and expanded organizational effort collaboration, insight and input of the poor as well as iteration based on feedback from the many failed humanitarian engineering efforts. It means mobilization of the new culture to encourage the wealthy part of the globe to make the economic sacrifices necessary to create and apply technology in effective ways (Cahill, K., 2005, p. 19)[12].

Humanitarian Engineering: Core Features

As cited above, humanitarianism has gone through a number of developmental phases. Over the latter decades of the 20th century, a new context for the practice of engineering has been constituted. One can abstract some key attributes of the humanitarian engineering ideal that emphasize the notions not just of crisis intervention humanitarianism but also vulnerability reduction leading to more rapid crisis recovery and even crisis prevention. The central feature of the humanitarian movement as a whole has been the exercise of active compassion for those on the margins of social wealth and power. This marginality can be temporary or more long-term, but in either case humanitarian action aims to serve the well-being of otherwise marginalized populations.

In contrast to corporations which aim for relatively near-term profit, and governments which fund in light of election cycles and thus constituent dependencies, humanitarian engineering projects ideally engage local communities in direct participation in determining project needs and directions, and think in terms not of years but of decades in the impact. Additionally, they seek strategies, designs, and technologies that promote both the sustainability of natural systems and cultural traditions (see, e.g., Azpagic et al., 2004[13] and Mulder, K., 2006[14]).

Engineering itself has been described as design within a context or under constraints —constraints largely imposed by physical, political, cultural, ethical, legal, environmental, and economic phenomena. Insofar as this is the case, humanitarian engineering may conveniently be described as working to escape what has been called the "social captivity of engineering" by capitalism or nationalism or some other form of wealth and power (Goldman ,1991[15]; see also Johnston et al.,1996[16]). In doing so, however, humanitarian engineering seeks to work within a new self-imposed constraint of seeking to help meet the basic needs of under-served populations. In brief, humanitarian engineering in the most general terms is 'the artful drawing on science to direct the resources of nature with active compassion to meet the basic needs of all—especially the powerless, poor, or otherwise marginalized'.

HUMANITARIAN ENGINEERING EDUCATION

As Bernard Amadei and William Wallace have stated,

> *A new form of engineering education is needed, one that covers a wide range of technical and non-technical issues, including water provisioning and purification, sanitation, public health, power production, shelter, site planning, infrastructure, food production and distribution, and communication.... The challenge of creating a sustainable world demands a new and holistic look at the*

role of engineering in society … to allow all humans to enjoy a quality of life where basic needs of water, sanitation, nutrition, health, safety, and meaningful work are fulfilled.

— Bernard Amadei and William A. Wallace,
"Engineering for Human Development"(2009)[17].

The development of humanitarian engineering education naturally follows the rise of student interest in humanitarian engineering. Such education will obviously benefit from an appreciation of engineering as a context dependent, externally constrained activity, as well as from some general knowledge of the history and development of humanitarianism. But we would emphasize, as is the case with most engineering problems, that there is seldom a single right way to design a humanitarian engineering curriculum. Instead, even more so in this regard than in many others, there is a recurring need to take clients, aspirations, resources, and context into account.

What Counts as a Humanitarian Engineering Project

Deciding what truly counts as a humanitarian engineering project is not always easy. Efforts to clarify understandings in this regard within the Colorado School of Mines (CSM) undergraduate Humanitarian Engineering Minor program have led to the formulation of a set of four guiding criteria:

1. There must be a need that originates with the people directly benefitting from any proposed work.
2. Whatever need is involved should be related to a basic human need, although it is also possible to include higher level needs such as education and economic development.
3. Good communication is essential with the people directly benefitting from the work and/or commonly through an NGO intimately familiar with the local context.
4. The need should be one that can benefit from engineering skill and knowledge.

One way to operationalize the first criterion is to use the engineering design process systematized as the "quality function deployment technique" (see Cohen, L., 1995[18]). The fundamental idea is to begin by identifying stakeholders and then working with them to establish a set of prioritized needs. Subsequent analysis compares competing solutions and finally, based on such inputs, design specifications are developed.

The second criterion is more problematic than it may initially appear to engineers. The reason is that human needs depend on human interpretations, which in turn are strongly influenced by cultural beliefs about the nature and meaning of human life. Nevertheless, from a perspective that necessarily reflects Western engineering beliefs, a hierarchy of physiological needs exists defined by survival time for anyone denied access to a number of basic life requirements. At the same time, to think only in these terms would significantly limit humanitarian engineering. It is thus necessary to move beyond such immediately physiological or technical considerations, to psychological, social, and political concerns, when thinking about basic needs.

Working with criteria three and four promotes, even more than criterion two, appreciation of the degree to which psychological, social, cultural, and political aspects of a project are often as much, if not more, crucial than technical ones. Communication is crucial among all those involved in humanitarian engineering projects, engineers and non-engineers alike. Therefore, education in communication skills that go beyond abilities in simple technical communication are important. Communication has to be oriented not just toward the facilitating of technical team effectiveness but toward the creation of interdisciplinary communities. Such recognition promotes deeper understandings of (sustainable community) development (Bridger and Luloff, 1999[19]). If projects really are to benefit others, it is crucial to seek out local sources of knowledge and to value them, which can sometimes demote the importance of technical engineering skills and knowledge. This idea, known as participatory action research, is an extension of ideas from Freire (1970)[20], and has been elaborated by Stephen Biggs[21] (see analyses in Fals-Borda and Rahman, eds., 1991[22]). In order for any humanitarian engineering project to be socially sustained, there must be ownership on the part of the local people.

A major source of ownership comes from the engagement or participation of the local people in all aspects of the design process. Freire would go further to say that the oppressed are the only ones with the power to free themselves and their oppressors from the oppressive relationship. After the oppressed become educated about their oppression, they must develop solutions to both their problems and those of their oppressors who have had a part in causing the problems in the first place.

Participatory research, which can include engineering design and construction work, includes a spectrum of at least four modes of participation[23]:

1. Contractual : Local people are contracted into the projects of the researchers to take part in theirinquires or experiments.
2. Consultative: Local people are asked their opinions and consulted by researchers before interventions are made.
3. Collaborative: Researchers and local people work together on projects designed, initiated, and managed by researchers.
4. Collegial : Researchers and local people work together as colleagues with different skills to offer, in a process of mutual learning where local people have control over the process.

As a result, it is possible to conceptualize a need among engineers to look for opportunities to help build capacity for autonomous action among those with whom they work. In this regard, a series of questions adapted and expanded from Baillie (2006)[24] can serve as a template for self-examination. In thinking about any project, it is useful to ask:

- Who benefits and who pays?
- Who stands to gain or lose?
- Who decides who needs what and when?
- Who is contributing to the design and implementation?
- How will the project be sustained?

This new understanding of Freire's book among others calls for a modification of the humanitarianism definition, and thus the definition of the humanitarian engineer. We now understand that the local people with whom we work are not powerless and indeed hold great power (through education) to overcome any oppression that may exist. Additionally, though a human being may be poor in economic terms, they may be wealthy in other ways: intellectual or intuitive capacity, indigenous knowledge, family values, etc. Therefore, the definition of the humanitarian engineer is modified to 'the artful drawing on science to direct the resources of nature with active compassion to meet the basic needs of all—especially the economically poor, or otherwise marginalized'.

THE NEEDS QUESTION

Six distinct groups will benefit from the long-term and sustained efforts to develop the goals and critical aspects of a Humanitarian Engineering program. These groups represent such a large constituency that hopefully the concepts described herein will ultimately become interwoven in the fabric of engineering education in general. The six groups discussed here are: the Global Community (primarily people in the "traditional" world), students, faculty, industry, and the government and non-governmental organizations (NGOs). For present purposes we combine government and NGOs.

Needs of the Global Community

The world is and has always been full of human suffering. The global community needs young people educated in the art of communication with enhanced social/cultural sensitivity in addition to knowledge of appropriate and sustainable technologies to help meet basic human needs. Humanitarian needs can be conceptually distinguished into three major categories. These are: emergency humanitarian response, preventive humanitarian action and humanitarian development.

As the title of the first category implies, emergency humanitarian response needs relate to natural or human-made disasters. The failures of past emergency humanitarian responses have been documented by Reiff[25] and are currently being revised as many aid organizations contemplate the 2010 earthquake disasters in Haiti and Chile. Universities are generally poorly equipped to deal with the emergency response need.

However, we believe that preventive humanitarian action and humanitarian development can be addressed well by the engineering education community, including the possibility for a valuable service learning practical capstone experience. These areas are the focus of Humanitarian Engineering efforts across the country; preventing human-made disasters, minimizing the impact of natural disasters, and aiding in community development by design.

Clearly, preventive and development needs are complex and of enormous scope. What is needed is that which the anthropologists have referred to as a collegiate relationship with or participatory involvement of the local people[22]. Developing relationships takes time and patience, but we believe will in the end, yield great benefit. For example Ramaswami et al. (2007)[26] describe several examples of indigenous solutions to problems that were superior to those provided by their more affluent counterparts.

The Student Need

Downey et al. (2006)[27] identified a set of challenges that face engineers from diverse cultures and societies working together on international engineering design teams. They define the term global competency for the engineer and suggest that engineers from different cultures define problems differently. They also provide measures for assessing student performance at attaining a specific set of learning outcomes. While there are certainly challenges associated with this culturally diverse mix of professionals that must be added to the student repertoire, significant and complex challenges in societal and cultural differences also exist between the team of professionals and their stakeholders, the local traditional people (with basic outstanding needs). A key factor in the success of a humanitarian engineering endeavor is the ability to listen, indeed the ability to listen contextually as described in the recent publication by Lucena, Schneider and Leydens (2010)[28] is critical.

Prospective students are pleasantly surprised to learn about the types of Humanitarian Engineering senior design projects available at universities across the country. It is possible to attract students who had not previously thought that engineering was the field for them until they realized the possibility of making a direct and positive contribution to addressing humanitarian needs. Human motivation including that of our students is piqued when working on projects deemed altruistic. Maslow argued that there is a general progression within humans, from the physiological to higher level needs (See Figure 3.1). For example, he suggested that aesthetic needs do not enter one's mind if one is genuinely hungry and thirsty. That said, experience has shown that the participants (faculty and students alike) often gain more out of the process (in learning, experience, etc.) than the local people. While the local people give their time, resources and trust, the students become aware that, because of the tight university schedule, their time onsite is necessarily short, unless they decide to return for an extended visit and commonly feel that they are the more significant beneficiaries of the experience.

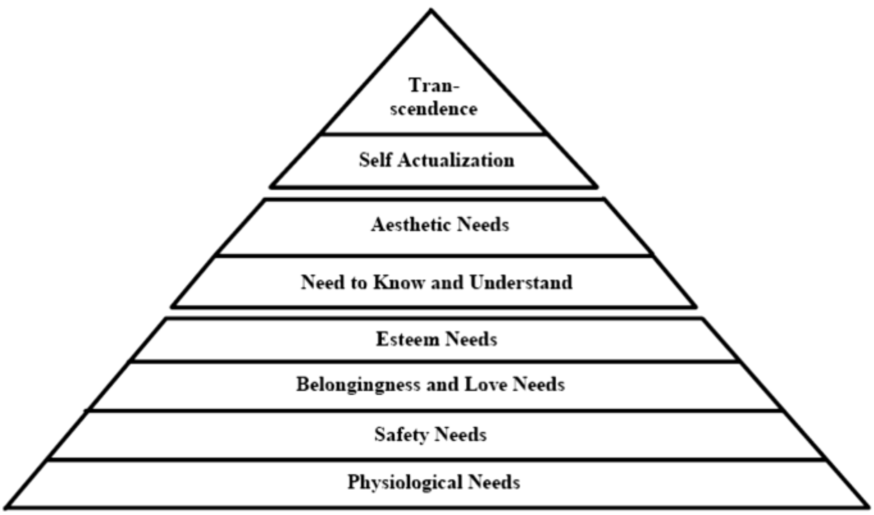


FIGURE 3.1 MASLOW'S HIERARCHY

The Industry Need

One of industry's needs in this regard is evidenced by survey results as well as discussions with engineering recruiters from major multinational corporations. Industry and recruiters were asked, "What do you feel are the attributes required in future engineering graduates compared to those of the engineering graduates of the past twenty years?" The quickly provided answer was "increased sensitivity to societal and cultural issues". Some recruiters then related stories about how past insensitivity to societal/cultural issues have resulted in costly consequences. Such stories are common within technology companies that have international reach, but it should be no surprise that similar issues occur on projects within the borders of the United States.

Various industries have recognized that their business sustainability depends in no small part on their ability to achieve social acceptance within the local community in which they work.

The Government and NGO Needs

The United States government has many organizations that provide aid to the traditional world. The Peace Corps has already been mentioned, but there is also U.S. Agency for International Development (USAID) and international programs within other governmental agencies. The U.S. military also has active programs through the Army Corps of Engineers and the Navy Seabees to perform infrastructure construction projects throughout the world. In the book, *Stones to Schools*[29], the former Chairman of the Joint Chiefs of Staff, Admiral Mike Mullen recognized the importance of this sensitivity:

> *"Only through a shared appreciation of the people's culture, needs and hopes for the future can we hope ourselves to supplant the extremist's narrative."*

Paul Hawken's *Blessed Unrest*[30], written in part to explain the large number of non-profit or non-governmental organizations that are trying to do positive work around the world, argues that this movement is the largest in human history. Though little data exists, many engineers are likely working with several of the kinds of organizations Hawken describes. However, little centralized efforts currently exist for defining a career path for interested students. The reality is that such organizations seek engineers seasoned with tempering experience from the Peace Corp or some other service organization.

The Faculty Team

It is critically important that a humanitarian engineering program be administered by an interdisciplinary team with representatives from at least the humanities/social sciences and engineering academic communities. Within many, perhaps most, universities this is no small feat. For various reasons, the ivory towers have high and strong walls that must be overcome if a successful program in humanitarian engineering is to be developed.

There are always challenges to consider when working in interdisciplinary teams. A few useful references are Klein (1990)[31], a recent publication from the NAE entitled Facilitating Interdisciplinary Research and Pellmar et al. (2000)[32]. Some potential barriers to interdisciplinary research are cited in Table 3.1.

TABLE 3.1 POTENTIAL BARRIERS TO INTERDISCIPLINARY RESEARCH

Potential Barrier	Barrier Explanation	Team Goals
Attitudinal	Researchers may recognize the need for interdisciplinary work but remain reluctant to leave their disciplinary focus. Interdisciplinary science is viewed as second-rate	Disseminate gained knowledge in high-quality publications to prominent journals and conferences
Communication	Over use of language and jargon specific to a particular field	Use common language, learn the language of another field, frequently communicate
Intellectual Turf	Other disciplines viewed as less rigorous or important than their own	Work to understand and appreciate the value and limits of each team member's expertise
Team Building	Mutual trust in teammate's skills and expertise	All voices are heard, work toward mutual trust and respect.
Leadership	Credible, skilled at modulating strong personalities and in group dynamics, maturity in field, previous experience in conducting interdisciplinary research	Team will support the leadership
Facilitating Interactions	Organize the physical environment to promote the encounter of disciplinary researchers	Team will coordinate seminars and advertise both on and off campus, and initiate interactions with an external Advisory Board

Another problem often encountered in development of a Humanitarian Engineering program, especially during the process of achieving faculty approval to initiate the program, is the belief that all of engineering is humanitarian. Put another way, the question was asked, "Does that mean the rest us are working on un-humanitarian engineering?" Good question. The response is in the definition cited earlier of humanitarian engineering: the artful drawing on science to direct the resources of nature with active compassion to meet the basic needs of all—especially the economically poor or otherwise marginalized. The key difference is the target audience.

New Dimensions in Engineering and Education

Given this model, it is tempting to think of the motivation of humanitarian engineers is situated on higher levels of the hierarchy or power, with the aim of meeting the lower level needs of those being assisted. This is one possible interpretation. At the same time, there is something insidious if not insulting in a framework that ends up placing those on the initiating side of humanitarian work on a higher psychological level than those on the receiving side. Moreover, this power differential — and especially the resulting dynamics — surely reflects the beliefs and assumptions of American engineers operating in the context of what has often been described as a needs-based materialistic culture (see, e.g., Illich, I., 1967[33]). What, we may ask, are the relationships between typically modern discussions of need in contrast with more traditional notions of the good? Maslow's model may thus function not only as an explanatory model but also as a framework for self-questioning.

One result of such introspection might be a critical reformulation of ideas about how we live in the "affluent world" and the imagination of models for environmentally sustainable living in a sustainable global economy. After considering the energy and material intensive aspects of our society, one cannot help but question its use as a model. Might we be able to learn how to live more sustainably from the traditional people that we thought we were visiting to help? Additionally, as one aspiring humanitarian engineer noted with regard to himself: 'Initially, I was excited about [humanitarian engineering] because of the opportunities to design appropriate technologies for needy international communities. While this excitement does still exist, [after study and experience] I am much more leery; during the process I learned a lot about technology in society, the need to challenge structures, the need to work in one's own community, and the dangers of international placements' (VanderSteen, J., 2008, p.288)[34].

The words of Gustavo Esteva[35], friend and colleague of Ivan Illich describe well the challenge of "helping".

> "If you come to help, don't come. But if you see that your struggle is our struggle, then come and stay with us for awhile. After some time we may find something to work on together."

As we struggle with the immense challenges of meeting the world's basic human needs into the foreseeable future, we realize that this is not a problem only of technology or of helping, but more so a problem of learning to listen and work together in collegial relationships with people living in our local and not so local communities.

Considering the other side of the coin, we believe that engineers have something to offer. We live in a technological world. While it is highly unlikely that technology will provide a magic elixir for these substantial problems that we now face, it can be a part of the solution. Therefore, the humanitarian engineer must be prepared to 'artfully draw on science to direct the resources of nature with active compassion to meet the basic needs of all—especially the economically poor or otherwise marginalized, always seeking a balance of listening and learning from the traditional people while humbly sharing appropriate engineering knowledge'.

Acknowledgements

This work in humanitarian engineering (HE) was initiated as part of a block grant from the William and Flora Hewlett Foundation, entitled, Engineering Schools of the West Initiative (ESWI). Their early and generous support is gratefully acknowledged. Additionally, many students and colleagues from Colorado School of Mines participated in developing the HE minor program. Though there are too many to recognize here, several of these have been exceptional contributors and are acknowledged

as follows, Sanaa Azim, Heidi Bauer, F. Edward Cecil, Laurin Cooper, Joseph Crocker, Joan Gosink, Jon Leydens, Ning Lu, Juan Lucena, Barbara Moskal, Junko Munakata-Marr, Arthur Sacks, George (Jerry) Sherk, Jay Straker, Marcelo Simões, Catherine Skokan, Robert (Doug) Sutton, Julie VanLaanen and Natalie Wagner and Sandy Woodson.

REFERENCES

[1] United Nations, *Millennium Goals Report 2009* (New York, United Nations, 2009) http://www.un.org/millenniumgoals/pdf/MDG_Report_2009_ENG.pdf (accessed April 5, 2010).

[2] Karian, Michael. (1996). Technology and the Environment. In R. L. Custer & A. E. Wiens (Eds.), *Technology and the Quality of Life.* (Council on Technology Teacher Education Yearbook). Peoria, IL: Glencoe.

[3] Mitcham, C. and Munoz, D., *Humanitarian Engineering,* Morgan and Claypool Publishers, Caroline Baillie, Series Editor, 2010.

[4] http://www.encyclopedia.com/doc/1G2-2830904902.html (accessed June 27, 2011).

[5] Vitruvius, *Ten Books of Architecture,* translated by Morris Hicky Morgan, Harvard University Press, 1914.

[6] http://www.gap-system.org/~history/Biographies/Al-Biruni.html (accessed June 27, 2011)

[7] Koen, Billy Vaughn (2003) *Discussion of Method: Conducting the Engineer's Approach to Problem Solving,* New York: Oxford University Press.

[8] Pfatteicher, Sarah K.A., (2003), "Depending on Character: ASCE Shapes Its Forst Code of Ethics, " *J. of Professional Issues in Engineering Education and Practice,* vol. 129, no. 1, pp. 21-31.

[9] Ward, Lester F. (1883) *Dynamic Sociology,* vol.2. New York: Appleton.

[10] Smyser, W.R., *The Humanitarian Conscience; Caring for Others in the Age of Terror,* Palgrave McMillan (2003).

[11] Albertson, Maurice L., *Andrew E. Rice and Pauline E. Birky. (1961) New Frontiers for American Youth: Perspectives on the Peace Corps.* Washington DC: Public Affairs Press.

[12] Cahill, Kevin M., Ed. (2005), *Technology for Human Action,* Ney York, Fordham University Press and Center for International Health and Cooperation.

[13] Azpagic, Adisa, Perdan Slobodan, and Clift, Roland, Eds. (2004), *Sustainable Development in Practice: Case Studies for Engineers and Scientists,* Chichester, UK: John Wiley.

[14] Mulder, Karel (2006) *Sustainable Development for Engineers; A Handbook and Resource Guide,* Sheffield, UK: Greenleaf Publishers.
[15] Goldman, Steven L. (1991) "The Social Captivity of Engineering," In Paul T. Durbin, ed., *Critical Perspectives on Nonacademic Science and Engineering* (Bethlehem, PA: Lehigh University Press), pp. 121-145.
[16] Johnston, Stephen, Lee, Alison and McGregor, Helen (1996) "Engineering as Captive Discourse," *Society for Philosophy and Technology Electronic Journal,* vol. 1, nos. 3-4.
[17] Amadei, Bernard and Wallace, William A., (2009) "Engineering for Human Development" IEEE Technology and Society Magazine, vol. 28, issue 4, pp. 1-5.
[18] Cohen, Lou (1995) *Quality Function Deployment: How to Make QFD Work for You.* Englewood Cliffs, NJ: Prentice Hall.
[19] Bridger, J.C. and Luloff, A.E. (1999) "Toward an Interactional Approach to Sustainable Community Development," *Journal of Rural Studies,* vol. 15, no. 4, pp. 377-387.
[20] Freire, Paolo (1970, 2009) *Pedagogy of the Oppressed,* 30th Anniversary Edition, Continuum International Publishing Group.
[21] Biggs, Stephen. (1989) Resource-poor Farmer Participation in Research: A Synthesis of Experiences from Nine National Agricultural Research Systems. OFCOR Comparative Study Paper 3. *The Hague: International Service for National Agricultural Research.*
[22] Fals-Borda, Orlando and Rahman, Mohammad, eds. (1991) *Action and Knowledge: Breaking the Monopoly with Participatory Action Research.* New York: Apex Press.
[23] Cornwall, Andrea and Jewkes, Rachel (1995) "What is Participatory Action Research?" *Social Science Med.,* vol. 41, no.12, pp. 1667-1676.
[24] Baillie, Caroline. (2006) *Engineering Within a Local and Global Society.* San Rafael, CA: Morgan and Claypool.
[25] David Reiff. (2002). *A Bed for the Night,* New York, Simon and Schuster.
[26] Ramaswami, Anu, Julie B. Zimmerman and James R. Mihelcic. (2007) Integrating Development and Developing World Knowledge into Global Discussions and Strategies for Sustainability . 2 Economics and Governance," *Env. Science & Technology,* vol. 41, pp. 3422-3430.
[27] Downey, Gary Lee, Juan C. Lucena, Barbara M. Moskal, Thomas Bigley, Chris Hays, Brent K. Jesiek, Liam Kelly, Jane L. Lehr, Jonson Miller, Amy Nichols-Belo, Sharon Ruff, and Rosamond Parkhurst. (2006) "The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently." *Journal of Engineering Education,* vol. 95, no. 2, pp.107-122.
[28] Lucena, Juan, Jen Schneider and Jon Leydens,. (2010) *Engineering and Sustainable Community Development.* Morgan and Claypool Publishers, Caroline Baillie, Series Editor.

[29] Greg Mortenson (2009) *Stones into Schools Promoting Peace with Books, Not Bombs in Afghanistan and Pakistan.* New York, Viking.

[30] Paul Hawken. (2006) *Blessed Unrest; How the Largest Movement in the World Came into Being and Why No one Saw it Coming.* New York, Viking, The Penguin Group.

[31] Klein, Julie Thompson (1990) *Interdisciplinarity: History, Theory and Practice.* Detroit, MI: Wayne State University Press.

[32] Pellmar, T; Eisenberg, L. (2000): *Bridging Disciplines in the Brain, Behavioral and Clinical Sciences.* Washington D.C.: National Academy Press.

[33] Illich, Ivan. (1967) "The Seamy Side of Charity", *America,* vol. 116, no. 3 (January 21), pp. 88-91.

[34] VanderSteen, Jonathan D.J. (2008) *Humanitarian Engineering in the Engineering Curriculum.* Ph.D. Thesis, Civil Engineering, Kingston Ontario, Canada: Queen's University.

[35] Esteva, Gustavo (2008) Personal Communication.

Students in the 'Entrepreneurship for the Public Good' program at Berea College, Kentucky visit with entrepreneurs in Appalachia for their service learning projects.

"Concern for man himself and his fate must always form the chief interest of all technical endeavors. Never forget this amidst all your diagrams and equations."

— Albert Einstein

CHAPTER 4
Using the Social Entrepreneurship Model to Teach Engineering Students How to Create Lasting Social Change

Debbi Brock
Anderson University

Susan D. Steiner, PhD, CPA
The University of Tampa

Lois A. Jordan, PhD, PE
The University of Tampa

Introduction

Addressing society's most intractable social problems takes perseverance and commitment. Faculty from around the world have embraced the powerful pedagogy of service learning as a tool to engage students in finding solutions to some of society's most pressing social problems. This chapter introduces the Social Entrepreneurship Model for engineering faculty to help students craft innovative solutions by building a sustainable business model that achieves social impact.

There is a strong movement among university students towards humanitarian efforts to make an impact on the lives of others. Those currently attending college - the Millennial generation (also nicknamed Generation G for Generosity)[1] - are inspired to combine their passion to do good in the world with their professional pursuits. In line with these trends, interest in social endeavors among engineers has grown rapidly during the last decade. Engineers Without Borders–USA has grown to over 12,000 members in about 8 years and boasts student chapters at 41 college and university campuses throughout the United States. Engineers for a Sustainable World, founded in 2002 by a Cornell University engineering student, has student chapters on 23 college and university campuses.

We believe that one of the best ways to train engineers on how to achieve social impact is by teaching them about social entrepreneurship. Many social service organizations are addressing social problems the same way that they addressed them ten or twenty years ago. As the world's most pressing problems continue, are we developing long term solutions to the problems or creating more dependence? Social entrepreneurship breaks the mold and encourages individuals to act differently, to embrace innovation and to attack the status quo.

In this paper, we introduce the Social Entrepreneurship Model (SEM), which brings together the elements of social impact, innovative solutions, and sustainable business models to address society's intractable problems. We then describe a number of education programs and co-curricular activities around the globe that take full advantage of the combination of engineering and social entrepreneurship perspectives to teach students how to tackle social change. We end with a discussion of the implications and recommendations for educators who wish to prepare their engineering students for the challenges of finding significant, innovative, and lasting ways to solve long-standing social challenges.

Social Entrepreneurship Model

As in most disciplines, academics in social entrepreneurship have not embraced one definition of the field[2,3]. For the purposes of this article, we define social entrepreneurship as "the creation of **social impact** by developing and implementing a **sustainable business model** which draws on **innovative solutions** that benefit the disadvantaged and, ultimately, society at large"[4]. Our social entrepreneurship definition and model evolved from a content analysis of twelve definitions of social entrepreneurship from some of the most cited researchers and organizations in the field[5]. The three bolded phrases above are highlighted because they are the most common differences identified when comparing social entrepreneurship to other organizational efforts. First, social entrepreneurship differs from traditional entrepreneurship because of its primary focus on social impact and long-term social change rather than financial gain for its owners. Second, social entrepreneurship differs from other social efforts because of it strategic business-based approach to resource gathering, operations, and performance outcomes. Third, social entrepreneurship differs from traditional business models because of its focus on innovation, be it products, services, or processes. The Social Entrepreneurship Model is presented in Figure 4.1 and explained in more detail below.

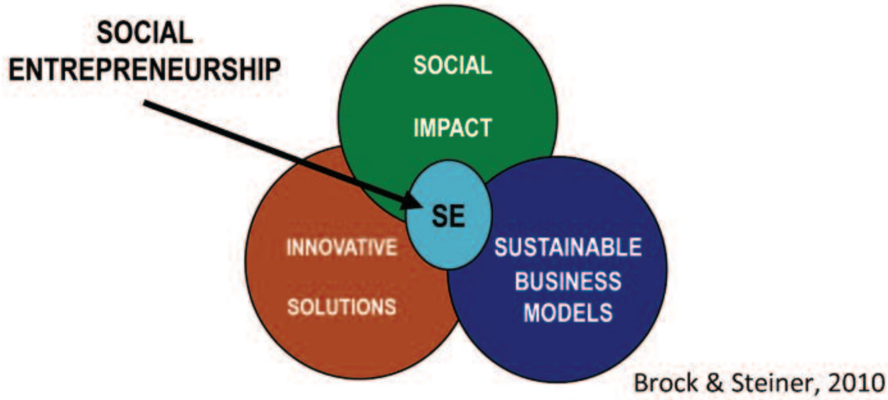


FIGURE 4.1: SOCIAL ENTREPRENEURSHIP MODEL

Social Impact

Social entrepreneurs, humanitarian engineers, and non-governmental organizations (NGOs) have the same goal: solving social problems. Providing positive social impact that addresses community needs is at the heart of social entrepreneurship. This social aim is central and explicit, guided by the organization's mission statement[6,7]. As part of this perspective, social entrepreneurs assess and/or demonstrate their effectiveness based on the triple bottom line: Profit, People, and Planet. The triple bottom line takes into consideration not only the economic impact of decisions that companies make, but also the impact to the environment as well as to the people affected[8].

In addition, social entrepreneurs reject the charity or philanthropy model. Instead, the empowerment model is embedded in how goods and services are created, paid for, and distributed. As a result, social entrepreneurs often develop financially sustainable and mutually beneficial solutions to social problems through partnership with the beneficiaries[9,10,11].

An ideal model of the many aspects of social impact is Barefoot College. Barefoot College was built around the concept of the village as a self-reliant unit. It was founded in 1972 by Bunker Roy and a group of India's top university students who saw the needs of India's jobless rural youth. Barefoot College trains India's poor to become "barefoot" doctors, teachers, engineers, and other technology driven experts so that they can, in turn, create a better living environment for others. For example, this organization has trained over 460 "barefoot" solar engineers, primarily illiterate women, who come from remote villages around the world. During six months of training, they learn how to install and maintain solar technology for rural electrification programs. To date, these solar engineers have built and maintained systems that provide solar electricity to over twelve thousand households in India as well as six thousand households in seventeen countries in Africa, Asia, and South America. Barefoot College graduates not only enhance the quality of life of their communities, but also their own quality of life by earning a living wage, not the lower average market wage[12].

Another example of social impact is Ciudad Saludable ("healthy city"), which was founded in 2001 by Peruvian engineering student Albina Ruiz to address the environmental and human problems caused by uncollected garbage in Peru. The government-run service had been unable to collect the fees needed to maintain the system's infrastructure due in large part to customer dissatisfaction with the system's poor performance. Ruiz broke this negative cycle by developing local citizens into successful "micro-entrepreneurs" who now provide private garbage collection to replace the ineffective government-run service. Ciudad Saludable not only provides a solution to the health and environmental problems caused by the uncollected waste, but it also provides self-employment opportunities to local residents in areas with high levels of unemployment. The thirteen micro-enterprises created by Ciudad Saludable permanently employ over 150 people and benefit over three million inhabitants in Peru[13]. In addition, some of Ciudad Saludable's micro-entrepreneurs have gone on to build other profitable businesses producing organic fertilizer from the waste collected. Ruiz's work has been so successful that she has trained over 120 municipal authorities in recycling techniques and provided jobs for 3,000 recyclers in Peru and Bolivia[14].

Innovative Solutions

Innovation is at the soul of entrepreneurship, and fostering innovation in social entrepreneurship is no different[15,16,17,18]. Schumpeter's seminal work contributed to the field by explicating how the entrepreneur innovates and uses "creative destruction" for economic growth[19]. In a similar vein, social entrepreneurs create "large scale change through pattern breaking ideas"[20]. As Bill Drayton, founder and CEO of Ashoka, the largest supporter of social entrepreneurs in the world noted, "Social entrepreneurs are not content just to give a fish or teach how to fish. They will not rest until they have revolutionized the fishing industry"[21]. Innovations can come in a variety of forms – not just in terms of technologies that create new products and services, but in terms of the ways that the organization operates and delivers value to its constituencies.

Figure 4.2 KickStart Water Pump

One innovation success story is KickStart (formally Approtec), which was launched in 1991 with the sole mission to create appropriate technologies to end poverty in sub-Saharan Africa. The technologies used include a sunflower seed smasher to create cooking oil, a brick making machine and an irrigation pump that runs on human power. The pump, its most successful technology to date, doubles the yield of a farmer's crop and sells for as little as $78. The efforts of the social entrepreneurs who founded KickStart, Martin Fisher and Nick Moon, have resulted in 95,000 successful new businesses in Africa, which have lifted more than 473,000 people out of poverty[22]. In Kenya alone, KickStart has generated revenues equivalent to 0.6% of this country's GDP[23].

Another example of the successful use of innovation is GlobalResolve, founded in 2006 by Arizona State University Polytechnic professors Mark Henderson, Brad Rogers, David Jacobson and Rajiv Sinha. It mission is to build sustainable business ventures in the villages of developing countries that address the problems faced by the people of these villages. In a 2008 project, GlobalResolve developed a clean-burning stove fueled by corn that not only prevents the respiratory health and pollution issues associated with previously used wood and charcoal stoves, but also provides the residents of rural African villages with the opportunity to manufacture and sell both the stoves and the corn-based fuel to surrounding villages[24].

Sustainable Business Model

Even the most socially redeeming and potentially profitable innovative concept or product may not lead to successful adoption and a sustainable organizational venture. It is critical that all the elements of the product or service launch as well as its on-going operations be thought through in a coherent, integrated fashion. An effective business model, which presents the logic of the organization and the ways it creates value for its stakeholders, is therefore key to a venture's success[25].

Social entrepreneurs strive to create sustainable business models that avoid reliance on grants and donations to survive[26,27]. Many also see business models as opportunities to create new markets to serve the "bottom of the pyramid" – viz., poorest socio-economic groups[28,29,30]. In addition, new technologies and innovations often require the foresight and discipline that a well-articulated business model provides in order to achieve successful results[31]. Moreover, a formal, documented business model acts as a blueprint, which enhances the ability of a social enterprise's operations to be successfully expanded and replicated[32].

For example, Kiva.org was built on the microfinance model advanced by Nobel Prize winner Mohammad Yunus, founder of Grameen Bank. Microfinance entails providing very small, non-collateralized business loans to those in poverty to start or expand very small businesses. The goal of microfinance is to spur self-sufficiency through self-employment. Stanford graduates Matt Flannery and Premal Shah took the model to the next level by utilizing the Internet to facilitate person-to-person microfinancing. Specifically, Kiva fosters the matching of entrepreneurs in developing economies with individual lenders across the globe. These lenders may lend as little as $25 (and would then be grouped with other lenders interested in the same project). According to Kiva.org, a loan is made about every 30 seconds, the average loan amount is approximately $400, it takes less than one week to fund a loan, and approximately 98% of all loans are repaid. As of May 2010, over 350,000 entrepreneurs among the poorest of the poor have been helped through small loans totaling over $139 million dollars[33]. Although it is not a high tech company in the traditional sense, Kiva exists solely because of advances in information technology and the Internet, and it continues to expand accordingly.

Another example of the power of a business model is Aravind Eye Hospital, which was launched by Dr. G. Venkataswamy to provide cataract surgeries to the poor in India to avoid needless blindness. His business model was "to mass-market cataract surgery the way hamburgers and pizzas are marketed by McDonald's and Pizza Hut"[34]. Innovative process efficiencies, such as using webcams to evaluate potential patients in remote villages, the use of state-of-the-art equipment and assembly-line processes in the operating room, and the self-manufacture of all materials needed for eye care and surgery, allow the organization to see more than 2.5 million patients and conduct an average of 300,000 surgeries per year while providing first rate eye care services at affordable costs. Poor patients (currently 70% of all patients) do not have to pay for their procedures. System efficiencies allow the fees from the paying minority of patients to be able to support the cost of free medical care for those who cannot pay[35].

Social Entrepreneurship and Engineering Education

Social entrepreneurship is a nascent area in formal engineering education. There are a small but growing number of universities across the world creating social entrepreneurship courses and programs tailored to engineering students.

For example, the Department of Social Engineering at the Tokyo Institute of Technology recently began offering a graduate program in Social Entrepreneurship. Its stated goal is to "train future Social Entrepreneurs who will be able to solve various social problems by creating sustainable and innovative systems with new ideas, thus making the world a better place"[36]. Stanford University formed the Department of Management Science and Engineering with the goal of applying engineering analysis to social problems while also producing graduates with the skills needed to become business leaders. The Humanitarian Engineering and Social Entrepreneurship program at Penn State seeks "the convergence of the tripartite university missions of teaching, research and outreach to educate globally-engaged social problem solvers and create sustainable value for developing communities, while generating and disseminating knowledge and lessons learned"[37]. In addition to courses and honor thesis opportunities, this program offers an Engineering and Community Engagement Certificate.

Teaching students how to create social entrepreneurial ventures is not always part of a degree program. One of the more popular co-curricular activities is business plan competitions. There are over two dozen student competitions in social entrepreneurship across the globe[38]. A small number of competitions, such as the National Idea to Product (I2P) Competition for Social Entrepreneurship, accept only technology-focused projects. Most competitions are similar to the Global Social Entrepreneurship Competition (GSEC) hosted by the University of Washington; they are open to students university-wide. Since GSEC's inception, over 300 students from more than 25 countries have participated in the competition. GSEC fosters interdisciplinary collaboration across academic institutions and fields of study (e.g., business, engineering, health sciences, international studies, law and public administration).

There are also highly competitive social entrepreneurship internships and fellowships. For example, the Global Center for Social Entrepreneurship, which was established in the School of International Studies at the University of the Pacific, offers all its students internships with frontline social entrepreneurship organizations domestically and internationally as well as incubator apprenticeships. Engineers for Social Impact (E4SI) is a fellowship program that provides top engineering students with the opportunity to work with "social enterprises driving market-based solutions to development in India. It serves a dual need: matching talented Indian students with worthy social enterprises and increasing awareness of for-profit approaches to development"[39].

Student-run organizations that promote social entrepreneurship education and projects are gaining prominence on college campuses. Engineers without Borders (EWB) and Engineers for a Sustainable World (ESW), which were mentioned earlier, are two social mission organizations designed specifically for engineers that have student chapters at 64 colleges and universities. Students in these organizations not only are exposed to the concept of social entrepreneurship in symposia and conferences, but typically undertake community projects. There are also college initiatives, such as the Massachusetts Institute of Technology (MIT) Sloane Entrepreneurs for International Development (SEID). This student-run organization "seeks to drive sustainable global development through entrepreneurship, by fostering productive collaborations between students and new ventures in emerging markets and by raising awareness of current challenges and success models"[40].

These co-curricular activities not only expose engineering students to social entrepreneurship, but they have led to viable social enterprises. For example, Husk Power Systems (HPS), which was founded by three

University of Virginia students — Manoj Sinha Charles Ransler, and Gyanesh Pandey — has grown exponential since its inception in 2008. The students' business model was to generate reliable power to the rural areas of Bihar, India's poorest state, by designing, building and operation off-grid 35-100 kW mini-power plants that convert rice husks, the renewable waste product of rice milling, into electricity. These students received $50,000 in seed money for their venture after winning the Dell Social Innovation Competition hosted by the University of Texas. As of May 2010, HPS provides power to more than 100,000 people in over 90 rural Indian villages in India's indigent "Rice Belt." HPS also adds to the triple bottom line by employing local residents and by selling silica, the by-product when rice husks are burned, to concrete manufacturers[41,42].

Implications

Engineers are naturally skilled at innovation. This quality, combined with the fact that engineering curricula typically provide all the necessary technical skills, means that engineers will generally be well prepared for addressing the innovation aspects of our Social Entrepreneurship Model. Unfortunately, they are much less adept at the critical business aspects of the model. Employers believe that non-engineering competencies, such as economics and management, are not adequately covered in engineering education[43]. Research suggests that engineering education would be enhanced by the addition of courses in accounting, finance, marketing, organizational behavior, commercialization of technology, and strategy[44]. The typical engineering curriculum is focused on mathematics and sciences, with as much as fifty percent of the courses in the field of engineering. Even if a student wished to take elective course work beyond general baccalaureate requirements, most engineering curricula leave no time to do so. Furthermore, interdisciplinary degrees are not valued by most universities[45].

What happens when engineers take academic courses in entrepreneurship or social entrepreneurship? Studies have found a significant positive relationship between entrepreneurship education and the tendency to start new business ventures. Social entrepreneurship programs are a source of "trigger-events" that ultimately raise the students' entrepreneurial attitudes and intentions[46]. One study found that 40% of engineering students who receive education in entrepreneurship eventually start their own businesses[47]. Other research has concluded that entrepreneurship education can have tangible outcomes and that "entrepreneurship is not about who the entrepreneur is but what the entrepreneur does"[48].

What should this mean for educators? First, we should make the resources that we already have more readily available to engineering students. Courses in the necessary business and entrepreneurship topics currently are being taught in business schools, so we should encourage synergies between engineering and business students in the same classroom as well as have engineering and business faculty co-teach courses. Research has found that while both groups had high creative potential, they have divergent creative styles[49]. Engineering students tend to channel their creativity toward practical, incremental problem solving, whereas business students tend to focus on the radically new and are generally more market-oriented. Hence, a shared learning experience will benefit both engineering and business students through the blending of their respective strengths and the opportunity to learn from one another by seeing things from a different perspective.

Second, we should make it easier for engineering students to learn about and enroll in social entrepreneurship courses. The courses should be cross-referenced with engineering course numbers and listed in engineering course offerings. Prerequisites should be appropriately set so that engineering students are not prohibited from taking them due to their lack of other business coursework. Because the typical engineering curricula is already very full, we should also consider ways to merge business and entrepreneurship courses into engineering programs as substitutes for other courses. Another option would be to advocate multi-disciplinary degrees in business and engineering so that engineering students add the appropriate business courses to their academic schedule from the start.

Third, we should find ways to introduce the concept of social entrepreneurship into courses throughout the engineering curriculum where appropriate, rather than continue to offer it as a "stand alone" course[50]. In this way, engineering students will be more apt to consider social entrepreneurship as a routine engineering endeavor as well as be more apt to see its application in numerous situations.

Finally, we should continue to expand the availability of hands-on social entrepreneurship learning opportunities for engineers through internships and/or projects, with emphasis on cross-functional team experiences with business students. Engineers tend to learn more easily by doing. Similarly, much entrepreneurship knowledge is difficult to teach in the traditional classroom and is best served by experiential learning[51,52]. By sharing resources with organizations such as Teach a Man to Fish, Engineers without Borders (EWB), National Collegiate Inventors and Innovators Alliance (NCIIA), and Engineers for Social Impact (E4SI), we can ensure that our Generation G students have access not only to opportunities for hands-on learning, but also to the tools and resources needed to achieve sustainable social impact.

Conclusion

Social entrepreneurship differs from other social and organizational efforts because it uses technology and innovation to address societal challenges by creating long term, self-sufficient business enterprises. In this regard, social entrepreneurship is the only truly "sustainable" model of humanitarianism in place today, combining the best elements of a business perspective and humanitarian engineering. Engineers, equipped with this added knowledge, can have an even greater ability to develop and implement lasting solutions to the world's most intractable social problems than they have today.

REFERENCES

[1] *trendwatching.com,* "Generation G," February 2009, http:/trendwatching.com/trends/generationg/ (accessed May 4, 2010).

[2] Johanna Mair, Ignasi Martí, "Social Entrepreneurship Research: A Source of Explanation, Prediction and Delight," *Journal of World Business* 41, no. 1 (2006), 36-44.

[3] Shaker A. Zahra, Eric Gedajlovic, Donald O. Neubaum, Joel M. Shulman, "A Typology of Social Entrepreneurs: Motives, Search Processes and Ethical Challenges," *Journal of Business Venturing* 24, no. 5 (2009), 519-532.

[4] Debbi D. Brock, Susan D. Steiner, "The Social Entrepreneurship Model: Building Sustainable Innovations to Achieve Social Impact," (paper, presented at *Third Research Colloquium in Social Entrepreneurship,* Skoll Centre, Oxford University, June 22, 2010).

[5] Debbi D. Brock, Susan D. Steiner, "Social Entrepreneurship Education: Is It Achieving the Desired Aims?" 2008 USASBE Proceedings, (San Antonio, TX: US Association for Small Business and Entrepreneurship, January 2008), 1133-1152.

[6] Gregory J. Dees, *The Meaning of Social Entrepreneurship,* Stanford University: Kauffman Center for Entrepreneurial Leadership, www.caseatduke.org/documents/dees_sedef.pdf (accessed May 31, 2010).

[7] Sutia Kim Alter, "Social Enterprise Models and their Mission and Money Relationships," in *Social Entrepreneurship: New Models of Sustainable Social Change,* ed. Alex Nicholls (Oxford University Press, 2006), 205-232.

[8] John Elkington, "Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development," *California Management Review* 36, no. 2 (1994), 90–100.

[9] Sharon H. Alvord, David L. Brown Christine Letts, "Social Entrepreneurship and Societal Transformation," *Journal of Applied Behavioral* Science 40, no. 3, (2004), 260–282.

[10] Helen Haugh, "Community-Led Social Venture Creation," *Entrepreneurship: Theory and Practice* 31 no. 2 (2007), 161–182.

[11] Ana Maria Peredo, James J. Chrisman, "Toward a Theory of Community-Based Enterprise," *Academy of Management Review* 31, no. 2 (2006), 309–328.

[12] Roy Bunker, "Empowering the Rural Poor to Develop Themselves: The Barefoot Approach, *Innovations: Technology, Governance, Globalization* 3, no. 2 (2008), 67-93.

[13] PBS, *The New Heroes: Albina Ruiz,* www.pbs.org/opb/thenewheroes/meet/ruiz.html (accessed May 20, 2010).

[14] Skoll Foundation, www.skollfoundation.org/grantees/a-e.asp (accessed May 24, 2010).

[15] James Austin, Howard Stephenson, Jane Wei-Skillen, J. (2006), "Social and Commercial Entrepreneurship: Same, Different, or Both?" *Entrepreneurship: Theory and Practice* 30, no. 1 (2006), 1-22.

[16] Alvord, Brown and Letts, *"Social Entrepreneurship and Societal Transformation,"* 260–282.
[17] Gregory J. Dees, *The Meaning of Social Entrepreneurship.*
[18] Roger L. Martin, Sally Osberg, "Social Entrepreneurship: The Case for Definition," *Stanford Social Innovation Review* 5, no. 2 (2007), 28-39.
[19] Joseph Schumpeter, *Capitalism, Socialism, and Democracy,* (New York, NY: Harper & Row, 1942).
[20] Paul C. Light, *The Search for Social Entrepreneurship,* (Washington, D.C. Brookings Institution Press, 2008).
[21] Drayton, William, "Everyone a Changemaker: Social Entrepreneurship's Ultimate Goal," *Innovations: Technology, Governance, Globalization* 1, no. 1 (2006), 80-96.
[22] Kickstart, www.kickstart.org, (accessed on May 24, 2010).
[23] New Profit Inc., *About Kickstart.* www.newprofit.com/cgi-bin/iowa/do/invest/ 15.html (accessed on May 24, 2010).
[24] W.P. Carey School of Business, Arizona State University, "Social Entrepreneurs Develop Cleaner Alternative to African Wood-Burning Stoves" *Knowledge@W.P. Carey,* July 16, 2008, http://knowledge.wpcarey.asu.edu/ article.cfm?articleid=1627 (accessed on May 28, 2010).
[25] Ramon Casadesus-Masanell, Joan Enric Ricart. "From Strategy to Business Models and onto Tactics," *Long Range Planning* 43, no. 2-3 (2010), 195-215.
[26] Nicolas M. Dahan, Jonathan P. Doh, Jennifer Oetzel, Michael Yaziji, "Corporate-NGO Collaboration: Co-creating New Business Models for Developing Markets," *Long Range Planning* 43, no. 2-3 (2010), 326-342.
[27] James D. Thompson, Ian C. MacMillan, "Business Models: Creating New Markets and Societal Wealth," *Long Range Planning* 43, no. 2-3 (2010), 291-307.
[28] C. K. Prahalad, *The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits,* (Philadelphia, PA: Wharton School Publishing, 2004).
[29] James D. Thompson, Ian C. MacMillan, "Business Models: Creating New Markets and Societal Wealth," *Long Range Planning* 43, no. 2-3 (2010), 291-307.
[30] Charles Wankel (ed.), *Alleviating Poverty through Business Strategy,* (New York, NY: Palgrave Macmillan, 2008).
[31] Henry Chesbrough, Richard S. Rosenbloom, "The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-Off Companies," *Industrial and Corporate Change* 11, no.3 (2002), 529-555.
[32] Debbi D. Brock, Susan D. Steiner, "Scalability: A Critical Yet Ignored Element in Social Entrepreneurship Preparation. (paper presented at the Second Research Colloquium on Social Entrepreneurship. Raleigh-Durham, NC, June 26, 2009).
[33] Kiva, www.kiva.org/ (accessed May 30, 2010).
[34] G. Sankaranarayanan – Chennai, "The Man and Vision Behind Aravind Eye Hospital," *Express Healthcare Management,* September 1-15, 2003.

[35] Aravind Eye Care System, www.aravind.org, (accessed on May 25, 2010).
[36] Tokyo Institute of Technology, Dept of Social Engineering, Social Entrepreneurship Program, www.soc.titech.ac.jp/major/npm_new/npm_e_080116.htm (accessed May 20, 2010).
[37] Pennsylvania State, Humanitarian Engineering and Social Entrepreneurship, www.engr.psu.edu/hese (accessed May 20, 2010).
[38] Debbi D. Brock, Ashoka's Global Academy for Social Entrepreneurship, Social *Entrepreneurship Teaching Resources Handbook.,* March 2008, www.universitynetwork.org/handbook, (accessed February 12, 2010).
[39] Engineers for Social Impact (E4SI), www.e4si.org/portal/fellowship (accessed May 20, 2010).
[40] Massachusetts Institute of Technology, Student Entrepreneurs for International Development (SEID), http://mit.edu/org/s/seid (accessed May 20, 2010
[41] Andrew C. Revkin, "Husk Power for India," *New York Times,* December 24, 2008.
[42] Husk Power Systems, www.facebook.com/home.php?#!/pages/Husk-Power-Systems/34694426057 (accessed on May 30, 2010).
[43] Monica Edwards, Luis M. Sanchez-Ruiz, Edmundo Tovar-Caro, Enrigue Ballester-Sarrias, "Engineering Students' Perceptions of Innovation and Entrepreneurship Competences," (paper, presented at 39th ASEE/IEEE Frontiers in Education Conference, San Antonio, TX, October 19, 2009).
[44] Andres C. Salazar, "Supplementing Engineering Education with Business Training," in *Proceedings of Teaching Entrepreneurship to Engineering Students Conference,* edited by Eleanor Baum and Carl McHargue (Monterrey, CA: Engineering Conferences International Symposium Series, January 2003), 237-241.
[45] Salazar, "Supplementing Engineering Education with Business Training," 237-241.
[46] Souitaris, Stefania Zerbinati, Andreas Al-Laham "Do Entrepreneurship Programmes Raise Entrepreneurial Intention of Science and Engineering Students? The Effect of Learning, Inspiration and Resources." *Journal of Business Venturing* 22, no. 4 (2007), 566-591.
[47] Teresa V. Menzies, *Entrepreneurship and the Canadian Universities: A Report of a National Study of Entrepreneurship Education* (St. Catharines, Ontario, Canada: Brock University, 2004).
[48] Dawn R. DeTienne, Gaylen N. Chandler, "Opportunity Identification and Its Role in the Entrepreneurial Classroom: A Pedagogical Approach and Empirical Test" *Academy of Management Learning and Education* 3, no. 3 (2004), 254.
[49] Henrik Berglund, Karl Wennberg, "Creativity Among Entrepreneurship Students: Comparing Engineering and Business Education," *International Journal of Continuing Engineering Education and Lifelong Learning (IJCEEL)* 16, no. 5 (2006), 366-379.

[50] Paul Tracey, Nelson Phillips, "The Distinctive Challenge of Educating Social Entrepreneurs: A Postscript and Rejoinder to the Special Issue on Entrepreneurship Education," *Academy of Management Learning & Education* 6, no. 2 (2007), 264-271.

[51] Tracey and Phillips, *"The Distinctive Challenge of Educating Social Entrepreneurs,"* 264-271.

[52] Magnus Aronsson,, "Education Matters – But Does Entrepreneurship Education? An Interview with David Birch." *Academy of Management Learning & Education* 3, no. 3 (2004), 289-292.

Instead of attempting to re-engineer products originally designed for wealthier markets, Frugal Engineering targets development of products that begin with the BOP population as the primary target customer. BOP customers have unique needs that must drive the product innovation process.

"You see things, and you say: 'Why?'
But I dream things that never were,
and I say 'Why not?'"

— George Bernard Shaw

CHAPTER 5
Frugal Innovation

Dan O'Neill
ASU Polytechnic, Arizona State University

John Takamura, PhD
Arizona State University

Nalini Chhetri, PhD
Arizona State University

Mark Henderson, PhD
ASU Polytechnic

Bradley Rogers, PhD
ASU Polytechnic

Introduction

Frugal Engineering is a concept that has emerged in the last few years to describe how the product/service (hereafter, product) development process must be completely rethought and rebuilt in order to design, develop and deliver innovative solutions to customers at the Base-of-the-Pyramid (BOP)[1]. Instead of attempting to re-engineer products originally designed for wealthier markets, Frugal Engineering targets development of products that begin with the BOP population as the primary target customer. BOP customers have unique needs that must drive the product innovation process.

Frugal Engineering can be thought of as engineering under constraints dictated by these needs, not the least of which is "extreme affordability," the requirement that products be affordable for customers earning a dollar or two a day. Product purchases must also occur within the cash flows of those customers, who typically have seasonal, uneven cash flows, but who are also willing to save for purchases and/or finance them through various forms of microfinance.

Add to extreme affordability the fact that BOP products often have to operate in extreme conditions with little maintenance, waste or inefficiency, and must be serviceable in a manner that is as equally affordable as the original price. Meanwhile, product developers have realized that BOP customers have the same expectations of quality and desirability that customers have in all markets.

In sum, engineers must design and build high quality, feature-appropriate technologies and products that are affordable, require low maintenance, reduce waste and inefficiency, are designed with the socio-ecological context of the customer in mind, and can be purchased by the customer within the context of their income and cash flow situation. These constraints lead to a complete rethinking of the engineering processes used to develop BOP products. This may result in a rethinking of design processes for the developed world as well.

Instead of features being engineered out of products originally targeted at higher priced markets, Frugal Engineering begins with a clean sheet and targets high quality, durable, affordable products with just the right need-feature-benefit configuration required by the BOP customer. Products must generate a significant return for the customer. For instance, they need to reduce labor and land requirements in agricultural economies. Because they are low price and low margin, products must employ few assets, which, paradoxically, can result in a high return on equity for the investor[2].

The result is a requirement that engineers developing BOP products have a deep understanding of the unique requirements of the BOP customer, and that they work to an engineering process that is qualitatively different than that employed for developing most products today. In practice, this means that product development teams must evolve and embrace interdisciplinary team structures that include members who are expert in the needs of people living at the BOP, working side-by-side with engineers, manufacturers, designers and business members schooled in ways of doing business in specific cultural settings.

Frugal Innovation

At GlobalResolve we are codifying such a process of product development so that we can teach to and learn with students from a wide variety of disciplines. GlobalResolve is a unit at the College of Technology Innovation on the Arizona State University Polytechnic campus. It is a social entrepreneurship concentration in the Technology Entrepreneurship and Management program. GlobalResolve develops products and services for BOP consumers by engaging students in a variety of experiential, problem-based engineering and social entrepreneurship courses, in which faculty and students collaborate with BOP customers and partner universities, NGOs and governments in Africa, Asia and Latin America, as well as poor communities in the U.S.

In developing the GlobalResolve Methodology, we realized that Frugal Engineering was not quite the right paradigm to use. GlobalResolve faculty who have participated in the development and delivery of the curricula have come from a variety of disciplines, including International Development, Global Studies, Science-Technology Policy, Sustainability, Anthropology, Design, Engineering and Business. Like many of our cohorts around the nation who are building similar humanitarian engineering and social entrepreneurship programs, we have come to recognize the intensely multi- or trans-disciplinary nature of the BOP product development process and have developed our methodology with that nature in mind.

The process is more aptly called Frugal Innovation, a term that has emerged even more recently than Frugal Engineering[3]. Frugal Innovation is a more comprehensive term embracing all those disciplines that must be brought to the table to build future products. Frugal Innovation must not only help lift billions out of poverty, but must aid in the "sustainability transition" preserving our life support systems along the way. This is nothing less than innovating innovation. We are one of many groups around the world re-imagining the process by which we think about building future products.

One way to explore the new thinking process of Frugal Innovation is to consider the many topics to which it is closely related.

Strong Sustainability

Frugal Innovation can be seen as an implementation of Strong Sustainability[4]. One definition of frugality is "characterized by or reflecting economy in the use of resources." Frugality is conservation oriented, which is precisely what sustainability addresses: saving something for future generations. Sustainability is a broad concept with many definitions and interpretations. The most common is the Brundtland definition: "development that meets the needs of the present without compromising the ability of future generations to meet theirs"[5]. A perhaps more useful concept is that of a sustainability transition in which poverty, hunger and disease are systematically reduced, while preserving the life support processes of the planet[6].

In any case, sustainability has been interpreted in many ways. Sustainability raises the question(s) "sustain what for whom for how long to what end?" Among other things sustainability suggests the Precautionary Principle, which might translate to "if you don't understand the unintended consequences of your action, don't take it." Sustainability calls for mindful action, in which a wide range of consequences is thoroughly considered. Understanding unintended consequences in engineering has always been critical, important and difficult. It is more so with sustainability added as a design constraint.

One perspective of sustainability is the "capitals" perspective. While there are a variety of capital taxonomies, capital stocks typically include natural, human, social, cultural, physical and financial capital. From a capitals perspective, there are different approaches to sustainability. Weak sustainability suggests that we can trade one capital stock for another, as long as overall capital stocks are preserved, thus, ensuring that overall standards of living and human well-being are maintained. For instance, we can turn natural capital into financial capital, and use that financial capital in new ways to meet our future needs.

Strong sustainability takes the position that specific capital stocks are not substitutable. For instance, once a species is lost it can never really be replaced. Or, when we run out of a mineral resource, it is gone forever. While certainly debatable, Frugal Innovation seems oriented towards conservation. Frugal Innovation might embrace the Precautionary Principle as an element of the innovation process, and seek to preserve critical capital stocks. Doing so requires recognition that sustainability is about maintaining the "web of life," which by definition requires a systems approach in which the details of engineering and innovation processes are viewed in terms of their broader impact. That is, the system is King.

Systems Thinking

Frugal Innovation is a systems thinking approach to addressing the challenges of poverty, disease, gender issues and environmental degradation faced by BOP populations and captured in the Millennium Development Goals adopted by the United Nations. Addressing these challenges is not "merely" a matter of finding innovative ways to lift billions out of poverty, though that is the first and foremost goal. We assume as people emerge from poverty that many of the ills of the world will be addressed. More broadly, this approach allows us to rethink problems of the BOP population in the overall context of the world they inhabit, including addressing the socio-ecological processes that link these challenges that are unique to them.

The world must achieve the daunting goal of poverty alleviation in a manner that is environmentally, socially and culturally sustainable. The emerging discipline of sustainability refers to these types of challenges as "wicked problems" that have no easy solution[7]. The demand placed on the Frugal Engineer, or more appropriately, the Frugal Innovation Team (FIT), is one of systems thinking, embedded within the framework of Sustainability Science and Studies. The demands of sustainability require that the FIT approaches problems from a "system of interest" perspective. Innovation must occur within a given socio-ecological system, generally understood to be a complex adaptive system[8,9,10]. At GlobalResolve we call these CASES, for Complex Adaptive Socio-Ecological Systems.

This means that the FIT must be introduced to and employ some cocktail of concepts, disciplines, methodologies, methods, tools and techniques that addresses systems thinking, systems dynamics, complexity, complex adaptive systems, and systems engineering. The issues include being able to understand the research being produced by various sustainability disciplines, model the CASES of interest, and use those new understandings and models in the innovation-entrepreneurship processes that the FIT commands.

Because of the complexity of BOP challenges, Frugal Innovation is by its very nature a highly multi- or trans-disciplinary approach. Product development is set within a CASES context. It requires a wide variety of knowledge, skills and, thus, disciplines, to address such problems in a "people, planet and profit" triple-bottom line manner. A critical part of the process is thinking about impacts and trade-offs. Engineering is fundamentally a process of designing to trade-offs. Along with anticipating unintended consequences, Frugal Innovation takes trade-off thinking to a systems level.

System Innovation

Thus, Frugal Innovation requires System Innovation. Our focus as product developers is usually to perceive the product in relationship to the customer. However, in order to build products that are more broadly sustainable, we must learn to innovate at the system level. We must consider the customer-product in relationship to the whole system. This has been seen and experienced in engineering service learning projects for many years. We might resolve a water problem, while creating the unintended consequence of an energy issue, or perhaps even worse, a serious cultural problem.

In this way, Frugal Innovation is the next generation of Systems Engineering (SE) that takes into account the impacts of innovation on the ground that is nested within the concept of diverse needs of a global population. SE has come and gone as a discipline taught in engineering schools in the U.S. For the last several years, disciplinary silos have dominated the landscape in schools of engineering. A few truly outstanding SE programs exist. Even these often consider multi-disciplinary teams to be comprised only of engineers from a variety of engineering disciplines. But, more and more programs are combining the skills of design, engineering and business, the cumulative effect of which will lead to a higher likelihood of sustainability. Because of the trans-disciplinary nature of innovation at the BOP, Frugal Innovation must take this process to the next level by embracing specialists from even more disciplines that are not normally part of the product development/business cycle.

We've seen a number of "stealth mode" programs in universities around the nation begin to include team members from other disciplines, such as anthropologists, ecologists, biologists, health professionals, technical writers and humanists of a variety of stripes. Many of these programs are being developed in response to the complexity of BOP innovations. Crazy faculty go beyond job requirements to transform service learning projects into humanitarian engineering/social entrepreneurship ventures by acting as CEO's of start-up companies. They coordinate the activities of many faculty and students in multiple courses over multiple years, while simultaneously employing university-based technology transfer and venture acceleration processes. In many ways, these ventures represent the most sophisticated systems engineering education being done in universities today. These programs need to be codified and supported by engineering schools. To do so requires a next generation of innovation process thinking.

Innovation System

Frugal Innovation is an Innovation System. There are many approaches to systems engineering. Frugal Innovation must take the best of these approaches and add elements of international development, sustainability sciences, design and business to the innovation process. The GlobalResolve Methodology, referred to earlier, (Figure 1) is our attempt to do just that. Each of the large circles represents a major process while the small circles and bullet lists represent the system component processes and areas of expertise. As a team, we realized that BOP product development within a sustainability system innovation context required a highly systematic, though flexible, approach. We are attempting to take the best of our multi-disciplinary experiences and combine them in a repeatable, systematic, iterative process for BOP product development. While the Innovation System must incorporate many disciplines, design, engineering and business remain as core competencies.

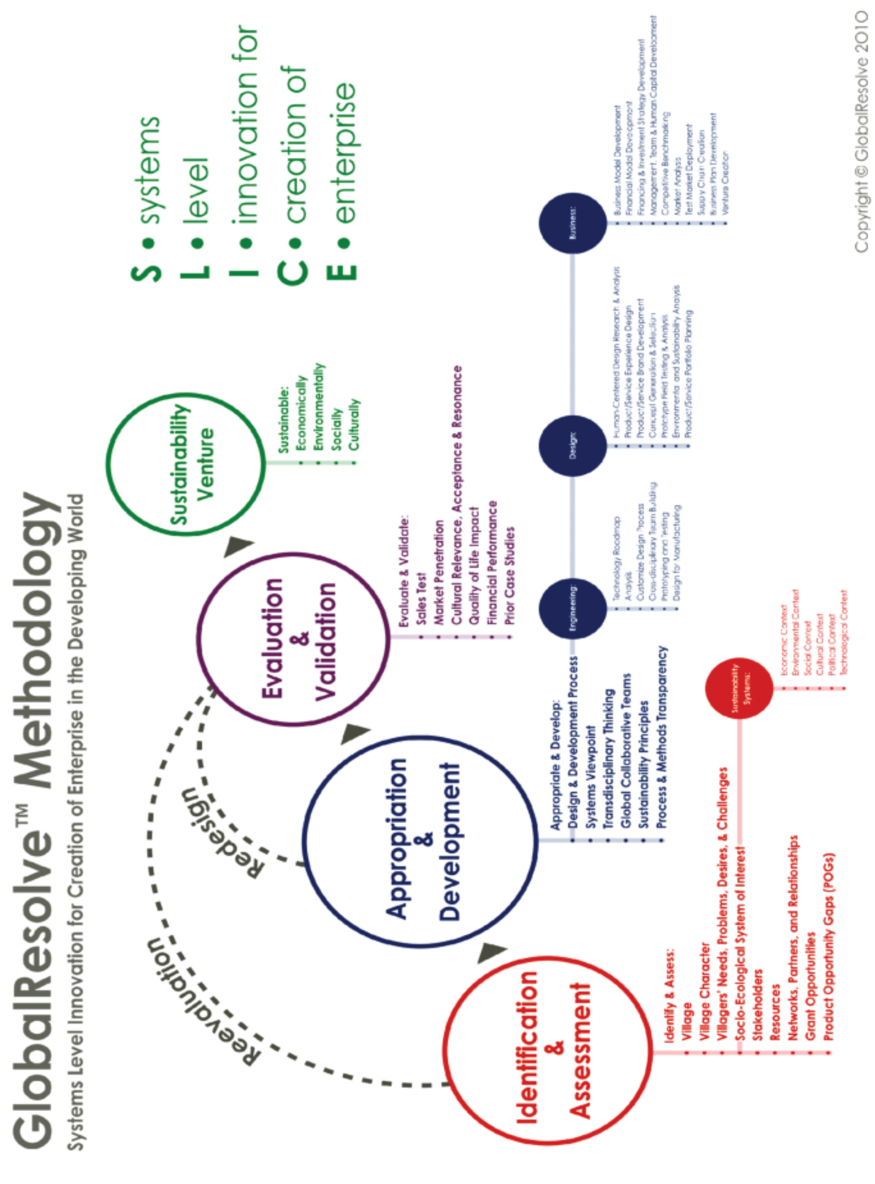


FIGURE 5.1 THE GLOBALRESOLVE METHODOLOGY

Design Innovation

Frugal Innovation is Frugal Design, which takes User-Centered Design as a basic principle, but extends it to Systems-Centered Design that takes into account the needs of the Earth, as much as the needs of the customer. This requires Design Innovation. State-of-the-art design for the BOP requires a rethinking on 'design thinking.' In order to design products with true value for the BOP, innovators need to understand the importance of community collaboration and must embrace this fundamental approach to product development. The transition from User-Centered design to Human-Centered design to Earth-Centered will also require another transition to Culture-Centered design, whereby special emphasis on the cultural integration of artifacts (devices), technologies (both existing and emerging), and their interaction in terms of cultural practices will be the focus of systematic problem solving. 'Radical changes' or innovation in the way products and services are designed, priced and delivered to the BOP must be done in order for success[11].

At its best, the new design process is characterized by co-creative collaboration with communities not just as consumers or users of products, but also as the producers and manufacturers of them[12].

Frugal Engineering

Frugal Innovation includes that with which we began: Frugal Engineering. Engineering is solving technological problems under constraints, so adding a "frugality" constraint makes sense and, in fact, creates products that fit the BOP challenge set. The term Concurrent Engineering (CE), which was popular during the 1990s, consisted of a multi-disciplinary team working together to solve engineering problems. Frugal Engineering is the modern-day version of CE applied to BOP problems and including all of the disciplines listed in Figure 1. Just as Design Innovation includes cultural integration, Frugal Engineering adds technology and the very important consideration of unintended consequences that appear because of cultural, economic and physical changes resulting from introducing new products into BOP communities. Unintended consequences are best mitigated through disciplinary diversity.

As an example, consider a project GlobalResolve that undertook to introduce smokeless cooking fuel to communities in Ghana. This case study is discussed further later in the paper. Engineering experts handled the design, fabrication and assembly of the ethanol still and the stoves, but two unanticipated and unintended consequences emphasized the necessity of a diverse team. First, with the removal smoke, mosquitoes and other insects return to the kitchen and there is a risk of increased malaria. Second, because the women buy cooking fuel, they no longer have to spend hours a day collecting wood. However, in some communities that collecting time was spent by groups of women hunting for wood together means social time as well. They spend this time to discuss personal and family issues, solve community problems and, in general, support each other. It was obvious after recognizing these consequences resulting from making a new fuel available, that experts are now required in medicine, etymology and culture.

Value Network Assembly for Impact at Scale

From a business perspective, Frugal Innovation is about engaging BOP populations as consumers and suppliers in new value adding businesses that can achieve impact at scale. Polack[11] famously suggests to work only on innovations that will affect at least a million people. While we don't believe that literally, since many great engineering service learning projects have been done that affect a single village, perhaps even a single family, his point is well taken: when possible, seek to do innovation work that results in the highest impact on the most people. In Frugal Innovation, the target business model and value network themselves become design and engineering requirements/constraints.

The Monitor Group[13] identified nine archetypes of business models that seem to be working in BOP contexts. Often the challenge is not only to envision, design, engineer and develop the product. Additionally, the team might need to create the business model, and corresponding value network, from whole cloth, a costly and risky proposition. Often the manufacturing, distribution, marketing and sales infrastructures are simply not in place to deliver the product to the intended customer, or to engage the BOP person as a supplier. This is one reason why BOP business models often require many years to take hold and scale. In other cases, some portion of the value network must be created from scratch, but other portions can be superimposed on an existing network, such as a distribution network consisting of thousands of small vendors, or the client network of an institution offering microfinance.

Microfinance is often a critical element of an overall financial and investment strategy for BOP venture creation. Monitor Institute (2009) characterized the new investment segment as Impact Investing, in which participants invest first and foremost in ventures that can have a social impact at scale. Some investors are "return first" investors that seek a market rate of return. Others are "impact first" investors that are willing to forgo higher returns in favor of higher impact, though they typically seek recovery of principal. The most recent trend is "yen-yang" investments in which a variety of impact investors take different parts of an investment that most closely meet their investment profile, in order to fully finance the product development, creation of the business model and assembly of the value network.

For U.S.-based universities, it is indispensable that teams work with in-country, on-the-ground resources that are knowledgeable in the business ways of the local culture, in order to bring the whole picture together. In one of our first projects we worked through this entire process. To develop the gel-fuel clean cook stove in Ghana, GlobalResolve collaborated with two Ghanaian universities and a Ghanaian NGO. Together we identified an initial target market that was likely to buy the product/service, and found an ideal early adopter customer. We selected an agricultural input for ethanol production, figured out how to best gel the ethanol in local conditions, prototyped several versions of a stove that was efficient enough and would meet the demanding cooking needs of the customer, transferred the design to a local manufacturer who further refined it, produced several test runs of gel fuel, built multiple versions of the stove and executed several cooking tests. To scale the business the supply chain must be optimized to the lowest cost and financing/investment sought for its expansion[14].

When fully in place across Ghana, the value network will potentially consist of tens of thousands of customers, dozens of stove and gel fuel manufacturers, hundreds of agricultural input suppliers and many, many distributors, all working to deliver an integrated whole product-service/benefit bundle co-created among several players specifically for Ghana, and branded for that context.

Brand Innovation for the BOP

Problem solving for the BOP does not end when the product has been designed and developed, but actually extends far down the process to the branding of the product for consumption by the BOP customer/supplier. Regarding how enterprises can successfully operate at the BOP Polak states that '…they will need to make radical changes in how they design, price, and deliver products and services to poor people[11] (p. 44).' Any product intended for the BOP will require these 'radical changes' not only in the way enterprises design their products but how they brand them as well. It is safe to assume that many of the traditional brand marketing methods used for the middle to top portion of the economic pyramid will not work at the base of the pyramid mainly because many of the individuals that occupy the BOP are illiterate and have no access to mass media channels.

In order to understand the brand awareness and brand beliefs of the BOP, considerable time spent conducting participatory ethnographic studies in rural villages, peri-urban and urban slums and other developing communities is necessary. Ethnographic observations and co-creative interviews should be some of the research activities that take place throughout the product development process. Participatory Rural Assessment or PRA should be considered a standard approach in not only developing rapport with rural villagers but also as a method for understanding the needs of rural villagers in the context of the village[15,16]. Rural villager and slum dweller participation in ethnographic observations of their daily life will aid the product development teams in understanding how the BOP will deal with their various artifacts and situations not only from a usability perspective but also from a material-cultural perspective. Co-creative interviews in which rural villagers and slum dwellers actively participate in the design of the product and brand will help the product development teams to better understand how the BOP perceive the product/brand under development and will ensure better acceptance and adoption of the product and its brand once it is produced.

So, Frugal Innovation is not about innovators delivering products and services *to* the BOP population. It is about creating impact at scale *with* BOP customers and suppliers, with their best interests in mine.

Doing Good, Doing Well

Frugal Innovation is "Doing Good, While Doing Well." It recognizes the bifurcated nature of BOP product development in terms of why we do it. While there is a general recognition that BOP businesses must generate self-sustaining cash flows, there are at least two very distinct BOP innovation-entrepreneurship narratives. One is the "doing good" narrative, which might also be thought of as the "social justice" narrative. This is the narrative that dominates the BOP discussion in the U.S. today. It captures the ethic and ethos of much of our student population, who are being referred to as Generation G, for generous[17]. This narrative combines humanitarian engineering and social entrepreneurship into a force for doing good in the world that is stripped of the "charity hangover" that dominated international development in the past. From a prosperous-Western perspective, embedded in this narrative is the idea that we are "giving back" to the world, and righting a wrong that our current economic system has not been able to address.

The second narrative is the "doing well" notion, which might also be thought of as the "Fortune at the Bottom of the Pyramid" narrative. This ethic is unabashedly profit-oriented. Prahalad (2006) pointed out the size of the market, and the asset-light, high return-on-equity potential of BOP products. It is this ethic that is derived from their fiduciary responsibilities that must drive the Global 2000.

Together, these two narratives form the idea of "doing good, while doing well." Both are capitalistic and for-profit oriented but have in common a desire to address the ills of the BOP. Both mostly intend to do so by providing BOP populations with new sources of income, and innovative labor and energy saving technologies.

In this decade, however, another compelling reason has arisen for U.S. universities to embrace Frugal Innovation: it is likely the next source of disruptive innovations that could displace many highly valued products in the developed world. We are staring in the face of the "Innovator's Dilemma" on steroids writ large on a global playing field. Major companies like GE have recognized this and are rebuilding themselves accordingly, usually not with U.S. Engineers who as cultural outsiders are at a disadvantage in developing BOP products.

Reverse Innovation

Frugal Innovation is Reverse Innovation, a label that suggests BOP innovation will flow back into developed markets, eroding the global market position of many of our best companies[18]. From a poor-South perspective, this is the opportunity for companies and entrepreneurs in the developing world to turn the innovation tables, and generate enormous wealth by not only serving BOP markets, but by infiltrating wealthier markets with new value propositions. Who among us would not want a high quality product that meets a need, yet is an order of magnitude less expensive than currently available in "top-of-the-pyramid" products?

U.S. business schools often deemphasize cost-based competition. Forgoing cost positioning in favor of the differentiated high-value ground is stressed. This instruction can ignore the great value that cost-based competitors have consistently created in markets over the history of the industrial and information ages. Think Walmart and Southwest Airlines. Think the microprocessor and any number of exponentially advancing technologies driven by ongoing price-performance increases that obey Moore's and similar laws.

Examples or "reverse innovation" abound. One is the mixing chamber or spacer that attaches to asthma medicine "puffers" or atomizers to improve the diffusion into the lungs and that typically cost $50. A Frugal Innovation program has produced a functional spacer that is die cut from thin cardboard and assembled with no tools into a spacer. Reverse Innovation would take that cardboard version, possibly change it for developed world application, and keep the costs low so that it may sell for $0.50 instead of $50. This version is more sustainable, uses less material, less labor and is completely recyclable[19,20]. Or, how about the $2,000 Nano car from Tata? We saw a similar product come to the U.S. a few decades back called the Toyota Corolla, an initially cheap car that got on the quality curve early. The rest is history.

Choose a rationale, or mix of rationales, for incorporating Frugal Innovation into the curricula of U.S. engineering, design and business programs: social justice, profit generation, or global competitive survival. In any case, the engineering education mandate is becoming clearer.

Global Collaboration in Higher Education

In the end, we are largely concerned with how we train engineers and other disciplines through service learning in a complex, global, modern world. In higher education, Frugal Innovation involves global teams collaborating to solve BOP challenges through innovation and entrepreneurship.

At Arizona State University we continue to develop our curriculum in Social Entrepreneurship that includes working on BOP problems not only with multi-disciplinary teams at ASU, but also with partners in Africa, Asia, Latin America and poor regions in the U.S. We partner with universities close to the target communities where we intend to introduce and pilot test products resulting from our Frugal Innovation methodological process. We create "global virtual innovation teams." Part of a team is at ASU and part is at the partner university. The community members are, of course, critical members of the team. We maintain close communication and interaction throughout the projects, supplementing annual visits with the best of today's web-based collaboration technologies. The global, technology-enabled nature of the teams allows frequent feedback and beta testing of prototypes with potential BOP customers. As with the best of similar programs in the U.S., we recognize that product and venture development often requires coordinating the efforts of many faculty and students, in many courses, over multiple years. University Intellectual Property and venture creation policies and processes must be observed and executed along the way.

In so doing, we believe we are developing and delivering the next generation of innovation processes to our students and community partners, in service to all of our stakeholders, including ourselves.

Conclusion

Frugal Engineering is a concept that has emerged over the last few years to describe the new way in which we must think about the engineering processes, and how we need to rethink ways to develop products and services for demanding BOP customers and environments. We have realized over time that such processes, by their very nature, must approach BOP challenges from a systems point perspective, in a systematic, collaborative and highly interdisciplinary method. Frugal Engineering is embedded within a larger System Innovation context and, thus, should be thought of as an element of Frugal Innovation.

Frugal Innovation, in turn, is nothing less than the systems engineering discipline we must adopt if we are to ensure prosperity for the global human society. Engineers have a critical role to play ensuring the well-being of the billions of people living in poverty today and in the future, as well as for the billions more that will be added in the coming decades. Engineers have an equally critical role to play in the sustainability of the planet as we care for its well being.

Ultimately Frugal Innovation is an ethic and responsibility, and in many ways a higher calling: one that serves the human race, the earth and all its inhabitants in new, innovative and frugal ways that protect our resources, while taking advantage of the exponentially increasing technologies that can create abundance out of scarcity. Thus, in the university context Frugal Innovation is at heart, a service learning paradigm that will soon be an indispensible cornerstone of the best global engineering curricula.

REFERENCES

1. Seghal, V., Dehoff, K., Paneer, G. (2010) The Importance of Frugal Engineering, *Strategy + Business,* 59: 1-5.
2. Prahalad, C. K., (2006) *The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits,* New Jersey: Pearson Prentice Hall.
3. Moore K. (2011) The Best Way to Innovation? An Important Lesson from India, *Forbes*, http://www.forbes.com/sites/karlmoore/2011/05/24/the-best-way-to-innovation-an-important-lesson-from-india/, Posted 5/24/2011, Accessed online 03/05/2012.
4. Daly H.E., Cobb, J.B. (1994) *For The Common Good: Redirecting the Economy Toward Community, the Environment, and a Sustainable Future.* Boston: Beacon Press.
5. World Commission on Environment and Development (1987) *Our Common Future.* Oxford: Oxford University Press.
6. Kates R, Parris T. (2003) Long-term trends and a sustainability transition, *Proceedings of the National Academy of Science*, July, 100(14): 8062-8067.

[7] Seager T, Selinger E, Wiek A (2011) Sustainable engineering science for resolving wicked problems. *Journal of Agricultural and Environmental Ethics* http://dx.doi.org/10.1007/s10806-011-9342-2, Doi: 10.1007/s10806-011-9342-2, Accessed online first on March 1, 2012

[8] Liu J., Dietz T., Carpenter S.R., Alberti M.R., Folke C.R., Moran E.R., Pell A.N., Deadman P.N., Kratz T.N., Lubchenco J.N., Ostrom E.N., Ouyang Z.N., Provencher W.N., Redman C.L., Schneider S.H., Taylor WW (2007a) Coupled human and natural systems, *Ambio,* 36: 639-649.

[9] Liu J., Dietz T., Carpenter S.R., Alberti M.R., Folke C.R., Moran E.R., Pell A.N., Deadman P.N., Kratz T.N., Lubchenco J.N., Ostrom E.N., Ouyang Z.N., Provencher W.N., Redman C.L., Schneider S.H., Taylor W.W. (2007b) Complexity of coupled human and natural systems, *Science,* 317: 1513-1516.

[10] Levin, S.A. (1998) Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* 1(5): 431-436.

[11] Polak, P. (2008) *Out of Poverty: What Works When Traditional Approaches Fail*. San Francisco: Berrett-Koehler Publishers.

[12] Simanis, E. & Hart, S., (2008). *The Base of the Pyramid Protocol: Toward Next Generation BoP Strategy,* Ithaca: Cornell University.

[13] Karamchandani, A., Kubzansky, M., Frandano, P. (2009) *Emerging Markets, Emerging Models: Markte-based Solutions to the Challenges of Global Poverty*, Monitor Group, March 2009.

[14] Henderson, M., Bekki, J., Doss, A., Tsang, J., Akhavan, O. (2010) Creating Supply Chains for New Ventures in Developing Countries, NCIIA Conference, San Francisco, March 25-27, 2010.

[15] Chambers, R. (1992) Rural appraisal: Rapid, relaxed, and participatory. IDS Discussion Paper 311, University of Sussex, http://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/774/Dp311.pdf?sequence=1, Accessed March 1, 2012.

[16] Chambers, R. (1994) Participatory rural appraisal (PRA): Challenges, potentials and paradigm, *World Development*, 22(10): 1437-1454.

[17] Guest, P. (2012) "One Brand Taps 'Generation-G' And The Rise Of The Philanthropic Consumer", The Huffington Post, http://www.huffingtonpost.co.uk/2012/01/09/one-brands-tap-generation-g-ethical-consumer_n_1194786.html, Posted January 10, 2012, Accessed March 4, 2012.

[18] Immelt, J.R., Govindarajan, V., Trimble, C. (2009) How GE is Disrupting Itself, *Harvard Business Review*, October 2009.

[19] Green, E. (2012) Respira!: An Extremely Affordable Device for Better Asthma Care, http://www.changemakers.com/disruptive/entries/respira-extremely-affordable-device-better-asthma-care, Posted July 15, 2007 2:24am, Accessed March 4, 2012.

[20] Fischer, G., Camargos, P. (2002) Paediatric asthma management in developing countries, *Paediatric Respiratory Reviews*, 3(4): 285-291, December 2002.

Rural Kenyans exploring healthcare technology developed through Penn State's Mashavu program

> ***"Try hard to find out what you're good at and what your passions are, and where the two converge, and build your life around that."***
>
> — Joshua Lederberg

CHAPTER 6
The Philosophy and Praxis of Convergence to Shape an Emergent High-Impact Learning Through Service Program

Khanjan Mehta
The Pennsylvania State University

Overview

The preceding chapters have provided an overview of skills and attributes students should possess in order to be successful in their careers over the coming decades. These chapters have described various Learning Through Service (LTS) educational models which arguably assist in facilitating mastery of such skills by students. Significant emphasis has been placed on the fact that for these future engineers to be adequately trained to meet the challenges of the next generation, they must also master many other skills traditionally not thought of as part of the engineering curriculum. In this educational quest, one is struck by the similarities with a much earlier time in history and the generations that attempted to develop a broadly educated "renaissance person." Such a person was trained in multiple disciplines, spoke several languages, understood philosophy and scientific teachings, appreciated literature and art, and engaged in athletics. This renaissance philosophy is making a resurgence, albeit with new terminology: the concept of "T-shaped" people. T-shaped people possess deep analytical skills and domain knowledge (the vertical stroke of the 'T') as well as broad empathy toward other skills and knowledge bases encountered in business and other disciplines (the horizontal stroke of the 'T').

Several academic and co-curricular programs described in previous chapters strive to develop these versatile professionals by engaging them in real-world LTS opportunities. A growing number of these LTS programs at universities engage students in the development and implementation of appropriate technology-based ventures. The aim is generally two-fold: a) to provide students with compelling educational experiences, and b) to address the needs of marginalized communities, whether they be at the so-called 'base of the pyramid (BOP)', or others domestically or internationally, who are simply too constrained to meet their basic needs on their own. These endeavors are usually well meaning, creatively designed, and enthusiastically deployed. However, for many of them, the sustainable impact does not match the vision set forth at the outset. This is due, in part, to an imbalanced valuation of immediate educational experiences for students over the long-term sustainable impact for such marginalized communities.

From a macro perspective, evaluations of international development efforts to assist communities in a sustainable fashion have revealed unsatisfactory results or failures. For example, in 2004, the African Development Bank judged that 78% of the funds it disbursed were for projects that were ultimately unsustainable. Similarly, the Independent Evaluation Group (IEG), the World Bank's private sector arm, examined the performance of 627 projects that were implemented between 1996 and 2006. Its findings reveal that over 40% of all projects were unsuccessful at generating positive development results, and that in Africa specifically, more than half of the investments had low development ratings. Furthermore, when assessment of such projects is broadened to encompass a time frame beyond the immediate completion of the projects, the number of favorable assessments falls considerably.

Against this backdrop of highly mixed results from the efforts of professionals who attempt to affect change in such communities, we can examine the growing number of academic programs and extra-curricular clubs that engage students in developing appropriate technology-based solutions for developing communities around the world. Anecdotal stories and summaries of technology-based social ventures mirror the literature of the more formal development programs. Through these stories, we hear of 'outsiders' going into communities and implementing projects like solar panels, biodiesel systems, and water treatment facilities. From our evaluation, it appears that the following questions are often not asked, nor acted upon: Does this project result in sustainable value for partnering communities? Is the project's sustainable value measured? Does the project lead to self-determined development for the community? What are the results of the project in the long term? Questions arise on the engineering and sustainability aspects of such projects as well as the larger context of globalization, social justice, professional ethics, and cultural balances. A dismal track record of development efforts brings into question the efficacy, ethics and sustainability of interventions by external agents.

At the same time, this is an unprecedented opportunity for universities to take the lead on building collaborative LTS programs that concentrate their resources to counter the failings of past development efforts. The quest is to ensure that the significant time, money, and energy expended on projects by faculty-student teams results in meaningful and sustainable value-addition for the partnering communities. This chapter discusses the philosophy, praxis, pitfalls and practical lessons learned while striving to build an emergent high-impact LTS program at Penn State. The Humanitarian Engineering and Social Entrepreneurship (HESE) Program, referred to in this chapter, is a work-in-progress. This internationally-recognized program has led over 30 ventures in ten countries over the past fifteen years. Many of these ventures have failed, some have succeeded in reaching thousands of people while a few of them are on the slow but steady path towards sustainable existence and scaling up to 'multi-million smile enterprises'. The insights shared in this chapter are based primarily on the author's experience with the academic program since joining the effort eight years ago and bear the burden of his myriad biases, prejudices and ideologies.

Philosophy of Engagement

The HESE Program defines successful, sustainable projects as those largely determined by local people, with outsiders playing only a limited role. This is because external actors, while well-intentioned, may fail to understand the community dynamics and identify the most significant barriers to realizing the ventures. To mitigate this problem, HESE students begin by identifying the *sticky information* that relates to the societal context of the problem. They do so in collaboration with appropriate partners to overcome impediments in a systematic fashion. The focus is on finding an optimal distribution of time, money, and sweat to be shared by the communities and partnering organizations. This equity is critical to achieving project sustainability. Sustainability, as we have come to understand it, refers to the notion that a project should be technologically appropriate, environmentally benign, socially acceptable, and economically sustainable. The program brings together students and faculty from every college across campus. It seeks the convergence of the tripartite university missions of teaching, research, and outreach by educating globally engaged, social problem solvers; creating sustainable value for developing communities; and generating and disseminating knowledge and lessons learned.

Building long-term relationships with multi-sectoral partners and leveraging indigenous knowledge to foster developmental entrepreneurship form the foundation of all our initiatives. While we practice the pedagogy of service learning to further the social ventures, we are not comfortable with using the word "service." The focus of the program is not to "serve" anyone but to build equitable reciprocal relationships with diverse partners and work shoulder-to-shoulder with them to develop technologies and launch entrepreneurial ventures that prioritize the social returns while being economically sustainable. There is a growing recognition among students and faculty that they typically gain more from their engagement than what they give back to the partnering entities. **Empathy, equity and ecosystems form the cornerstones of our philosophy of entrepreneurial engagement.** This sentiment is captured by a quote from Dr. Govindappa Venkataswamy, the founder of the Aravind Eye Hospital in India:

> *"When we grow in spiritual consciousness, we identify ourselves with all there is in the world. Then there can be no exploitation. It is ourselves we are helping. It is ourselves we are healing."*

Integrated Design, Business Strategy, and Implementation Strategy Development

Over the past fifteen years, HESE has led several technology-based social ventures in the US, Kenya, Jamaica, El Salvador, India, and other countries. The primary challenges for these projects were not on the engineering side, but were related to the cultural, social, ethical, and business planning aspects, mostly during project implementation. The key challenges, from most to least important, have been designing and evaluating appropriate systems; ensuring equity between the stakeholders; identifying marginalized stakeholders and engaging them in the project; understanding and managing power dynamics and privilege systems within communities; identifying and incentivizing champions; public relations; and business planning with non-cash equity.

For example, in Jamaica, the most significant challenge for an anaerobic digester project was the development of trust between the partnering universities, identifying specific roles and duties, and following through with full participation by each. While building a bridge in El Salvador, disputes within the community as to where the bridge would be constructed and who would benefit were critical. An understanding between all the stakeholders about their precise roles, duties, and benefits would have facilitated a smoother implementation of the project. For a windmill power system in Kenya, ensuring equitable contributions from the various stakeholders was the major challenge. These diverse experiences illustrate the need for a systematic process of implementing a solution in a collaborative and harmonious manner.

This implementation process encompasses several delicate activities including community identification and partnering, building trust, establishing communication protocols, relationship building, and making decisions by consensus. The community is the core entity that must not only claim ownership of the project, but also contribute to its genesis, organization, goals, funding allocations, and business plan. People in the community must have a voice and authority on all aspects of the project. These are not merely concerns that need to be intellectually acknowledged; rather, they demand systematic, concrete steps. Preparing students to engage in such projects enriches their educational experience while simultaneously serving as the first step towards increasing the probability of success of such ventures. There is a need for structured methodologies, along with practical tools, to implement and evaluate the ventures in an equitable, sustainable, and scalable manner. This implementation strategy can also be referred to as the "go-to-market" strategy from an entrepreneurial perspective.

If the goal is to actually launch sustainable social enterprises, university-based educational programs cannot engage in the design of appropriate technologies, develop business plans, and implement solutions in a linear piecemeal fashion. The engineering design team cannot simply hand their technology to the team tasked with developing the business plan, with the implementation team then taking the technology and the business plan into the community. Presenting the technology and the business plan to the community, even if they are the perfect solutions, is not the optimal approach either. Under such circumstances, the odds are against the community leaders actually championing the externally developed technology and business plan. **A collaborative and integrated "triple helix" approach of system design, business strategy, and implementation strategy development is essential. The process of operationalizing the design and the business/implementation strategies is as important as the product itself.** This integrated design and implementation process encompasses conceptualization, validation, design, field-testing, implementation, and evaluation, all done in an iterative fashion. While some phases in the lifecycle can be executed remotely, the locus of the work needs to move to the community as the venture progresses. The team must bring together distinct stakeholders and engage them in a structured process from conceptualization through assessment to ensure they are creating sustainable value for the community while meeting their own objectives.

When developing the venture, it is essential to acknowledge the frequent imbalance in the academic environment between knowledge generated within the academy based upon positivistic epistemologies and knowledge generated through observation, experience, and experimentation that occurs in the cultural context of communities. This locally generated knowledge can be referred to as "indigenous knowledge." This place-based knowledge is about the ways of knowing, seeing, and thinking that are passed down from generation to generation, and which reflect thousands of years of experimentation and innovation in all aspects of life. Positivistic, research-based knowledge has for a variety of social, political, economic, and cultural reasons gained favor in academia, while indigenous knowledge is often viewed with skepticism, if not contempt. The dichotomy between these views is often overlooked in the classroom.

As a consequence, students, armed with their laboratory-generated knowledge, find themselves in the field where the development perspective of "what will work in this village" is more immediately critical than a "scientific" understanding of the biological or physical mechanisms that are "causing" the problem. Students must be prepared to recognize this dichotomy of epistemologies and work with community partners to make collaborative design, sustainability and implementation decisions that consider the multiplicity of life concepts and ways of knowing.

Towards a Radical "Convergence"

Frans Johansson, in his book *The Medici Effect*, recounts the story of the Medicis, a banking family in Florence, who were patrons in a wide range of disciplines. Thanks to the Medicis and other like-minded families, sculptors, scientists, poets, philosophers, financiers, painters, and architects from all over Europe and as far as China converged upon the city of Florence. There they found each other, learned from one another, and broke down the barriers between their disciplines and cultures. Together they formed a new world based on new ideas—what became known as the *Rinascimento*, or the Renaissance. The city became the epicenter of a creative explosion, and one of the most innovative eras in history followed. Johansson calls this phenomenon the "Medici Effect."

Johansson posits that the maximum probability of groundbreaking and revolutionary advances is at the convergence of concepts, disciplines, countries, and cultures. These advances are accelerated by modern computational power, communication infrastructure, and easy access to information for everyone. Can we recreate the scenarios that preceded and propelled the Renaissance in our quest for promoting humanitarian engineering and social entrepreneurship education that results in lasting positive impact? Using modern technology, can we bring together wildly different ideas from various disciplines and rapidly explore the potential of the resulting unique, concept combinations to become radical innovations? How do we ensure that our innovations will be technologically appropriate, environmentally benign, socially acceptable and economically sustainable? How do we design systems with the intimate involvement of all stakeholders so that the design meets their needs and use preferences as well as contributes to a self-determined improvement of their livelihoods and agency? How do we shape a new renaissance that addresses global disparities and suffering with sustainable systemic solutions? **The HESE program is based on the fundamental philosophy that the answer to "wicked" global challenges is through a convergence of 1) concepts, disciplines, and epistemologies; 2) cultures and countries; 3) teaching, research, and outreach; and 4) multi-sectoral partners that share a common vision and purpose.**

The various programs detailed in this book share the goals of enhancing the educational experience for students while improving the lives of marginalized communities. Most programs share the convergence philosophy to a certain extent as they strive to meet expectations set by respective educational accreditation bodies, professional societies, and industry. Common threads amongst the programs include engaging in multidisciplinary efforts, enhancing cultural and global awareness, and engaging industry partners in LTS programs. Praxis of the convergence philosophy adds significant rigor to the student experience, while increasing the probability of success for scalable social ventures.

Convergence of Concepts, Disciplines, and Epistemologies

Social entrepreneurs need to understand not only the immediate problems they are trying to solve but also the larger social system and its interdependencies. A trans-disciplinary systems approach allows for the introduction of new paradigms at critical leverage points. It can lead to cascades of mutually reinforcing changes that create and sustain transformed social equilibriums. In essence, the social problems to be addressed and the potential solutions are fairly complex and require concepts and skills from various disciplines of engineering, agriculture, medicine, business, earth and mineral sciences, information science and technology, liberal arts, law, international affairs, and education. Melding concepts from the different disciplines can lead to new paradigms and realistic solutions and truly unleash meaningful innovation.

Programs to foster innovation in developing countries are often designed and funded by people living and working in developed countries, with the consequence that these programs frequently espouse Western notions, processes, and policies of innovation and development. They often approach innovation using scientific methods and empirical data to test and validate hypotheses, and fail to consider alternate epistemologies; ways of knowing and the cultural context under which innovation frameworks and processes might be formulated or operationalized. This contrasts with people in developing communities, who utilize their indigenous knowledge to address local challenges and develop new ways of doing things. For instance, the Maasai women know that the splinters of the wild olive (oloirien) tree can be burnt and used to smoke milk gourds to sterilize their milk. This practice has been used for generations, but the wild olive was neither tested nor analyzed for such preservative properties. The lack of scientific knowledge about the mechanism of an innovation on the part of the communities prevents many positivist thinkers from considering these indigenous methods as innovations or acknowledging their value.

The real-world context and focus on indigenous communities around the world fosters *inreach*, or the bringing back of prior knowledge, perspectives, problems, and solutions to inform, guide, and enrich initiatives. The HESE program brings together students and faculty from every single discipline across campus to work on technology-based social ventures. An illustration of a transformational convergence was a recent collaboration between engineering and women's studies. The team realized that social entrepreneurship encompasses the power and practicality of capitalism, inclusiveness of socialism and passion and critical eye of feminism. Working with the Women's studies department in the College of Liberal Arts, we discovered how concepts from these three philosophies can be used to make our ventures more feasible and sustainable. We also learned the importance of deconstructing social situations that form the foundation of the problems that we are trying to address with technology solutions. In product development parlance, we learned effective methodologies like analyzing the various power relations to unravel the "sticky information" related to the problems faced by these communities. Sticky Information refers to information that is difficult to replicate and diffuse because it is embodied in the people, places, organizations, societal constructs and other contextual entities. The sticky information, including an understanding of the various power relations, helps identify key stakeholders, marginalized stakeholders, constraints and resources to be considered in the design process leading to innovative and sustainable solutions. In essence, a radical convergence of concepts, disciplines, and epistemologies can help develop an enabling framework for passionate students and faculty to break down the barriers amongst them, and between them and the collaborating communities.

Convergence of Cultures and Countries

We live in an interconnected, global world. We strive to develop engineers who are aware of the global nature of their profession, and the challenges and opportunities that it brings. LTS programs should provide experiential and immersive international and domestic educational opportunities with an entrepreneurial flavor in order to develop world-class engineers and entrepreneurial, global citizens. Development of a large network of partners and collaborators - communities, industry, community-based organizations, non-governmental organizations, faith-based organizations, governmental agencies, UN agencies and similar programs, is essential. Such entities provide the social capital to enable synergies that facilitate the shared quest for sustainable solutions. Communication among collaborators is essential, and overcoming logistical hurdles to achieve an optimal level of interaction is a significant obstacle.

The importance of empathy must be stressed along with advocating relationship-based projects over project-based relationships. Sustainable solutions require intimate understanding of the community and its resources, constraints, political and economic conditions, as well as the indigenous knowledge its members use to address problems. Indigenous knowledge is gradually being re-evaluated and considered as an inspiring source of strategies for sustainable development. This knowledge has immense value for the culture in which it develops and also for entrepreneurs and problem-solvers seeking solutions to community problems across the world. For solutions to be successful and sustainable, they must be designed with the intimate involvement of all stakeholders so that the design meets their needs and use preferences and contributes to a self-determined improvement of their livelihoods and agency. There is no data available on the importance placed on indigenous perspectives and knowledge by the many students who travel to remote communities bringing with them their pre-conceived projects and technological solutions to "help" local residents solve what the students have determined to be pressing local problems. How can universities prepare students to be socially and globally conscious leaders and entrepreneurs that respect and appreciate indigenous knowledge? How do we bring the perspectives of indigenous people with different epistemologies and philosophies of life into the classroom? For whose benefit are we engaging in outreach projects? If it is for the community's benefit, how can students ignore the vast store of knowledge that its residents have accumulated over time? If we want students to have an appreciation for indigenous knowledge, it is important to make the information in sociology and anthropology textbooks "come alive" for them. The humanities and social sciences help bring in these perspectives and epistemologies into the classroom to prepare students to work in the field.

Technological innovation focused on Western populations, and trickled down or recycled to the poor, has arguably contributed to endemic global disparities and the continued dependency of Southern, or post-colonial, people. We need to prompt students to create strategies designed for those at the base of the pyramid to empower those individuals to lift themselves out of poverty and dependence. This approach is based on the notion that development should lead to freedom, and that indigenous communities will thrive if they find themselves in an environment in which they can effectively influence their lives. Self-determination is defined as an individual's ability to pursue goals that are personally meaningful to them and may be conceptualized and operationalized at the individual or aggregate levels (e.g., a village or a sub-segment of a community). According to many development scholars, individuals inherently seek their optimal development, but this kind of development is only attainable if individuals are supported by a nurturing environment that helps them meet three basic needs: a) they live in social contexts that help individuals feel competent, b) they enjoy a sense of being autonomous and c) they experience a sense of being related. Such needs, when satisfied, will facilitate intrinsically motivated self-help behavior.

From a design perspective, understanding the user's needs requires a level of scrutiny and empathy for not only the partners in the host community, but also the role of the university team in that context. The convergence of cultures facilitates the development of trust and empathy that can ultimately lead to stronger solutions and entrepreneurial ecosystems to support and scale them in the longer term.

Convergence of Teaching, Research and Outreach

We believe that teaching, research and outreach should be intricately connected, so as to optimize venture accomplishments and provide rigorous educational experiences at the same time. Students should be encouraged and mentored to publish their original work in peer-reviewed journals and conference proceedings. Students and faculty in the HESE program conduct research and publish in several areas ranging from social entrepreneurship theory, systems thinking, food security, post-harvest technologies, telemedicine systems, cellphones, social networks & trust, indigenous knowledge systems and development, educational assessment tools, tropical diseases, equitable tourism and so on. Making effective presentations and clearly articulating ideas is another essential skillset that students develop when they travel to conferences and make presentations. Students should also be encouraged and mentored to participate in various local and national competitions focused on social enterprise.

The convergence of participatory research and social entrepreneurship uncovers and emphasizes the community's self-determined needs, resources and aspirations and helps leverage them to create sustainable value. Ideas, products and services imposed from the outside that lack community buy-in are likely to fail. Even if they succeed economically, they are less likely to succeed socially and might not improve the community's holistic wellbeing. Partnering with the appropriate local organizations is particularly important for student ventures because a lack of understanding of the foreign culture's inner workings can result in negative consequences for the community. Participatory research is a pragmatic approach to understanding the context and how the technology venture might create sustainable value for the communities involved. This type of research engages stakeholders in a collaborative and open environment where all participants are considered equal and active partners in local problems, resources and solutions. The findings of these research initiatives can lead to better designs and systemic solutions while the research process can help build trust and ownership amongst the stakeholders and facilitate the implementation of the solution.

Participatory research, when conducted in an organic and truly inclusive manner, can catalyze a community by educating them about the venture (intervention) and how they might benefit from it. The venture might offer micro-enterprise opportunities to some stakeholders and lead to improved livelihoods, while directly addressing a problem faced by another stakeholder group. While the educational opportunities brought about by the research process can be transformative by themselves, they can also accelerate the formation of a reliable customer base for the venture and increase its likelihood of economic success. This customer base is likely to be loyal to the venture since they have contributed to it and have a sense of pride and ownership in it. For example, consider an LED lantern venture in a rural community. A participatory research endeavor to understand the socio-economics of the community might be initiated to help formulate the business and implementation strategies and establish the product's supply chain. Local youth might coordinate the study and seek inputs from all the community members. While eliciting their thoughts, the youth might explain the problems with kerosene lamps and how the LED lanterns can provide more light while improving health and saving money. This approach would bring the community together and educate them about LED lanterns while also developing the customer base for recharging the lanterns on a regular basis.

While such research endeavors are inherently focused on the specific community, the results can be relevant to other communities and entrepreneurs tackling similar challenges. It is beneficial to disseminate these findings, observations, and lessons learned to academic and practitioner communities through conferences and journals. This is also an opportunity to enhance student learning gained from the entrepreneurial ventures by concurrently involving them in original, institution-approved research. Several challenges emerge while planning and conducting research projects in developing country contexts and many of them can be addressed by appropriate local partnerships. Partners can be particularly helpful in navigating the inherent contradictions and challenges of the university Institutional Review Boards (IRBs) that oversee all research projects. Collaborative frameworks have proven beneficial to the validation and implementation of social ventures. Various methodologies that engage diverse stakeholders to validate the venture as well as help them negotiate their roles, responsibilities and returns have been field-tested and found to be instrumental to the overall success of the venture.

The success of a social venture hinges on a business plan based on valid assumptions, accurate information and access to the knowledge of local partners. Participatory research, through its organic and qualitative approach, can help validate assumptions and gather relevant information to craft a venture's business and implementation strategies. Stakeholders' participation in the research endeavor can lead to expectations and ownership which, although desirable, have the potential to negatively impact the success of the venture and limit its scalability. Simultaneously, the information inaccuracies that owe their genesis to the expectations built by the venture can compromise the validity and integrity of the research endeavor. Research conducted for ventures is a highly context-specific process and engaging participants in each location where the venture is to be initiated may not be feasible. For infrastructure-based ventures, scale-up will likely occur through replication rather than by expanding operations in one location. In this case, the business strategy, based on participatory research that engages a single community from one location, may not be ideal in another location. The designs for the venture must be determined by the needs of the people. Research is the means by which one can collect information on those needs and resources. There are two possible ways to scale-up a venture: scale-up operations or replicate the model. For example, a venture can make a treadle pump in one location and then ship it across the region or country to scale-up operations, or the venture can replicate the business operations in various regions of operation. Engaging people in every place and every location might not be achievable and thus tension arises when considering how much to customize and how much to standardize when a venture is being designed and implemented. Oftentimes, it is beneficial to standardize operations to facilitate quality control, build brand identity, and facilitate scale-up.

Consistency and standardization help develop trust, an extremely important characteristic of successful ventures. Standardizing the concept-of-operations versus customizing the design and business strategy across several regions presents interesting research questions related to several disciplines.

Engaging in such integrated research and entrepreneurship projects is an excellent opportunity for faculty to meet their publication requirements while also advancing the state of the art in the praxis of development and social enterprise. Alignment of research agendas and support from peers, especially with respect to promotion and tenure, remain two of the largest obstacles to capitalizing on such opportunities. While faculty interest in publishing in this domain might be challenging, our experience over the last four years indicates that students are very receptive to the idea of working on conference and journal publications and are willing to go significantly above and beyond what is expected of them to get their papers published.

Convergence of Academia and Industry

Collaborations between universities and industry are absolutely essential in a knowledge-based economy. The historic involvement of publicly-funded universities in the United States, particularly with applied agricultural research and industry are well-known. Many universities—equipped with modern experimental equipment, the ability to provide high-quality analytical services, and an improved knowledge of how to work with the private sector—have been very successful in building strategic partnerships with local and global industry. They have also been able to successfully launch their lab-developed innovations into the local, national, and global marketplace. These partnerships have led to lucrative, sponsored research contracts and licensing agreements. A synergistic interdependence is created between academia and technology-driven enterprises, helping universities play a role in their country's economic development. The importance of university research in the United States system of technological innovation is admired, and is often cited as a model that other countries, particularly in the developing world, should emulate.

Academia and industry create social and economic value. They also face the challenge of balancing these often competing goals. The university's core mission is to serve as a primary intellectual and cultural resource for society and is fulfilled through its tripartite goals of teaching, research, and community engagement. To accomplish this, it depends heavily on contributions from business and government, in addition to individuals and foundations, and is expected to experiment with different means of addressing social needs. In turn, it is expected that government or business will reward worthy performance by providing sustained support and helping scale-up or replicate successful, socially-oriented programs. However, the income-generating side of the university often fails to see eye-to-eye with the society-serving side. Whereas the income-generating side must court corporations for cause-marketing partnerships, the society-serving side must monitor and even denounce corporations for their poor social performance. The core role of industry is to produce goods and services demanded by customers in a competitive market in a manner that generates a favorable return on investment and creates the capital required for future investment, innovation, and risk-taking. However, industry is also expected to be socially responsible and contribute to the community, not only by producing important goods and services, providing jobs and generating a tax base, but also by being a good corporate citizen. R. Scott Fosler in his book "Working Better Together" discusses the convergence of government, industry and non-profit organizations to unleash social innovation.

> *"Government, business, and nonprofit organizations in the United States historically have worked together to achieve important public purposes. Today, such cross-sector collaborations, partnerships, and alliances are more important than ever in addressing the increasing number of complex public issues that spill over sectoral boundaries. The three sectors have been exploring new ways of carrying out their core roles, employing strategies and practices that are changing the relationships and blurring the distinctions among them. So cross-sector collaboration today is required not only to tackle complex public problems that no one sector can handle alone, but also to better understand and redefine the relationships and strategies of the three sectors."*
>
> – R. Scott Fosler

A significant gap, commonly called the "valley of death," exists between a technology's genesis through sponsored research and its dissemination to market through early-stage companies. In the American context, early-stage technology business incubators, venture creation workshops, idea-to-product competitions, and other initiatives have emerged to help bridge this valley of death and get innovative products to market. However, to date, fewer such support mechanisms have emerged for social enterprises that originate from the confines of academia. Amongst the few current, capable, and active supporters is the National Collegiate Inventors and Innovators Alliance (NCIIA). The NCIIA does exceptional work in supporting the development of socially-beneficial businesses through their "e-team" philosophy, which encourages student-led, faculty-mentored teams to create social enterprises. While a few student start-ups have successfully launched their products in the developing world, umpteen other teams with high potential for impact have failed because they could not make a multi-year commitment to their ventures. Even for teams that decide to make the commitment, the academic linkages that provided them with experiential learning opportunities, access to subject-matter experts, laboratory facilities, and other valuable resources, are likely to weaken over time. While it is essential for the student venture to be independent, the gradual separation from academia is a loss for everyone. The student team loses access to valuable resources, academia misses out on the real-world energy and "inreach" that the venture can infuse into the learning and research environment, while the probability of the innovative product reaching the market is reduced. Consequently, there is a need for other models of entrepreneurial engagement.

Faculty-led, multi-year venture teams with students championing various aspects over the venture's lifecycle is another valid approach to bridging the "valley of death." This is a novel way of thinking for most university systems, and brings up complicated questions around intellectual property, conflict of interest, faculty promotion and tenure, and liability. Unconventional intellectual property policies and candid discussions on such issues can lead to an open and trusting culture that results in stronger academic programs and larger real-world impact. Our team has observed that stakeholders are often overly concerned about who will own the intellectual property, even though they realize that they do not have the resources or interest in actively monetizing the intellectual property. Open-sourcing the intellectual property at the outset eliminates some of the conflicts and tensions, and can be especially helpful in developing partnerships with industry and non-profit partners. Notably, open-sourcing some of the key aspects of the technology does not prohibit student teams, industry, or academia from refining the technology and monetizing it in different ways. HESE ventures are integrated into credit courses through the "eplum model" of student engagement. These are multi-year academic ventures where student teams advance the project through various phases of its lifecycle. While students are still at the helm of these ventures, faculty members are intricately involved in all aspects of the projects and essentially lead the ventures across their entire lifecycle.

Industry and professional experts provide domain expertise on various HESE ventures. Companies are often excited about how their own products can be used for technology-based social ventures. Innovative academia-industry-nonprofit partnership models can serve as conduits between companies, students, and developing communities, thus creating win-win situations for all entities. For example, we have developed a partnership where application engineers from National Instruments Corporation advise teams in a bioengineering class working on the design and prototyping of low-cost biomedical devices based on virtual instrumentation. Venture capitalists, medical professionals, and legal professionals from around the United States are vital resources for our core teams and advise on our venture's strategy on an ad-hoc basis. Beyond the participation of universities and village communities, there are a number of stakeholders who play crucial roles in project sustainability. These include non-governmental organizations (NGOs), community-based organizations (CBOs), religious groups, international aid agencies, foundations, and government-sponsored development groups in the countries we work in. Like all who endeavor in the development field, these entities are not without shortcomings. For example, they may have unsubstantiated wariness of university participation for various reasons, including a lack of understanding of the context and scope of projects, lack of formal relationship between themselves and university groups, fear of competition, and fear of the unknown. At the same time, these groups can be phenomenal champions that facilitate technology transfer and provide structure and support to interventions by university groups through their experience, personal relationships, and access to information. Many NGOs have been operating for long periods of time in communities and have attained the trust and confidence of community members and leaders, providing an invaluable asset to venture teams.

Convergence and Praxis of Educational Models and Philosophies

> "*A new form of engineering education is needed, one that covers a wide range of technical and non-technical issues….The challenge of creating a sustainable world demands a new and holistic look at the role of engineering in society …… to allow all humans to enjoy a quality of life where basic needs of water, sanitation, nutrition, health, safety, and meaningful work are fulfilled.*"
>
> – Bernard Amadei (Founder of Engineers without Borders - USA) and William Wallace (Author, Becoming Part of the Solution: The Engineer's Guide to Sustainable Development)

The pedagogy of service learning has been studied and evaluated over a substantial period of time. Service learning incorporates two key elements, requiring students to, first, participate in an organized service activity that meets identified community needs and, second, reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility. Service learning draws on four criteria suggested by John Dewey for "projects to be truly educative":

1. Projects generate genuine *interest* among the students because they address a real problem.
2. Projects are *worthwhile* because they have an intent to create a real positive benefit for specific individuals.

3. Projects often present problems that demand students' *creativity* and self-directed learning.
4. Most experiences generally *span enough time* (typically at least an entire semester) to allow genuine learning to occur.

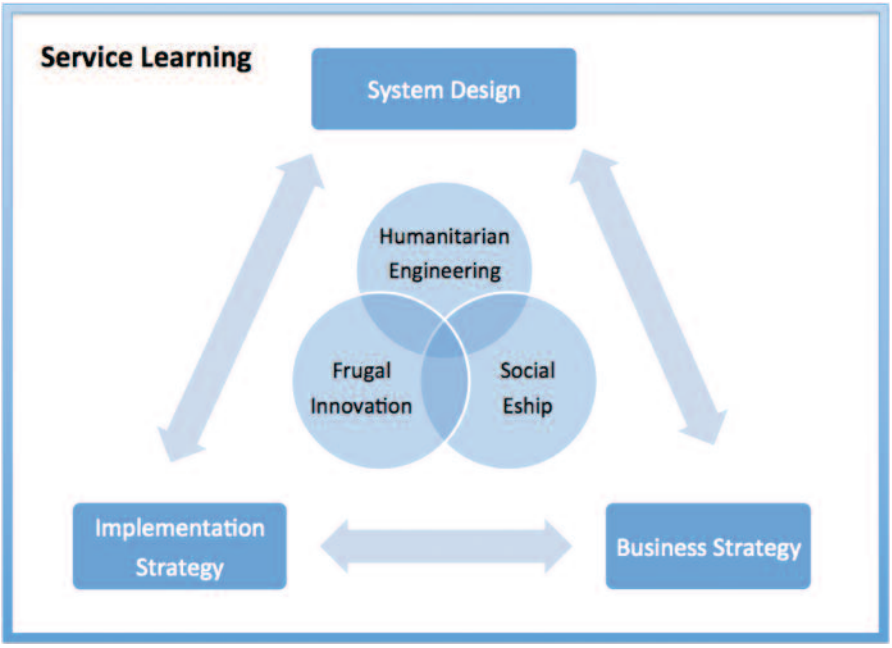


FIGURE 6.1 EDUCATION FRAMEWORK USING SERVICE LEARNING AS THE PEDAGOGICAL FOUNDATION FOR THE ENTIRE LIFE CYCLE OF FACULTY-STUDENT LED VENTURES

Rather than focusing on any one educational objective, or even several, the true power of LTS may lie in its ability to achieve a wide array of learning outcomes in an efficient manner. The Kellogg Commission on the Future of State and Land-Grant Universities recommended that service learning "should be viewed as among the most powerful of teaching procedures, if the teaching goal is lasting learning that can be used to shape student's lives around the world." Service learning, in its theoretical (i.e., equitable) form can act as the pedagogical foundation for any LTS program. With service learning acting as the foundation, the benefits and resulting synergies of engaging in humanitarian engineering, social entrepreneurship, and frugal innovation offer exciting opportunities to achieve the vision set forth by Amadei and Wallace. The framework offered in Figure 6-1 advances a "new form of engineering education," which results in a "new and more holistic look at the role of engineering in society." In this framework, the synergy and benefits of each educational area symbiotically benefits the others.

Humanitarian engineering may be defined as research and design under constraints to directly improve the wellbeing of marginalized communities. The most distinctive aspect of this type of engineering is its targeted audience, i.e., those that might be classified as marginalized, as well as its focus on actually implementing sustainable solutions to benefit those individuals and their communities. Designing solutions for complex problems in resource-constrained contexts necessitates systems thinking and a trans-disciplinary approach to develop innovative and realistic solutions. Humanitarian engineers must design and build high-quality, feature-appropriate technologies and products that are affordable, require low maintenance, reduce waste and inefficiency, and are designed with the socio-ecological context of their customers in mind. Humanitarian engineering necessitates a conscious and rigorous application of systems thinking. Systems thinking is a holistic approach to solving complex problems by considering each issue as a part of a web of interconnected systems, rather than independent entities with unrelated consequences. Such an approach focuses attention on the larger picture and wider processes of change, rather than concentrating on discrete outputs at the project level. Systems thinking can be especially helpful in navigating the complexity and chaos inherent in technology-based social ventures in developing communities.

Social entrepreneurship extends the humanitarian engineering efforts by attempting to "create *social impact* by developing and implementing *sustainable business models* while drawing on these *innovative* solutions that benefit the disadvantaged and, ultimately, society at large." Innovations, especially in developing communities, owe their genesis to everyday needs in their inherently resource-constrained environments. An understanding of innovation as defined and practiced by these communities can provide us deeper insights into the cultural and sociological processes that drive the emergence of these context-specific innovations. Grassroots innovation takes on various avatars in different cultures - such as the concept of *bricolag*e in France, a *hack* in the United States or *jugaad* in India. A more sophisticated form of grassroots innovation, "frugal engineering" is practiced by engineering design firms, especially in emerging markets and can be interpreted as a form of low-cost engineering design to address local market needs. The Tata Nano car in India and Zhongxing Medical's low-cost X-ray machines in China are examples of technologies that cater to a large number of people and provide them with services that they were initially unable to afford. As frugal engineering takes the market by storm in the developing world, the need for introducing these simple, effective and inexpensive designs in the developed world is emerging as a complementary trend. This process of introducing products and services designed for the developing world in western countries at radical price points is referred to as "trickle-up innovation."

In today's interdependent world, it is essential to value innovations from western countries with advanced scientific know-how as well as developing countries with constrained resources. Constraints spark innovation, and innovative solutions can lead to economic growth and development in emerging economies while revolutionizing markets in advanced economies. For all HESE ventures, students are given very specific price targets that are determined by faculty after careful consideration of many factors. For example, we have challenged students to develop $10 biomedical devices for East Africa and students have repeatedly come up with ruggedized prototypes under that price point. Students have developed $200 greenhouses and $120 solar dryers by truly understanding the science and engaging in context-driven design that emphasizes user-centered design, extreme affordability and systems thinking. These radical price targets have been met without compromising on the desired features or the safety of the device.

A Fundamental Canon (often called First Principle) of many engineering professional bodies is to "Hold paramount the safety, health, and welfare of the public". If design teams identify and add safety features to a product for the developing world, the people cannot afford it anymore! How do you design products for extreme affordability and live up to the

First Principle at the same time? For the student teams, the key to success is integrated design, business strategy and implementation strategy development with a frugal innovation mindset. In order to succeed, teams need to negotiate amongst themselves (and their local partners) on whether a certain design goal (like safety requirements) will be met in the physical hardware design, in software (for cell phone/computer-based systems), through the business strategy by focusing on a specific market, the implementation process, the legal organization and user agreements, or stakeholder education. This negotiation requires deep understanding of the context, the users, and all aspects of the venture and epitomizes the praxis of convergence and systems thinking to create an emergent learning environment and high-potential entrepreneurial venture.

The rigorous integration of humanitarian engineering, social entrepreneurship, frugal innovation has the potential to transform a mundane service learning program that focuses on low-impact service activities to high-impact game-changing social enterprises. Several universities have broken away from service programs where students make presentations, paint walls at schools and install solar panels in an ad-hoc fashion to designing and launching sustainable and scalable ventures focused on solar lanterns, affordable greenhouses, biomedical devices and several other technologies that seek to sustainably address developmental challenges. Integration of the research component strengthens the venture while adding rigor to the student's education by further developing their entrepreneurial mindset and venture creation competencies. The scholarly research can lead to publications in refereed journals and conference proceedings, which serve as tangible outputs for the students while advancing the cumulative knowledge in the field at the same time.

A Problem is a Prerequisite; A Prerequisite is a Problem

One of the primary challenges to realizing this multi-faceted convergence in the academic arena is a host of institutional obstacles to student and faculty participation. Often these obstacles take the form of a required vertical integration of coursework and lock-step synthesis of knowledge over the four years of college education. For example, freshmen might be forbidden from taking senior-level classes until they are in their junior year or students from one discipline may be forbidden from taking courses in another discipline. Tacit prerequisites refer to cultural, socio-economic or political norms, perceptions and biases that preclude the development of open forums for collaboration. For examples, certain courses might be considered geeky and hence not welcome women while other courses/ventures might be seen as feminine and might dissuade male students. Some international educational opportunities might be too expensive and beyond the reach of certain student groups.

While these situations cannot always be prevented, conscious efforts need to be made to create an accessible program. At the same time, we fundamentally believe that formal pre-requisites should not apply to such integrated learning, research and entrepreneurial engagement programs. The technology aspects of the venture need a concerted engineering effort based in a self-selected core class. While this class must have a healthy mix of engineering and non-engineering students, targeted recruiting is not necessary for any partnering peripheral courses. It is essential for students to work in multi-disciplinary cross-functional teams to practice integrated engineering design and entrepreneurship. Students - freshmen through PhD students - from every single college must be brought together to achieve this convergence. The HESE Progam believes that three foundational pre-requisites for achieving the educational, entrepreneurial and research goals are:

- The courses/ventures must be open to students from all disciplines across campus.
- The courses/ventures must be open to freshmen through PhD students (and ideally high school students and individuals without formal education too)
- Students must be self-selected and intrinsically motivated to lead the core teams of the ventures. The real pre-requisites for students are time commitment, an open mind and passion.

These pre-requisites for the program fundamentally conflict with the notion of stipulating pre-requisites for the courses themselves. We have observed that students typically succeed without having taken specific stipulated courses earlier. In this section, we have provided several rationales to substantiate our apprehension of formal or tacit pre-requisites and confidence in students' academic success without the prerequisites. The key educational outcomes of our program are related to human centered design, social entrepreneurship, innovation, ultra-multidisciplinary teamwork, global awareness and engagement, systems thinking, ethics, etc. These knowledge, skills, competencies and mindsets are not linear educational pursuits. These are learning continuums and students (as well as practitioners and faculty) mature and get better with experience, engagement and association – that programs like HESE provide:

- Experience in a faculty-mentored rigorous environment.
- Engagement in the true spirit of collaboration and co-creation with community partners.
- Association with designers, users, innovators, and everyone that does…or does not matter.

Human Centered Design (HCD) is an approach to design, that grounds the design process in information about the people who will use the product. Jane Fulton Suri, CEO of IDEO talks about how "Observation, intuition, empathy and imagination about customers, end-users, and consumers can inspire and inform innovation". Empathizing with the users and understanding their social context is critical to success. Multidisciplinary teams with varied life experiences facilitate affective design. Radical perspectives and worldviews inform and inspire innovation that creates value for people. The notion of reductionism - that you can understand something best by taking it apart and studying all of its pieces - discourages us from zooming out, and looking at the big picture. Systems thinking encourages students to explore the interdependencies among the elements of the system and looking for meaningful patterns rather than understanding or rote memorization of isolated theories and facts. Children are born systems thinkers – they do not differentiate between subjects and bring everything they know to the table when trying to learn something new…and also think about the big picture at the same time. Younger but mature students bring these systems perspectives to their design teams.

In the real-world, there are no disciplines or pre-requisites. There are only "big, hairy" problems and appropriate solutions. Design teams often consist of fresh out-of-college professionals working shoulder-to-shoulder with experts with decades of experience. In the global arena and especially in programs like HESE, students often work with extremely well-educated professionals as well as people who never graduated middle school and yet are excellent engineers, designers and entrepreneurs. Entrepreneurship is about value creation – it's about playing by strengths. We want students to learn how extremely diverse teams can work together and build on their own and peers' strengths to meet the needs of the venture (and learn from that process). The extreme diversity in the classroom is an opportunity for the students to self-organize and learn how to play by strengths: Design, Entrepreneurship, and Systems Thinking in action!

There is a body of literature that explores how children are more creative than adults. Sir Ken Robinson, noted creativity researcher, argues that the schooling system is undermining creativity rather than nurturing it. In our program, some of the most innovative ideas have consistently come from lower division students rather than graduate students. Our assessment results over three years indicate that the top three things that students report learning from their field experiences are life skills, humility and innovation. Students consistently report learning innovation from our partners in developing communities that live in resource-constrained environments. Design and entrepreneurship both need creativity and discipline. Entrepreneurship is inherently chaotic while research requires order and discipline to uncover generalizable results. Balancing creativity and discipline & entrepreneurship and research can be particularly challenging in the extremely chaotic environment of developing countries. Dealing with ambiguity and chaos is another extremely valuable skill that's a learning continuum. The diversity of individuals on the design teams provides more chaos and the framework for optimal solutions at the same time!

Freshmen arrive in college with a high school education, 16-18 years of life experiences and fewer rigid notions. They possess the academic knowledge and experience to engage in design and entrepreneurship. The strength of the learning outcomes for the students from different disciplines and semester standings are going to be different. Although our assessment efforts did not delve specifically into this question, the data indicates that there are no specific rules on who benefits more – by discipline or semester standing or life experiences. The important point is that the students are maturing in the educational outcomes mentioned earlier. They have their own learning trajectories and it is inappropriate to compare them with other students who have their own learning tracks.

High-impact LTS programs have the potential to change the public perception of engineering as a care-giving profession that strives to improve the quality of life for people across the world. The majority of the students in the HESE program are women who want to rethink and employ engineering to solve global problems. Changing the perception of engineering, especially amongst women and under-represented groups, is important to building a diverse supply chain of engineers. Engineering, Design, Entrepreneurship are mindsets and approaches that are relevant to all disciplines and can learn from all disciplines.

HESE courses have a significant applied ethics component. The diversity of students and perspectives is a richer learning environment for ethics. "How do we prepare students to want to make ethical decisions?" and "how do we do so without indoctrinating them?" Our team's observations validate anecdotal claims by other similar programs that humanitarian engineering and social entrepreneurship programs draw passionate students that get emotionally attached to the projects, the people and their role in helping "make the world a better place". This presents a unique opportunity to engage them in the ethical intricacies with the dual purpose of ethics education and ensuring that the projects themselves are being conducted in an ethical and appropriate manner that results in self-determined development. We often refer to engineering as an art as well as a science. In practice, our educational system focuses much more on the science than the art. The HESE program provides the framework to explore the art as well as the science of integrated engineering design, business strategy and implementation strategy development and execution. There are no prerequisites for artists, innovators and entrepreneurs. Development of programs like HESE is an opportunity to rethink and redesign our educational system and ultimately fulfill the vision of Charles Vest:

"Making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering environments is more important than specifying curricular details."
– Charles Vest, President, NAE, President Emeritus, MIT

Conclusion

For most students, their experience with HESE is transformational as it exposes them to situations, opportunities and career paths they had never imagined. Some of our alumni are pursuing their entrepreneurial dreams, some have altered their career paths and pursued programs like Teach for America and Peace Corps, some have quickly become subject matter experts on innovation and emerging markets at the multinational corporations (MNCs) they work for, and some students are pursuing unconventional career paths like trying to start entrepreneurial degree programs at universities in the developing world! A common thread is that they consider themselves entrepreneurial global citizens and believe in the HESE quest to make the world a freer, fairer, friendlier and more sustainable planet. At the same time, HESE teams have led scores of potentially high-impact ventures in numerous countries over the last fifteen years. Many of these ventures have failed, some have succeeded in reaching thousands of people while a few of them are on the slow but steady path towards sustainable existence and scaling up to 'multi-million smile enterprises'.

Common strategic goals for colleges and universities are to emphasize innovation and entrepreneurship, internationalization, multidisciplinary teamwork and public scholarship. This presents a phenomenal opportunity for faculty to build and integrate high-impact LTS programs into the academic landscape. It is imperative that such programs raise the bar, and advance from low-impact service activities (aka painting orphanages, holding hands and singing songs) to rigorous collaborative design and entrepreneurship ecosystems that nurture sustainable self-determined development. Our experiences have taught us that such programs and emergent ventures can significantly benefit from a multi-faceted convergence of 1) concepts, disciplines, and epistemologies; 2) cultures and countries; 3) teaching, research, and outreach; and 4) multi-sectoral partners that share a common vision and purpose.

Engaging in potentially high-impact LTS programs that focus on scalable ventures can be extremely challenging and rewarding at the same time. Faculty members need to realize that the development of a program of this nature is a social venture by itself. It requires the same triple-helix strategy of integrated curriculum, business strategy and implementation strategy development (and execution). The organic coalition-building process is extremely important and needs to take into account the unique culture of the university system. Faculty need to gradually develop partnerships with other faculty members, departments and centers in every college of the university. The idea is to identify champions in those pockets and work together to build confidence and engage in larger collaborative academic projects over time. It will require several years of dedicated and persistent effort until the academic ecosystem matures and successful ventures start emerging. Equity, empathy and ecosystems serve as cornerstones of the philosophy of engagement during every phase of this quest; whether the journey is introspective, through academic silos and bureaucracies, or towards venture success with marginalized communities in resource-constrained environments.

Bibliography

(A significant portion of this essay is a synthesis of my previous publications. As pointed out earlier, this chapter is strictly an opinion piece. However, several themes discussed in this chapter have been delved in a more rigorous and indepth fashion in publications listed in this bibliography)

- Baskaran, S., Malekar, G., Mehta, K. "The Global Jugaad Commons: Cross-pollinating Concepts across Cultures", NCIIA Annual Meeting, San Francisco, March 2012
- Bell, C., Dzombak, R., Sulewski, T., Mehta, K., " Preparing and Complying with Institutional Review Board Protocols for Integrated Research and Entrepreneurship Ventures in Developing Countries", *Journal of Ethics and Entrepreneurship,* Vol. 2, No. 1, 2012
- Fernando, J. L. 2003. "NGOs and the production of indigenous knowledge under the condition of postmodernity", *Annals of the American Academy of Political and Social Science,* 590 (1), 54–72.
- Independent Evaluation Group, "Independent Evaluation Finds over 40% of IFC Projects Fail to Deliver Development Results," Bank Information Center, 2007
- Mathias, B., Grzybowski, A., Mehta, K., "When Participatory Research and Business Strategy Collide: Lessons from Base-of-Pyramid Ventures," NCIIA Annual Conference, San Francisco, March 2012
- Mehta, C., Mehta, K., "A Design Space and Business Strategy Exploration Tool for Infrastructure-Based Ventures in Developing Communities", *International Journal for Service Learning in Engineering,* Vol. 6, No. 2, 2011
- Mehta, K., Morais, D., Zappe, S., Brannon, M., Zhao, Y., "Milking the Rhino - Innovative Solutions Showcase: Promoting ethics education, user-centered design and social entrepreneurship in the global context", Engineering Ethics Division, ASEE Annual Conference, June 2011
- Mehta, K., Semali, L., Fleishman, A., Maretzki, A., "Leveraging Indigenous Knowledge to foster Developmental Entrepreneurship", NCIIA Annual Conference, Alexandria, March 2011
- Mehta, K., Brannon, M., Zappe, S., Colledge, T., Zhao, Y., "eplum Model of Student Engagement: Expanding non-travel based Global Awareness, Multi-disciplinary Teamwork and Entrepreneurial Mindset Development", International Division, ASEE Annual Conference, Louisville, Kentucky, 2010
- Mehta, K., Laliberte, N., Fleishman, A., Wittig, J., De Reus, L., Dowler, L., "Multidisciplinary Social Entrepreneurship Education Model: If Capitalism, Socialism and Feminism in concert strive, will Social Entrepreneurship thrive?," NCIIA Annual Meeting, Washington DC, March 2009

- Mehta, K., "Riding in Dala-Dalas with Social Scientists", part of a panel with Delcore, H. (Panel Leader), Spears, L., "Using Social Science to Unlock the Pan-Human Capacity for Innovation", NCIIA Annual Meeting, Washington DC, March 2009
- Mehta, K., and Bilen, S., "Championing High-Tech Renaissance: Sensor and Controller System Integration Course" Entrepreneurship Division, American Society of Engineering Education (ASEE) Annual Conference, Pittsburgh, PA, 2008
- Mehta, K., "Lessons from the Field: Setting up a Windmill Based Business in Rural Kenya", NCIIA Annual Meeting, Dallas, TX, 2008
- National Academy of Engineering. 2004. The Engineer of 2020. Washington, DC: National Academies Press.
- Newberry, B. (2004) The dilemma of ethics in engineering education, *Science and Engineering Ethics,* 10: 343-351.
- Nieusma, D., Riley, D., "Designs on Development: Engineering, Globalization and Social Justice," *Engineering Studies,* 29-59, 2010
- Poate, D., "Enhancing the Impact on Rural Poverty through Support to the World Bank's Portfolio," Natural Resources Institute, 2005
- Prahalad, C.K. and Hart, S.L. (2002) *'The fortune at the bottom of the pyramid',* Strategy+Business 6(First Quarter):2 -14.
- Riddell, Roger. Does Foreign Aid Really Work? Oxford : Oxford University Press, 2007.
- Sehgal, V., Dehoff, K., Panneer, G., "The Importance of Frugal Engineering", Strategy + Business, http://www.strategy-business.com/article/10201?gko=24674, 01/15/2011
- Senge, P., The Fifth Discipline: *The Art and Practice of the Learning Organization.* s.l.: Doubleday Business, 1990.
- Stepler, R., Garguilo, S., Mehta, K., Bilen, S., "Applying systems thinking for realizing the mission of technology-based social ventures in Africa", Systems Engineering Division, ASEE Annual Conference, Louisville, Kentucky, 2010
- Von Hippel, E. "Sticky Information" and the Locus of Problem Solving: Implications for Innovation. *Management Science,* 1994

EPICS design team from Purdue University and happy owners of a model energy efficient home for Habitat for Humanity

"Example is not the main thing in influencing others. It's the only thing."

— Albert Schweitzer

CHAPTER 7
Learning Through Service: Best Practices

William Oakes, PhD
Purdue University

Two decades ago I moved from industry to academia to help prepare engineering students for the practice of engineering. My view at that time was that the "proper" way to prepare students was to have them work on industry projects. While I still believe this is valuable, my experiences with service-learning courses have transformed my way of thinking. Service-learning can provide the environment where students develop the skills needed for an engineering career in today's global economy, as well as developing students to become engaged citizens and professionals. As an educational researcher, I see where service-learning can move students past thinking of their grades and into thinking like an engineer. Service-learning can also be looked at as 'sustainable education' where the products of the classrooms are used within local and global communities. I have gotten to the point where I feel emptiness when I teach a class that does not have a service-learning component.

With all the benefits that have been articulated in the other chapters of this text and others, there is still a slow rate of faculty involvement in service-learning and community engagement. This chapter lays out some common lessons learned from implementing service-learning in many different courses and contexts. The lessons are not laid out as a step by step process because teaching service-learning, like engineering design, is not a simple linear path.

Is now the right time to start?

Before we begin talking about how to do service-learning, we want to have you reflect on why you might want to integrate service into your portfolio of work and consider how it will fit. Service-learning can be an amazing experience, both for the faculty and the students. However, most research indicates that service-learning efforts require an increased time commitment on the part of faculty (and often of students as well). For the faculty member, this may entail interfacing with the community to determine project potential, identifying community resources and champions, seeking funding opportunities to support the project, travel logistics, and so on. For the student, very often the passionate response to empowering the student to make a difference in someone's life results in a significant time commitment being made. One item to consider in your service-learning approach is how this effort will fit with your other teaching and research responsibilities in terms of time required. This is especially true if you are a pre-tenure faculty member. Ask yourself how this effort would count toward promotion and tenure. If the answer is not at all, wait until you are tenured or look for ways to integrate the work in a way that promotes your career.

An example of this is integrating the service learning efforts into research proposals, such as for the National Science Foundation (NSF), which requires an education and outreach component for all research proposals. Service-learning can be that component and can add value to any proposal. Research has shown that service-learning aligns with efforts to attract and retain diverse students, so these approaches can add value to the proposals. Programs such as the EPICS Program at Purdue[1] and the SLICE program at the University of Massachusetts Lowell[2] have been funded by NSF. Linking to a model that has been funded by the NSF brings benefits to such a proposal. If your research can align with service-learning, such activities can be a way to engage undergraduates in the activities.

Another way to align with the institutional reward structure is publishing your service-learning work. This is a valid form of scholarship in many institutions and is a very satisfying and worthwhile endeavor. Within each of the projects you may facilitate, there may be opportunity for you to research both technological aspects of the design as well as the pedagogy used when administering the project and assessment results. Outlets for publishing the results of your work are growing through both journals and professional societies. The American Society of Engineering Education, for example, recently created a service-learning division (called the Community Engagement in Engineering Education) which explicitly sponsors sessions on engineering service-learning at the ASEE annual conference. There are several journals that take service-learning research and exemplars of practices. These include:

1. International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship[3]
2. Michigan Journal of Community Service Learning[4]
3. The Journal for Civic Commitment[5]
4. International Journal for the Scholarship of Teaching and Learning[6]
5. Journal of Higher Education Outreach and Engagement[7]
6. Journal of Community Engagement and Scholarship[8]
7. Advances in Engineering Education[9]

Conferences and other prominent forums for presenting the results of research and exemplars of practice include:

1. National Collegiate Inventors and Innovators Alliance (NCIIA) annual conference[10]
2. American Society for Engineering Education (ASEE) Annual Conference[11]
3. ASME/IEEE's Engineering for Change[12]
4. IEEE Global Humanitarian Technology Conference[13]
5. EPICS Engineering Service-Learning Conferences[14]

A successful service-learning experience not only enhances student learning and provides opportunities for research and subsequent publications, but it also allows for marketing and promotional opportunities by the department, college and university. Corporate, individual, and foundation donors typically view such undertakings very favorably. Securing external funding is another way to link the work into the institutional reward structure. For curriculum funding, the National Science Foundation has a program entitled "Transforming Undergraduate Education in Engineering, Science, Technology and Mathematics (TUES for short)[15]. This program has tracks to fund small grants that take a successful NSF funded model and adapts it to another context and institution. As mentioned previously, programs such as EPICS[1] and SLICE[2] meet those criteria in engineering. Other funding opportunities include:

1. National Collegiate Inventors and Innovators Alliance (NCIIA) annual conference
2. USDA
3. EPA P3 Program

If it does not make sense now, remember that the work will still be there when the timing is right. Too many valuable colleagues have been burned out or had to change jobs too soon. Make sure that you are starting this when it is appropriate for your career and your personal life. It is incredibly rewarding but you still only get 24 hours in a day, even if you are doing service-learning.

Where to do the Service-Learning, in a class or outside of a class?

One of the first questions you might pose is where to integrate the service and how to link it to learning. Many models integrate service directly into courses while others use extra- or co-curricular models to do service projects that promote learning. If your primary goal is the service project, then considering an extracurricular model may be best. If the motivation is to use service-learning as pedagogy to teach something, then a course-based approach may be best. We will explore both.

Course-based approaches range from a project embedded within an existing course to a dedicated service-learning course. Many courses and topics could benefit from inclusion of a project that provides a hands-on application to the theory of the course. Service-learning can provide just that. The most extensive example of a college implementing service-learning projects across multiple engineering courses is the SLICE initiative at the University Massachusetts-Lowell[2,16]. Models that have worked successfully include substituting a lab, a hands-on project, or a paper for the service-learning project. In all cases, the service-learning project is used to introduce or reinforce concepts already taught in the course.

The service-learning project can be required for all students in the class or as an option. When starting a service-learning project, using a pilot group with a voluntary option can work well. You can control the number of students and start with volunteers who would likely be more motivated. There are very successful models of having a voluntary service-learning project as an option for experienced faculty. There are advocates for both required and voluntary projects and both are valid approaches.

A more ambitious approach is to convert an entire course to a service-learning endeavor. The most common ways this has been done in engineering are in introductory courses or in design courses. Introductory courses can use service-learning as a way for students to learn about their discipline and provide powerful experiences for students to explore their future discipline in a way that is consistent with approaches cited as ways to attract and retain a more diverse student population[17-19]. In design courses, service-learning provides a context with real users and constraints and allows students to learn design through a human-centered approach.

A third version for curricular integration is a service-learning program. An example of this is the EPICS Program at Purdue University[20,21]. EPICS is a set of design courses that draws students from multiple disciplines. The EPICS Program manages the service-learning projects that span multiple semesters and even years. The staff of the EPICS Program manages the community partnerships, the design curriculum, and course infrastructure, including assessment. The idea is that the directors and staff of the program handle the overhead that goes with service-learning thus allowing faculty to participate at a lower level of time and commitment, making it easier for more faculty to participate.

Extra- and Co-Curricular Service Experiences

There are many opportunities for engineering students to contribute to many service projects. If the projects do not easily fit into courses, they can be managed outside of the curricular structure. There are umbrella organizations that can help facilitate projects. Some use the term “service-learning” when engaging students in extracurricular projects. Many of the same considerations afforded course-based projects are given to extracurricular projects, including reflection activities, to draw out the learning. The advantage of implementing service projects in an extracurricular fashion includes the freedom to allow projects to go where they need to based on the project requirements. Students can be given significant leadership to drive the projects.

Some faculty see the extracurricular path as a way to start service projects and to gain experience and then to move the experiences into the curriculum. There are some successes with this path but the author recommends if the intention is to integrate into courses - to start there. There are many examples when service learning efforts begin outside of a class, and when other faculty see the effort as being outside of a class, it can actually be a barrier to moving it into classes.

A model that is in between courses and extracurricular is co-curricular, where project experiences go along with classes but are not part of the traditional class. Some examples include extracurricular organizations collaborating with classes. Some faculty will work with students in a student organization to handle issues not appropriate in the courses. For example, a capstone design course may be working on a project that also needs money to implement their design. The fundraising would not be appropriate for the capstone design course so that is done by the student organization. Another approach is to have an experience that is beyond the course but builds on the course experience. At the University of Sherbrooke[22], a first-year design course designed toys for children with disabilities. The course had time to develop prototypes but they were not ready for the children. The students were offered an opportunity to take the prototypes and make them ready for the children and then to work with the children as volunteers after the course ended. This extended the design experience for the students and offered a direct connection to the community.

Learning in Service-Learning

When starting to plan to implement service-learning, it is important to start with the learning that is expected from the students. This is essential when planning for a course-based approach but is also vital for a co-curricular or extracurricular implementation strategy. Getting students engaged in a service experience that is related to their disciplines has many benefits and the opportunities for service to help others are incredible. However, when we place the service opportunities within the offerings of the university, we must be cognizant of how these fit into the learning objectives and expectations for the university.

For courses, this is essential. As faculty, we are charged with maintaining the academic integrity of the curriculum. Service-learning is a powerful pedagogy for learning but when service is placed into courses just for the service experience and without clear learning objectives or clear paths to connect with the core objectives of the courses, it can actually dilute the expected learning for the courses. There are many instances across many disciplines where well-meaning faculty have put service into courses that are not directly connected to the learning of the courses. This invariably creates problems and results in a backlash against service-learning.

Aligning service-learning efforts with course learning objectives is relatively easy. Simply ask how the service experience will enhance the learning objectives of the course you are considering. If you cannot answer this, then that service opportunity is not appropriate and you are better off not doing it. You must be able to make the direct connection with the learning objectives and the service to explain to faculty colleagues and to the students themselves.

There are many opportunities to do this. One of the most straightforward is when the service experience is an application of the course content. For example, students in a dynamics class might do safety analyses of local playground equipment. They would use the knowledge from the class to model the motion of the children. The service component might include local education or a report or presentation to local government agencies. A class on structures might design a bridge. A class on computing might create programs that could be used by local organizations.

Sometimes, learning objectives may have to be broadened to accommodate the service experience. Caution must be taken to not move them too far, but this is easily done by engaging faculty colleagues as sounding boards. I integrated service-learning into a first-year course once and had to expand the learning objectives. The course had many sections that all had common content and two projects during the semester. The learning objectives for the projects were very specific to the traditional projects. We rewrote the objectives together with the other faculty to be more general so they were applicable to a larger range of projects including service-learning, but did not change the intent of the objectives. Broadening allowed service-learning projects to be used as a substitute with clear goals that aligned with the other sections.

If an existing course is not the right place for service learning, and you are considering creating a new course or doing the service as a co- or extra- curricular experience, you should also consider how the service-learning can promote the broader goals of the university, college, or department. Creating a course or series of courses that align with the broader goals of the institution increases the likelihood that you are creating something that will be sustainable even after you depart. To do this, each, or at least many, of the stakeholders will need to have their needs addressed. A first step in this process is to identify the stakeholders and to make a list of their goals and needs. Identify how your effort helps to meet goals and needs for each of the stakeholders. This requires preparation of a kind of "elevator speech" for each group of stakeholders. Engaging the stakeholders or representatives in this process can be a way of building advocates. This may involve faculty, administrators, students, alumni, or corporate partners as well as the community you will be engaging. In addition to addressing needs, this process can also help to identify potential barriers and hurdles. Engaging skeptics in the process can disarm them.

An example of meeting needs is the linking of service-learning with meeting the ABET objectives. Service-learning fits very well with many of the ABET criteria. The reflective component of service-learning provides a vehicle to document the learning in outcomes that are often challenging in traditional engineering courses. Service-learning is often linked with the professional skill objectives, e.g. teamwork, ethics, social context - but do not shy away from including the technical or disciplinary objectives as well. Having students apply their classroom knowledge to a unique problem is a powerful learning opportunity for the technical as well as the professional skills. Too often, service-learning practitioners move to the "professional" skills (sometimes called the "soft" skills) too quickly or exclusively and this does a disservice to the power of the learning experience. Professional skills are a valid learning experience but they don't have to stop there.

Projects and Partnerships

Service-learning requires partnerships with the community, whether it is a local, regional, or global project. To be successful with community engagement, think of the community as a partner and not just a placement for the student projects. These partnerships should involve benefits for you, your students, and the community and its citizens. A common term in the community engagement literature is "reciprocal". Reciprocal means that there are mutual benefits and respect for all parties. You and the students will gain from the learning opportunity. How will the community gain? If the goal is for a tangible project to be delivered to the community, there are implications. If the community is used as a context for the learning - that needs to be made clear.

There are real opportunities to make a difference in the community through engagement but it takes planning and collaboration. Take time to learn about the partners. Treat them with respect and be honest with them. If there are things that you don't have figured out, let them know. They won't think less of you; in fact, they will find it refreshingly honest. They know what we are trying to do and can be great resources and partners but we need to treat them with respect.

The easiest way to do this is to tell them you want to be partners and to learn from them. Ask questions of them and listen to what they say. Take time to build a relationship with your community contact(s). This will pay dividends during the project work and it will be personally rewarding.

Where do I find them?

Getting started can seem challenging, but let me assure you that once you get engaged with the community, partnership opportunities will be coming out of the woodwork. You need to prime the pump. One place to look is on your own campus to see if there is a service-learning office. If there is not, is there a volunteer bureau that places student volunteers or a community relations office? These would also have contacts you can speak with or you can send a call for projects through.

Talk to faculty colleagues. You may have colleagues that are engaged in the community. Starting a project in an area of interest to a colleague also offers the opportunity to engage her or him too.

There are meetings locally of directors of agencies, for example United Way meetings. Leah Jamieson and Ed Coyle made one presentation at a United Way directors meeting and they left with more than 20 project ideas to start the EPICS Program[21].

Whether you are sending out a call or making a presentation, come with some ideas as examples. The community really doesn't know what we can do and they don't know what level your students are at or their particular set of expectations. I recommend that you include:

1. Academic year of the students
2. Capabilities of the students, what they have learned so far
3. Expectations of the course/service experience – how many hours, how many people
4. Deadlines and constraints, when will students do the service, when will they be done.

Project ideas can be found at in texts[23, 24], the Campus Compact website[25], Service-learning clearinghouse[26], EPICS[1], and SLICE[2].

Global projects ideas can be found at your office for international programs, Engineers Without Borders[27], Engineers for a Sustainable World[28], and Engineering World Health[29].

You will likely find multiple options to pursue and need to choose the best one. Choose the partner or partners carefully. Consider how each opportunity aligns with your goals for the students and yourself. The Purdue EPICS Program uses four key selection criteria:

a. Significance
b. Level of Technology
c. Expected Duration
d. Community Partner Commitment

Partner commitment is an important criterion - especially when beginning. Finding partners that you can work with and who understand what you are trying to do will provide you with allies as you learn how to make this work. You want to start with a high probability of success and selecting an initial partner or set of partners makes this more likely. As you develop experience and expertise, you can move to projects that may have more significance and are riskier for success, but start with success stories that you can share. You are building for the long haul.

Preparing the Students

For the students to be effective, they must understand the community, the partner, and the culture in which the project will be undertaken. This likely requires that students undergo training before they come in contact with the community or project, as well as during the project. This is true whether it is a local or international project.

This presents a challenge for many of us in engineering, but also an opportunity to reach out to others on campus. The reaction is almost always positive when engineering faculty seeks assistance from others in the areas of culture and diversity needed for such training. That is when the relationships are treated as reciprocal. Ask for expertise and help creating the experience. Allow your colleagues to bring in ideas on how to enhance the experience for your students. Identify together what are the issues needed for the student. Engage the community partner together when possible. Often, the community partners have expertise to help prepare the students.

Sometimes activities can be integrated into the project work that will help equip the students. This may include having students observe the community or the organization you are working with. Perhaps interviews could be done. These are techniques used in human-centered design processes that have been shown to lead to more effective designs as well as providing students with an opportunity to learn about the community and the context.

Preparing students for local projects often presents a challenge in that students do not think that they need it. If designing for someone with a disability, the students need to learn about the disability and learn about the stakeholders, such as parents and caregivers. What can they learn from them?

International projects are typically easier to get the students to see that they need preparation, but there is often more to prepare for. Issues of language and culture need to be addressed as well as issues related to travel. We have to walk a balance of motivating the students of the needs of the community we are serving but also helping the students to see the rich expertise and culture of those areas. This is a challenge and is approached more effectively as a team. Reaching out to colleagues from other disciplines or in international programs is a very worthwhile effort and helps to build bridges within the institution, which will help in the sustainability of your efforts.

Share expectations with the community

An important part of a reciprocal partnership is to set clear expectations so all parties are clear when they start. This is especially true for service-learning. It is beneficial to write down your expectations. LSU has a faculty handbook and an example of a faculty/community partner form as an example.[30]

You want to be clear on the roles and your expectations. What do you expect from the community and what should they expect from you? Some example questions to consider:

1. *Do you need the community members to meet with the students? How often, when and where (on campus or in the community)?*

   It is important to have the students meet with the community members early in the process. If a face to face meeting is possible, it can be done on campus or at the community. For local service projects, it is important to have the students see, and if possible, experience the context they will work with. Having students do work with the organization as volunteers can benefit their engineering work and give them a chance to get to know the organization. If it is not possible to be there, set up a call or on-line communication so they can be introduced to the partners. It is important for you to be there with the students for the first communication so they can hear the expectations from you and the partners.

2. *Will the students be in the community? How often, for how long and when? When they are in the community who will supervise them?*

Having students experience the community they are working with is important but also presents challenges. Students need clear guidelines and expectations for when they are in the community. Developing a code of conduct with your community partner that is given to the students can be helpful, both in building your partnership with the community and for the students. Do not assume that the students will know how to act. Be explicit on expectations. This is especially true when partnering with a different culture, domestically or abroad. Students will benefit from an introduction to the community, its needs, and culture. Work with your community partner to develop training and appropriate reflection activities for the students. When they are in the community, who will be with them and who will supervise them? Be explicit and as detailed as you can.

For international travel, it is common that students visit the site when they have completed the project to deliver or install the project. It can radically change the way the students approach the project if at least some visit the location before the project begins or early on. Consider taking a leadership group if it is not possible to take all of the students early on. Carefully consider the preparation of the students before travelling and make sure that you have the appropriate travel arrangements, visas, appropriate shots and medicines, and appropriate institutional approval. These all take time so plan well ahead.

3. *Is transportation needed for the students? Are there visas or other arrangements needed?*

How far is the community and will the students need transportation? This can be another criterion when selecting partners. The author used the criterion for first-year projects that partners needed to be along the bus lines accessible by students so they could get to the organizations. Some students may have access to cars. It is important to check with your campus on their policy for transporting students for service-learning classes. If your campus does not have a policy for service-learning classes, you may need to get approvals. The university's risk management office should be consulted. At some campuses, they treat a service-learning class like a semester-long field trip and give a blanket approval for the semester.

For international trips, you need to insure that passports and appropriate visas are taken care of. Do not assume the students have passports and give them enough time to get them. Also insure that all appropriate shots and medications have been taken care of for the students. Working with an international travel office on your campus can be invaluable.

4. *How will you and your students communicate with the community members? Do you need a central point of contact?*

Arrange with your partner how they will communicate with you and with your students. How frequently and by what means? If they are local, will they come to campus or will the students visit face to face? Can they use email or phone calls? There are some great video systems that use the internet to provide video conferences. Be explicit on when they would like to be contacted. Students tend to work on a 24/7 schedule and it is surprising the expectations they can have. Some partners like having a single point of contact with the students. Creating a liaison position that is in charge of the communication of the team or class is a way to create a leadership position and can serve the community partner.

5. *How will expenses need to be handled? Who is responsible for what expenses?*

At the start of the partnership, be clear on who is responsible for any expenses. Does the community partner need to cover any expenses during the development of the project or for maintenance or service of the project? Do not assume that they can or cannot afford something. Be explicit and ask. This is part of the partnership. Will the students be expected to cover any expenses? If the students are expected to cover some costs, make sure that the approach is consistent with the institutions policies and be clear to the students at the start.

6. *What will be the result of the service-learning? What will the community receive and when will they receive it?*

What will be the result of the project? If you are doing this as part of the course, include the expectations of what may or may not happen. Be realistic with your partner, it will build trust. If the goal is to have students complete a project, talk through what is the likelihood they will complete it and what will happen if they do not. There are many situations where faculty have planned to complete projects, promised the community and the students came close but didn't quite finish and the community members never received anything. The partners want to have a clear idea. Some programs have student pick up projects from the previous semester that are not finished and complete them. Be clear and honest with the community.

If the project is being done far away from your campus, consider the logistics of the project development and delivery of the actual project. How will the materials or finished project be transported. Will the partner need to assist? Is there preparation that is needed in advance of the delivery and, if so, who will be responsible for that? Be clear, detailed and honest with the community.

Most communities just want a clear picture of what they are engaging in and what to expect. They must choose whether it is worth it for them to engage with you and the honest assessment will allow and empower them to do just that.

7. *How will issues of liability (both for students in the community and for projects) be handled?*

Liability is a real issue and needs to be considered. At some campuses, fear of liability stops service-learning, but it does not have to. There are ways to handle it but it must be addressed. As part of the initial partnership discussions, talk about how to handle the product liability of what will be delivered. For simple, domestic projects, a hold harmless agreement can be handled. This should be approved by your institution and also by the partner. Make sure that the executive director and/or the board of the agency has approved the agreement. To be legal, it must be approved and signed by an authorized person at the agency. For international projects, check with the international office or with local agencies to find the equivalent forms to approve. For larger or more complex projects, your students may need approval of professional engineers. Their work may be the input for the professional engineers. There are models where assistive technology projects done by the students are reviewed or even finished by professionals. A house design may be given to an architecture firm to be approved or modified before construction begins. The student product may not be the finished project but a prototype and initial design.

If you will take pictures of students or community members and use them on a website or in publications, you need to get permission. Including a photo release as part of the course paperwork is an easy way to get this done for your whole class.

Student liability is another set of liabilities to consider. Does your campus require approvals to take students off campus? Almost all have ways to handle study abroad trips or field trips. You may need to have students approved using these mechanisms. For local service-learning courses, some institutions have instructors complete field trip forms for the entire semester so students are covered the same as if they were on a field trip. For international travel, many institutions have a procedure to approve travel abroad and make sure that you follow their procedure. Check if the location is on a watch list for the U.S. Department of State.

Beyond liability is the issue of student safety. Whether it is a local project or international, service-learning opportunities can lead to students being in situations that are not safe. We are responsible for the safety of the students and must plan carefully through any travel to insure that they will be safe. There are more than enough opportunities for students in locations that are safe.

8. *Are there any issues regarding intellectual property?*

Many projects develop innovative solutions to meeting a community need and can result in intellectual property. Talk with your own institutional office concerning how they handle student developed intellectual property and include your community partner in the discussions. If something results from the partnership, include the community members as co-developers if they have contributed.

9. How will the community be engaged in the learning? Will they participate in reflection? Will they need to review any student work? Will they need to complete evaluations?

At the start of the partnership, be clear what you would like from the partners involvement and what you would like them to do as part of the learning experience. Ask them what they are comfortable with and discuss your ideas for the learning components. What are their expectations of involvement? Would you like them to complete evaluations for the project, for the class or on individual students? Show them the evaluations you would like to use and ask for their feedback. Be strategic and respectful of their time. Will they have enough contact with individual students to evaluate them or should they evaluate an entire team or class? One approach for student evaluations is to have the partners evaluate an entire class or team and give them the option of identifying students that stood out (good or bad).

Be specific about how the partners should handle assignments from the students. For example, set a guideline when the partners should respond to the students. The students may have the expectation that they can send an evaluation to complete or a report to read and have it returned that day. Discuss with the partners what is reasonable. For example, 72 hour turn around for anything sent by the students. Give the community partner permission to stay within that guideline, even if students wait until the last minute. Telling the community partners what your expectations are is important and if you tell them that you do not expect them to accommodate students who procrastinate, it will give them permission to do so and reduce frustration with you, your students and the institution.

The community members can be great resources for reflection activities and class discussions. Talk to them about how to prepare students for the work and the community they will work with. They may have programs or approaches they use already and can lead discussions or provide materials for you to use with your class. Make sure that they know how you will prepare them for the experience.

10. *Be ready to be the bad cop.*

Do not make the community members be the "bad cop". Protect the community members from pressure from the students. Your role as the faculty leader is to oversee the project and the student work. If something needs to be addressed, make sure that the communication lines are open with the partner so they can let you know and you can address it with the students.

Multidisciplinary Participation

In addition community partners, service-learning can require additional partnerships on campus. One area that is common is the need to make the effort truly interdisciplinary. In engineering, this too often implies two engineering majors working together. If your projects are engaging people in the community, locally or globally, having students who think about, and can provide experience with, the community will be helpful or in many cases necessary.

Creating interdisciplinary partnerships is similar to community partnerships. It starts with a relationship. The EPICS Program at Purdue enrolls nearly 400 students per semester and draws from more than 70 majors. They have learned that to make inroads across campus, time needs to be invested to talk about the opportunities and to listen to the needs of colleagues across campus.

Securing the cross-disciplinary participation can be accomplished several ways, including:

a. Inviting faculty from other disciplines into your classroom as guest lecturers,

b. Team teaching a course with colleagues from those other disciplines,
c. Incorporating cross-listed course numbering to encourage student enrollment, or
d. Embedding portions of the project into other classes as part of their project-based curriculum.

Another method is to connect separate classes across disciplines. An excellent example has been developed at Penn State as the 'eplum' model, in which the core project team is tasked with the design of solutions to problems in host communities, but portions of the effort are embedded in pertinent 'other' classes. Often that means the course has perhaps 40 students enrolled, but pieces of the projects are embedded in 3-4 other course, increasing participation in the project to well over 400 each semester.

When engaging students from other disciplines, make sure that you do not set up unintentional barriers, such as the language used in the class. For instance, the Purdue EPICS Program uses the ABET outcomes as a guide for assessment - but they are specific to engineering. The list of outcomes that the students see was changed slightly but very significantly by replacing words such as "engineering" and "technical" with "in your discipline" and "disciplinary". In this way, students can apply their own discipline or major to the outcomes. They read the outcomes from their own perspective. This means that they need to be evaluated based on these criteria too, which requires some faculty training and calibration but has been very effective.

Meeting Student Needs and Expectations

One may think that altruism on the part of students is the primary reason many choose to participate in some form of 'service' – whether it be course-based or extracurricular. Research shows a much broader set of reasons. One study on why women participated in a service-learning class showed that the main reason was for the women to gain engineering experience. The context of the projects clearly played a significant role in choosing to participate, but the experience was the main reason. Many students enroll in a service-learning experience for altruistic reasons, while others do so to gain experience and learn, and still others to make their resume look good. This is not necessarily bad but can provide challenges. One should keep this diverse set of interests and motivations when recruiting students.

One best practice is to have a way students can share their expectations when they start. This can help to align goals and it can also help to set appropriate goals and expectations for all. Some students will enroll with different goals than one would expect. For example, this semester I had a computer student who enrolled in a service-learning design class explicitly so that he could do something other than coding. In the sharing of goals and expectations, he shared that he wanted to build something and have significant experience in doing so. We had him slotted as the webmaster and programmer. Good thing we asked!

Service-learning projects require diverse students from many disciplines. When developing a design for a village in another country, the social and cultural context has to be integrated into the work and this requires students from outside of engineering. Truthfully, almost any real project that will be deployed and used needs students from outside of engineering. This can be a challenge to manage. Just as we stereotyped the computer engineering student, faculty and students alike will stereotype each other at the start. Have time to share and calibrate what everyone's expertise, expectations, and aspirations are for the project and their work together.

Our goal is to harness the students' energy to develop their professional and disciplinary skills; to change the way they look at the world, their profession and the connection between them; and to make them better citizens. The students who signed up just to enhance their resumes are some who have the greatest potential for change. Be clear with expectations but open to the diverse set of students.

Recruiting Students

Consider how you will attract the type of students and the numbers that you need for the project. It can be very frustrating to select a community partner and not have enough students to work on their project.

Mass emails can attract students if you are allowed to send them. Social media, especially driven by students, can be a powerful tool. Some experienced students, and their faculty visit strategic classes and make short presentations. It can be helpful to have a small handout for students to take with them. Academic advisors can be strong advocates, especially when attracting students from other majors. We host luncheons for academic advisors each semester to update them on what we are doing and who we are looking for. Many students report that they enrolled because "their advisor recommended it". Some faculty have found that 'callout meetings' where students can see what they will be doing, are effective. Events can be great but take effort and money.

Industry Partnerships

I did a service-learning workshop a number of years ago and a manager from a large defense contractor participated for the whole day. He had come as part of the introductory gathering to say a few words about how much their company valued students with these kinds of experiences. It surprised everyone that he stayed the whole day. At the conclusion of the workshop, one participant asked him why he stayed. He reiterated what he said at the beginning and added that the values that service-learning developed were the exact set of values that his company and others are seeking. A defense contractor no less! This has been reiterated by many companies from many fields. They want students with the kinds of skills service-learning students develop. Service-learning participants are valued by corporate recruiters. Many of our students talk about how their experience helped them get and then succeed at their job.

Corporations are interested in service-learning and you can use this to help attract corporate partners to provide expertise, in-kind support, and funding. Just like influencing institutional stakeholders, you should be able to articulate the benefits to the corporate partners. These include the student experience and other attributes such as the higher diversity seen in many service-learning programs. Corporations are also interested in benefitting from positive publicity of the work they support. Some may benefit even from product development or research opportunities. Explore all possibilities but do not assume that the companies have to "get something" for the projects. There are many models where companies sponsor projects in which they have no direct benefit. If your college has companies that sponsor senior design projects, ask for permission to ask them if they would sponsor a service-learning project.

Reflection

When I started doing service-learning, I read as much as I could and all of the texts talked about the importance of reflection. At that time, there were few examples of engineering service-learning and I thought that the reflection was something that they did in the Humanities and Social Sciences and really didn't fit with engineering. I learned that I was wrong. Reflection is an important skill and appropriate for all classes. Researchers have found that reflecting on your learning experience improves your learning. Thinking about your thinking, metacognition, enhances learning. All classes, not just service-learning classes, should use reflection to improve learning. In service-learning though, reflection also plays an important role to insure the students learn what you hoped for and don't leave the experience having learned things you didn't intend.

Reflection is needed to connect the service experiences to the learning you want for the students. I have been amazed at the difficulty students have connecting service experiences to theoretical or conceptual parts of a course. Students compartmentalize the courses and concepts. We have actually taught them to do this. We cover chapters A, B and C and test them over that. Then we cover chapters D, E and F and test them over those. They will all get tested on the final exam - but not until then. The students use this model with the service-learning and assume that they don't need to connect it with other parts of the learning experience. The students need help seeing the connection with the service experiences and the other course content. Making the connections explicitly through reflection will make these connections.

Service-learning offers rich learning opportunities for students, but these are often missed without reflection. Reflection can be used to draw out learning and to capitalize on learning opportunities as they occur. For example, students may be designing something and they have a presentation or demonstration and they discover that a feature will not work.

Finally, reflection is also a guard against unintended learning. It is wrong to assume that students will learn what we want simply by putting them into new environments. Placing students into a community that has a different culture from theirs may actually reinforce preexisting stereotypes or prejudices if not processed through reflection. This may require activities to prepare students for their culture or context as well as during and after the experience. Having students reflect on their experience in writing or in discussions gives you the opportunity to see what they think they have learned and provides an opportunity for you to correct or address any issues before they leave your class or project.

How to do reflection

Reflection can be done in different ways. Students can write about what they are thinking or what they experienced. This does not have to be long. Research has found that the length of reflective writing is not as important as being done frequently and intentionally. Short frequent writings are important. A popular method in engineering is to have students keep a design or lab notebook and to write reflections in the notebook. The notebook keeps other information such as meeting notes, calculations and sketches and can be collected and graded. Some have students keep a blog that can be accessed by the instructor and graded. Reflections can also be done as formal assignments where students write a report or essay that is turned in and graded. In any of these options, students can write freely or they can respond to question prompts that you provide. You can also include readings that they respond to in their reflections. It is important to read the student reflections so that you can see what they are learning or think they are learning.

Reflections can also be verbal. Class discussions or small group discussions are effective ways to do reflection. A combination of short writing assignments, followed by small group discussions, are a great way to have students share their experiences. One on one discussion can be a powerful way to have students reflect on their experience. This can be in the form of an exit interview, for example.

If you do not feel comfortable leading reflection discussions or making assignments, look for resources on campus. Does your campus have a center for instructional excellence or faculty development? They can help facilitate. Asking colleagues from Liberal Arts to collaborate on reflection can be a great way to build bridges between departments. There are many reflection resources on the service-learning clearinghouse and the Campus Compact Website.

Assessment: Evaluation and Grading

Assessment in service-learning can really be broken down into two categories. The first is grading students if the service-learning is done within a course. The second category is evaluation of the student learning, student experience and the community experience and the impact achieved. Both are important and can be linked.

Grading

Faculty understand how to grade traditional courses and in service-learning we will use the same or very similar processes. Remember that in any class, grades are given for mastery of course content, and service-learning classes are no different. Grades are not given simply for time spent in service but rather the service is used to allow students to learn the course concepts more effectively. Grades are therefore determined in similar manners to traditional courses. If a service-learning project is placed in a statics class, the majority of the grade will be determined by the exams on the statics topics.

For project related experiences, service-learning is really not that different than other project courses. Let me use the first-year project example mentioned earlier. Part of the class was graded based on exams and homework but there were two projects. In the traditional project, the grades were determined by grading reports, an interim report, and a final, with pre-determined grading rubrics; a demonstration and peer evaluations. The traditional project's demonstration was usually some task or contest where the projects were tested to meet the common set of specifications. For the service-learning project, we paralleled the assignments and had an interim and final report that included student reflections. Since the service-learning projects were not all the same, we couldn't have a contest or common demonstration so we had a poster session with all of the projects. We also included a community partner evaluation as well as the peer evaluation.

The key to grading project-based work is to have students generate things that can be graded. Some call them artifacts. These include reports, written reflections, actual project prototypes, and notebooks. If using notebooks, consider what your objective is. Years ago, we taught students how to keep a proper notebook that could be used as a legal document. Students had to write in pen, number and sign pages while not skipping any pages. What we found was that students felt that they were being graded on format and not content. We have gone away from grading on format and allowing students to keep portfolios that include notebooks, three ring binders, blogs or combinations. Interestingly most still keep a notebook but many also use other media. We were looking at the content.

With any report, notebook or presentation, grading guidelines need to be determined. Examples include those from the EPICS Program[31]. They were developed by asking faculty and graduate assistants what they thought was an A student, a B student, etc. Some faculty make a class activity into developing the rubrics for the project and this can work well. Ask the students to help determine what an A (Excellent) project would include and how would we know. This has the added benefit of having the students buy into the assessment but it also takes class time.

A best practice is to have something due early in the project. This can be a project proposal or a timeline that requires action and engagement of the partner in some ways. It is surprising how many students look at the open-ended projects and don't know how to start. This has to be identified early and having something tangible due and graded is an excellent mechanism to do this. It allows the students to see how things are graded and it allows the instructor to make sure the students or teams have started the project and made contact with the community.

Another best practice in a service-learning class is a dry-run grading at the middle of the projects. This has worked in service-learning design courses where the entire course is dedicated to a service-learning project. At the middle of the semester, a mock grading with all of the artifacts can help calibrate students and faculty. It is recommended that students be given a grade and also feedback on what they are doing well and what they need to improve upon. Short interviews are very helpful to allow students to ask questions. Ten to fifteen minutes per student works for most students.

For teams, peer evaluations are an excellent tool. In small classes, this can be managed with paper evaluations or assignments that are sent to the instructor. For larger classes, there are on-line tools. One common tool is the CATME system (www.catme.org) which allows teams to evaluate each other and each member receives feedback from the team in a confidential manner. Tools like these provide the infrastructure to have peer feedback on students.

If the service involves specific hours at the community organization, some points could be allocated for the time. This is analogous to giving points for attendance. If attendance could be part of the grade for the class, then this would be appropriate to include in the grade.

Evaluations from the community partners can also be factored into the student grades. If the projects are done in teams, it works well to have the partners evaluate the teams and ask if any students stood out, good or bad. That way the partners don't have to rate each student but they can voice strong feelings one way or the other. Collecting community evaluations can be a challenge. Many partners are busy and it may be delayed so making the evaluations as short as possible is important. Ask yourself what you will do with the answers and only ask what is vital to the grading or the evaluation of the effort. Online surveys can work. Having the instructors email the evaluations to the partners and have them return by mail can also work. One method was for the instructor to email the forms and provide each team with a paper copy and envelope. The final report was required to be accompanied by either a sealed evaluation or an email confirmation that it was sent to the instructor. The students were responsible for insuring it was completed.

Data from the community partner evaluation will not all go into grading. It can provide you with information to guide the development of the experience. Ask the partners information about the experience. Were they satisfied with the experience? Was communication adequate? How could the program be improved? Ask the partners if they want to continue in future years. One way to make your life easier is to build partnerships that last so you don't need to find new ones each year. Asking at the end of a successful project is an excellent time or if there were issues that made the experience poor, you have time to address them quickly and maintain the partnership.

Assessing the community impact is a challenge but some easy methods include asking how many people were impacted by the project. One can also ask the partners to rate how much benefit they received versus the investment on their part.

Gathering data from your class and the project is important when seeking resources to continue the work. Keep records of the number of students and the demographics if possible, including major, year in school, gender, and ethnicity. Also include the average hours spent on the projects per student and the number of community members impacted by the projects.

Evaluations from the students are also important. Asking how they felt about the course and the experience provides valuable information. Some ask the students what they learned or what three things they learned from the experience. Keeping quotes from students is also good when looking to advocate for your work.

Student learning goes well beyond what they do for their grade. Reflections are an excellent way to capture the broader learning of the students. Having them complete and turn in a final reflection provides a great deal of information for you to assess both their learning and their experience. Posing a series of question prompts works well and provides a framework for their writing.

Planning and Implementation

Create a structure to support the development of the projects. Whether it is in a class, or as an extracurricular activity, one must set clear expectations for the students. The students should provide ownership of the project but you need to be an advisor or coach. A good coach watches for her or his team to be in trouble and may call a timeout when needed to prevent a bad situation. This is a great analogy for managing the service-learning projects. You are there to support and encourage. Creating an environment where they will succeed is important.

Have the students develop a plan with frequent progress checks or milestones. Have them demonstrate, whenever possible their progress, both on the project and their understanding. When things work well, have the student leaders facilitate meetings and manage the project plan. Students should be reporting, but make sure that you can verify, their progress.

It is human nature to wait until the last minute and there is a mind-set that "real engineering" happens when the team stays up for two or three days finishing a project. This is not good design and nor is it good project planning. The work that your students will be doing will be used by the community and it is important that they get it right. Remember that in traditional classes, we have been teaching them that 90% is excellent (an A) and 80% is good (B). One of the excellent learning opportunities for service-learning is that they have to get it completely right, just like in industry. As their coach or advisor, you have a responsibility to insure that the project is completed as you made a commitment to the community partner when you started the project. Letting students wait until the last minute is a recipe for disaster as we know there will be last minute issues that come up. A good coach puts her or his team in situations to make them successful and that is the art of guiding experiential education and service-learning in particular. In more traditional project-based learning, if the project doesn't work, the students can learn and we consider it a success. In service-learning, someone is depending on the outcome and while the students may learn, the community does not receive its benefit.

It is important when you are starting out with a group of students that you set short-term goals for the students so they can accomplish something tangible and you can assess them and provide feedback so that they can calibrate their expectations.

It is helpful to have students who take leadership roles and there are two philosophies with student leaders. One is to assign or elect students to specific roles, such as team leader, project manager, recorder, financial officer, etc. When assigning roles it is a good idea to define the roles with a short job description so that the students in those roles and others on the team understand their roles.

The other concept for leadership is shared leadership. This method has no formal leader but has roles on the team such as meeting coordinator, time keeper, recorder, and encourager. Students rotate roles and each has the opportunity to assume the roles on the team as well as receiving and providing feedback on how they and others did in these roles. Both leadership models have worked on student teams. When starting out, choose a model you are comfortable with.

Are you ready?

Service-learning can be an amazing experience for both you and the students. It is an adventure and when you start the semester, you really don't know where it will lead. This can be intimidating, especially when we usually teach classes with well planned syllabi that show exactly where we will be in each class. Life is not like that and the adventure of service-learning will prepare the students for life and the practice of engineering. Get ready to say "I don't know, but we can find out". That will happen and it is okay. You are learning together. When you are honest with the students and they see what you are trying to accomplish, they will respond very well. It is refreshing when you are in the role of a coach and fellow learner and not the expert performing in front of class.

Having said it is an adventure does NOT mean that you don't plan. The top three things that are needed when preparing for a service-learning experience are: Planning, Planning and Planning. Plan and be ready to adjust when things arise.

Start small and be successful and build on that success. Publish the success. It isn't research but publications are good at all kinds of institutions. Be smart about building institutional support and look for ways to integrate your work in your campus' initiatives.

Make sure it is the right time for you. Service-learning will take more time than a traditional class. If it is not the right time for you personally or professionally, especially if you are pre-tenure, wait and start later. The opportunities will still be there when you are ready.

Finally, remember the key word in service-learning is partnerships. You are in partnership with the community and you will learn from them as they will from you. You and your students are doing work WITH them, not for them. Treating them with respect and open communication will be, to paraphrase that famous old movie, the beginning of a beautiful [partnership]. Enjoy.

REFERENCES

[1] www.purdue.edu/epics (accessed 1/30/12)
[2] http://slice.uml.edu (accessed 1/30/12)
[3] http://www.ijsle.org (accessed 1/30/12)
[4] http://ginsberg.umich.edu/mjcsl (accessed 1/30/12)
[5] http://www.mesacc.edu/other/engagement/Journal (accessed 1/30/12)
[6] http://academics.georgiasouthern.edu/ijsotl/current.htm (accessed 1/30/12)
[7] http://openjournals.libs.uga.edu/index.php/jheoe/index (accessed 1/30/12)
[8] http://jces.ua.edu/ (accessed 1/30/12)
[9] http://advances.asee.org/ (accessed 1/30/12)
[10] http://nciia.org/ (accessed 1/30/12)
[11] http://www.asee.org/conferences-and-events/conferences (accessed 1/30/12)
[12] https://www.engineeringforchange.org/home (accessed 1/30/12)
[13] http://www.ieeeghtc.org/ (accessed 1/30/12)
[14] https://engineering.purdue.edu/EPICSU (accessed 1/30/12)
[15] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5741 (accessed 1/30/12)
[16] Duffy, J., Barington, L.,, Moeller, W., Barry, C., Kazmer, D., West, C., Crespo, V., "Service-Learning Projects in Core Undergraduate Engineering Courses", *International Journal for Service-Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, Vol. 3, No. 2, 2008
[17] Rosser, S. V. . *Female-Friendly Science*. Pergamon Press, Elmsford, NY, 1990
[18] Rosser, S. V. *Teaching the Majority: Breaking the Gender Barrier in Science, Mathematics, and Engineering.* Teachers College Press, New York, NY. 1995
[19] Seymour, E. & Hewitt, N. *Talking About Leaving: Why Undergraduates Leave the Sciences*, Boulder, CO: Westview Press,1997
[20] Coyle, E. J., Jamieson, L. H., Oakes, W. C , "Integrating Engineering Education and Community Service: Themes for the Future of Engineering Education", *Journal of Engineering Education*, Vol. 95, No. 1, January 2006, pp. 7-11.
[21] Coyle, Edward J., Jamieson, Leah H., Oakes, William C, "EPICS: Engineering Projects in Community Service", *International Journal of Engineering Education* Vol 21, No. 1, Feb. 2005, pp. 139-150.
[22] Michaud, Francois, Clavet, André, Lachiver, Gérard, and Mario, Lucas, Designing Toy Robots to Help Autistic Children - An Open Design Project for Electrical and Computer Engineering Education", *Proceedings of the ASEE Annual Conference,* St. Louis, MO, June 2000
[23] Tsang, E. (Ed.). *Projects that matter: Concepts and models for service-learning in engineering.* Washington DC: AAHE, 2000.
[24] Lima, M.and Oakes, W. *Service-learning: Engineering in Your Community,* Great Lakes Press, 2005.
[25] http://www.compact.org/ (accessed 1/30/12)

[26] http://www.servicelearning.org/ (accessed 1/30/12)
[27] http://www.ewb-usa.org/ (accessed 1/30/12)
[28] http://www.eswusa.org/ (accessed 1/30/12)
[29] http://www.ewh.org/ (accessed 1/30/12)
[30] http://appl003.lsu.edu/slas/ccell/facultyinfo.nsf/$Content/Handbook+for+Faculty?Open Document (accessed 1/30/12)
[31] https://engineering.purdue.edu/EPICS/Resources/Grading (accessed 1/30/12)

Students from the University of the Valley of Guatemala-Altiplano learn to maintain a manual backpack spraying device to enhance community crop production.

"You must look within for value, but must look beyond for perspective."

— Denis Waitley

CHAPTER 8
International Perspectives on Service Learning

Manuel C. Belino, PhD
Mapúa Institute of Technology
Manila, Phillipines

Martina Jordaan, PhD
University of Pretoria
Pretoria, South Africa

Carlos R. Paredes, PhD
University of the Valley of Guatemala
Guatemala City, Guatemala

The authors of the preceding chapters were all from universities located in the United States and have been engaged in Learning Through Service (LTS) activities, both domestically and internationally, from that perspective. It is worthwhile for the reader to obtain some insights on service learning in engineering from others who engage in similar work but are located at universities around the world. What types of programs are being employed by universities outside of the United States? How are they structured? What have they found to be successful over the years, and what suggestions do they have to enhance LTS programs overall?

Four universities who engage in LTS efforts are highlighted in this chapter: De la Salle University and Mapúa Institute of Technology (MIT), both in Manila, Philippines, The University of the Valley of Guatemala (UVG), Guatemala City, Guatemala; and the University of Pretoria (UP), Pretoria, South Africa. A special thinks to ASME for their assistance in identifying universities for inclusion in this chapter. The universities themselves are briefly described in the following paragraphs followed by an elaboration and description of the programs they offer in service learning in engineering. A comparative summary of the programs concludes the chapter.

University Descriptions

De la Salle University, Philippines

De La Salle College was founded in 1911 when the Brothers of the Christian Schools opened a school in the Manila. The academy grew in 1917 when the school was granted a charter authorizing it to confer an Associate in Arts degree, and again in 1930, when the College was authorized to confer the degrees of Bachelor of Science in Education and Master of Science of Education. During the Second World War, the College grounds were seized by the Japanese occupation forces and made into defense quarters. Classes continued during the war years, but academics suffered from a greatly reduced curriculum as did the welfare of the Brothers. On February 12, 1945, a band of Japanese soldiers massacred 16 Brothers and several families who had taken refuge with them in the College Chapel along with many others who were taken prisoner. Home from concentration camps at the end of the war, the Brothers resumed classes in July 1945.

During the following years, the undergraduate schools of Engineering (1947), Arts and Sciences (1953), Education (1959), Industrial Technology (1973), and Career Development (1980) were established. Also established were the graduate schools of Business Administration (1960) and Education (1963). As a result of the outstanding academic and professional contributions the school had made to Philippine private education, De la Salle College was elevated to the status of De la Salle University in 1975. The College of Industrial Technology was integrated with the College of Engineering in 1979 as an Engineering Technology Program. The Bachelor of Science in Computer Science Program was started in 1981 upon the organization of the Center for Planning, Information, and Computer Science. Beginning 1984-1985, the Computer Science Program was spun off as a program under the College of Computer Studies.

Mapúa Institute of Technology, Philippines

Mapúa Institute of Technology (MIT) is a non-sectarian institute for higher learning and a pioneer in technical education in the Philippines. The institute initially started out as a night school with 80 students enrolled in civil engineering and architecture. Today, MIT is the largest engineering school in the Philippines with at least 15,000 students. MIT was established in 1925.

The Institute is a reputable source of architects, engineers, and science graduates and constantly produces top caliber graduates in the architectural and engineering fields. MIT specializes in these fields at both the undergraduate and graduate levels. The university also has a wide array of other undergraduate programs, including: civil engineering, electrical engineering, industrial engineering, as well as computer science, multimedia arts and sciences, information technology, accounting, entrepreneurship, business management, hotel & restaurant management, and nursing.

The Institute has been granted Level IV Accredited Status to its Civil Engineering program by the Philippine Association of Colleges and Universities Commission on Accreditation (PACUCOA). It is one of the first engineering programs to be accorded such status. In addition, the Commission on Higher Education (CHED) recently recognized Mapúa's Mechanical Engineering (ME), Computer Engineering (CpE) and Electronics Engineering (ECE) programs as Centers of Development for Engineering (COD). Mapúa is also the first Philippine and East Asian educational institution to have ABET certification, judging the Institute to be on par with US-based colleges and universities.

Universidad del Valle de Guatemala

The Universidad del Valle de Guatemala - UVG (University of the Valley of Guatemala) is a private, not-for-profit, secular university located in Guatemala City, Guatemala. It was founded in 1966 by a private foundation which had previously overseen the American School of Guatemala. UVG operates three campuses: Central Campus in Guatemala City; Altiplano Campus in Sololá serving Mayan communities on a former military base; and South Campus serving agricultural communities on Guatemala's Pacific Coast. At present, the University has over 3,500 students enrolled at the three campuses. It was the first private university to provide a strong emphasis in technology in the country. Today, what distinguishes UVG from other high-quality Guatemalan universities is its innovative, practical approach to tackling the problem of accessibility to education for the Maya and other rural poor.

Prior to 1960, Guatemala effectively had only one university which was the State University, Universidad de San Carlos de Guatemala (USAC). USAC alone offered degrees, including those in engineering, medicine, law, economics, and social sciences. USAC was founded in 1879 and, until 1930, offered a degree program in "Topographic Engineering". In 1930 the name was modified and a degree program in Civil Engineering was subsequently offered. In 1960, private universities were permitted to offer courses for the first time with nearly all of them offering engineering degrees.

The University of the Valley of Guatemala was authorized in 1966 and initiated its engineering program within the School of Science and Humanities. Nevertheless, the engineering student population grew exponentially up to the point where they reached 30% of the student body. UVG began awarding engineering degrees in the early 1980's. With the high number of students enrolled in engineering, it was decided to separate engineering from Science and Humanities in 2005. The School of Engineering was founded in 2005.

UVG strives to produce professionals, trained technicians, and educators to be responsible problem solvers who can help Guatemala improve its education and health care systems; modernize its agriculture and food production systems; manage its priceless natural resources and promote an appreciation for its rich history and cultural diversity; and, secure a strong position in the world economy of the 21st century. UVG currently has nine engineering majors (Food Science; Computer Science and Information, Communication Technologies; Civil; Electronic; Industrial; Mechanical; Mechatronics; Management Science; and Chemical).

University of Pretoria

The University of Pretoria (UP) is the leading research university in South Africa and one of the largest in the country. The University has seven campuses as well as a number of other sites of operation, such as the Pretoria Academic Hospital. Central administration is located at the Hatfield Campus. UP offers more than 1,800 academic programs in two of the official languages, namely Afrikaans and English. Some programs and modules are offered only in English. In 1996, the University of Pretoria became the university with the highest research output in South Africa and has maintained this status. The University of Pretoria celebrated its Centenary in 2008.

The academic programs of the University are offered in nine faculties, as well as a business school. The faculties comprise a total of 140 departments and 85 centers, institutes, and bureaus. UP is at the forefront of tertiary education in the country and collaborates with world-class partners to ensure continued excellence in learning and teaching.

Program Descriptions

De la Salle University

The University believes the Christian man and woman will provide needed leadership in the development of the Philippines. The school seeks to develop this leadership quality in its students through a liberal Christian education. Its commitment to this type of education is based on a belief in the importance of Christian values and in the development of a concern for the country's social and economic problems by its students.

Toward this end, the De la Salle University-Manila Values Formation Program PAGKAMULAT (Panlipunang Kamalayan tungo sa Makabuluhang Layunin, Aksyon at Tungkulin) was introduced into the College of Engineering (COE) in 1989. The scope of responsibility of the Community Involvement Committee (CIC) of the College was broadened to include the promotion of La Sallian values - thus changing its name to Social Involvement/ PAGKAMULAT (SIPAG) Committee. The committee continued to evolve as the awareness and practice of the professional and ethical responsibility of engineers were integrated in the committee's work. The integration of such concern is not only due to the increased interest in the study of ethics today, but also the intent to actualize the vision-mission of the University and the mission statement of the College. Excerpts from these documents are as follows:

> …" Inspired by the charism of St. John Baptist de La Salle, the University harmonizes faith and life with contemporary knowledge to

nurture a community of distinguished and morally upright scholars who generate and propagate new knowledge for human development and social transformation." (DLSU- Manila Vision and Mission Statement),

…" to nurture technically competent practicing engineers imbued with La Sallian values who will spearhead the technological advancement and economic development of the Philippines and the improvement of the Filipino's quality of life." (COE Mission Statement).

To reflect this added dimension of the committee, it was re-named "SERVECom" which means Social/ Ethical Responsibility and Values Education Committee.

SERVECom is a permanent committee in the College of Engineering with a coordinator who reports directly to the Dean. Unlike some of the committees in the College, its Coordinator does not receive any honorarium and its membership consists of volunteers representing all the departments and sectors such as faculty, academic service faculty, co- academic personnel, and undergraduate and graduate students. The committee usually meets once a month or as necessary and is supported by a modest budget in the Dean's office to cover the meeting expenses and office supplies. Financial resources to support its projects are tapped from the departments, student organizations, the University Center for Social Concern and Action (COSCA), individual donors, government organizations (GOs), and non-government organizations (NGOs).

The objectives of SERVECom are:

1. to integrate whenever appropriate La Sallian values in the program and activities of the College.
2. to promote the awareness and practice of professional ethics in the College.
3. to promote volunteerism among faculty, students, and staff in the College's social action activities.

4. to tap the expertise of the College in servicing partner schools, communities and /or NGOs.

To accomplish these objectives, the committee undertakes the following:

1. To conduct lectures, seminars, or workshops on La Sallian values and professional ethics in engineering.
2. To encourage the COE community to attend religious activities such as retreats, recollection, prayer meetings, Bible studies, etc.
3. To sponsor masses on important occasions in the College and the University.
4. To coordinate with appropriate university units such as Center for Social Concern and Action (COSCA) and La Sallian Pastoral Office (LSPO) on community extension projects and Lasallian values integration program and religious activities, respectively.
5. To link-up with Lasallian Outreach & Volunteer Effort (LOVE) and form COE pool of volunteers.
6. To coordinate with external agencies such as GOs and NGOs on possible collaborative social action prospects.
7. To disseminate the activities of the committee through the bulletin boards, newsletter, and internet.

Mapúa Institute of Technology

The founder of the Mapúa Institute of Technology, Don Tomas Mapúa, envisioned an educational institution that emphasizes the importance of science and technology as well as one that creates an impact on the community and the quality of life of the Filipinos. The legacy of Don Tomas continues as the Institute's mission embodies it and states: "…the Institute engages in research with high socio-economic impact … and brings to bear humanity's vast store of knowledge on the problems of industry and community in order to make the Philippines and the world a better place" Similarly, the vision-mission of the School of Mechanical and Manufacturing Engineering (SMME) puts equal importance to community or extension service as follows: "… undertake community extension projects that uplift the living conditions of the poor and preserve the environment …".

To actualize both the Institute and the School mission, the Office of Social Orientation and Community Involvement Program (SOCIP) directs the extension service activities of the institution. Each school or department renders extension services related to the program, or field of expertise which includes participation by the administration, faculty, support staff, and students. The SMME has identified three extension service projects which we focus on:

a) Adopt-an-Engineering-School - an outreach project to a rural public college offering mechanical engineering which involves faculty and student development seminars/workshops/trainings, sharing the use of the Mapúa's laboratory facilities, book donation, and assistance to students for their industry internship;
b) Welding training program for the out-of-school youth in urban Manila (a program that equips poor young people with employable skills); and,
c) Installation of small-scale renewable energy power systems such as micro-wind and micro/pico-hydro-electric plant in the countryside.

The community/extension service activities undertaken by both of these academic institutions coincide very well with most companies' corporate social responsibility programs. Some companies have started to partner with our teams on projects such as the development of an electrical energy storing see-saw and merry-go-round for an orphanage playground. Others believe that such activities/ projects contribute to the character formation of the students, and thus, must be further promoted by the universities.

For both academic institutions, financial support for the projects comes from various sources like the school allocated budget, professional societies, civic organizations, government agencies, and industry. The community/extension service activities are undertaken as extra-curricular activities spearheaded by the student organizations or as co-curricular activities through one- year undergraduate thesis projects. Examples of MIT projects are pico/micro-hydro-electric plants; micro-wind turbine electric plant; and the merry–go–round for an orphanage playground. It must be emphasized that these projects are required for undergraduate students for their thesis project. The theses projects are required for graduation and students receive credit for them. Faculty members are assigned as thesis mentors/advisers. For DLSU, students receive numerical grades for the project, while MIT assigns a pass/fail grade. However, there are community/extension service projects undertaken by faculty, non-teaching staff, and students which are not considered curricular but extra-curricular activities for the students. In addition, neither institution has any certificates, minors, or majors in such disciplines.

In both academic institutions, projects undertaken in the communities are covered by a formal contract similar to a Memorandum of Agreement (MOA) or an informal Certificate of Commitment (COC). The role and responsibilities of each party are identified and agreed upon. The champions of the project typically include the coordinator of the community, or the extension service committee and its members along with the student leader of the volunteer teams. It is usually the Barangay Chairman (the local chief of the smallest political unit called ''barangay') or his designated leader who is the champion on the part of the community.

Sustainability of the project is always sought. Striving for social sustainability, meetings typically are held with various stakeholders prior to the implementation of the project. Community preparation, participation, and involvement are key elements to the success of the project. Before moving forward, the community must have a voice in the project and accept the project, and normally welcomes the team through a ceremony/ritual of the indigenous people. The relationship between the community and the school nearly always continues even after the completion of the project. A school representative occasionally pays a short visit to the community.

An example is used to demonstrate how economic sustainability is incorporated into our projects. In the case of the pico/micro-hydro electric plant installation, community organizers initiate the project by educating the leaders and members of the community as to the nature of the project and the benefits to be accrued. The community must feel comfortable contributing to the effort by contributing a minimal amount of money every month for the operation and maintenance of the plant. The community is advised to be self-reliant with minimal support from the school after the completion of the project. In the future, a cooperative system will be introduced in some communities.

From an environmental perspective, the micro-renewable energy systems are by themselves eco-friendly. This is the very reason these projects are readily accepted by the community.

Some identified members of the community are trained to operate and maintain the pico/micro-hydro electric plant to ensure technical sustainability. This assures the smooth operation of the plant after the completion of the project. However, technical advice from the school experts is rendered whenever needed. The university/institute representative through the College/School/Department community/extension service coordinator conducts an occasional visit to the community or there is informal communication between the coordinator and the community leader since a relationship has been established in the course of doing the project. Thus, formal and informal communication take place. The informal one is often frequent because this communication mode is cultural and the use of cellular phone technology makes it faster and easier. The school sees to it that a number of young faculty are trained to assure the continuity of the project should the senior members resign or retire.

Other examples of projects through De la Salle University are the design of low cost transport equipment and agricultural machinery such as mountain buggy, hybrid micro-transporter, electric vehicle, mobile drilling rig, and power-driven stripper harvester with re-thresher and cleaner.

The projects mentioned above are not only design projects. Often they provide opportunities to engage in research to enable successful design.

So far, we have not encountered any issues related to liability, although we believe it is an important consideration. If ever it becomes an issue, this is an item that we will include in the memorandum of agreement. Entrepreneurship (technopreneurship) is promoted to mechanical engineering students. They are encouraged to pursue thesis projects that have potential commercial value, but no formal coursework is offered in this area. Once in a while a seminar or a talk on technopreneurship is held for the senior students. The academy is open to offering technopreneurship as an elective course.

Feedback on the projects is obtained from both the faculty and the students through interviews and focused group discussions. The MIT Office for Social Orientation and Community Involvement Program (SOCIP) requires participants in every activity to complete a post- project assessment report. Some of the insights and lessons learned by faculty and student volunteers are captured in remarks such as the following:

> *"Although the project that we did in Ifugao was very basic engineering as compared to what we are learning in the classroom, its social impact was very evident as it changed the daily life of the people in the community through the provisions of electricity, a basic need that we enjoy and yet taken for granted."*

> *"It made me feel great as an engineering student to see the joy in the eyes of the people in the community when they saw for the first time lighted bulbs in their households."*

> *" I appreciated more my chosen profession in the way that I could apply so far what I have learned in engineering to help people, more so, an indigenous community."*

> *"I learned not only engineering stuff in this project but also the rich culture of the upland people in the Philippines."*

> *"It made the students realize how noble the engineering profession is through the accomplishment of such a relevant and meaningful extension service project which does not only improve the human condition but also uplifts the human spirit".*

University of the Valley of Guatemala

UVG has a project called "Engineering for Life" that partners with communities and seeks to engineer solutions to their day to day problems in health, food security, and economic survival. Engineering For Life is a program within a research project called Centro de Estudios Atitlan (CEAt). This research center started in 2009 as a result of an outbreak of cyanobacteria that polluted the clear water of Lake Atitlan close to the Altiplano Campus. The program seeks to apply engineering techniques to improve the life of the people within the lake basin. For example, biodigestors produce biogas for cooking purposes and the resulting reduction of deforestation. Water treatment systems are installed to demonstrate to communities the benefits of having such technologies. UVG has also demonstrated how to build macrotunnels (protected agriculture) so they will increase their crop productivity. The overall thrust of the program is to improve the lives of people by applying cheap and simple engineering techniques that can easily be applied by rural population.

Many students at UVG enroll in organizations like Students in Free Enterprise (SIFE) and develop entrepreneurial programs in the remote areas of Guatemala to benefit the people by improving their income. SIFE is an organization which brings together a diverse network of university students, academic professionals, and industry leaders around the shared mission of creating a better, more sustainable world through the positive power of business. By contributing their talents to projects that improve the lives of people worldwide, SIFE helps our students envision themselves as powerful forces for change.

USAC has offered an extension program from its inception through the "Ejercicio Profesional Supervisado" (EPS). The extension program is a practice period where the senior students must perform service related to their academic discipline in the countryside of Guatemala. The effort is mentored by staff from the USAC. The student is directly involved in applying their degree on behalf of the community. Social entrepreneurship has been part of the curriculum since the early 2000's and is available to students enrolled in engineering at USAC and most of the private universities, including UVG. Students typically are introduced to entrepreneurial concepts in courses where they are required to present a final project related to starting a business using the product of their design.

Slowly, the student communities at USAC and UVG have been focusing their enthusiasm and interests in helping the needy population in the countryside. The EPS students from USAC spend a semester in a rural community assigned by their school. In some cases these communities are very remote and the students live there for the entire term. This is mandatory. Private universities have not implemented a mandatory EPS. Most private universities are trailing behind USAC and their program with the EPS, but the impact of the work done by the private universities on the communities has been larger and more direct than USAC's.

Extension work is not mandatory at UVG and it is not clocked as part of the curricula. For UVG students, the work done through SIFE and UVG Student Association has generated an enthusiasm that has many students voluntarily doing extension work in areas close by their campus. Since 2009 they have extended their actions to more remote communities travelling sometimes 200 miles to reach them during a weekend work trip. The student enthusiasm is remarkable.

USAC's EPS program is a model program but lacks institutional coordination within the university. For example, engineering students might go to build a health station but the medical school sends their students to other places. That is why the EPS is described as more of an individual effort by the student and not more of an organized university effort directed to specific communities.

Another exciting result of our work is that industry has been slowly adopting a philosophy of increased social responsiveness through their Corporate Social Responsibility Programs. They are becoming much more supportive of such university efforts. They view such programs as a means of improving their image in the community as well as a means to have the graduates gain experience both as an engineer and by assuming a role in their Community Social Responsibility Programs. The largest business enterprises have such programs and if their recruits have training and experience in such activities, the effect is improved. For example, Exxon has a program where all their executives help maintain a school. They build walls, paint chairs, and have a much greater impact in the community due to their long term commitment. Perhaps this increased corporate interest in social responsibility is due to the efforts undertaken in our problem-based classes and communities not relying on free professional services.

While industry as a whole though has not yet asked for such training, it is very pleased that our graduates engage in such activities. Numerous major business enterprises (Exxon, Cementos Progreso, Pollo Campero, Ingenio Pantaleon) refer to the positive benefits for their firms due to the UVG graduate/trainee possessing greater social awareness.

In the case of our university, these programs are supported by donors/foundations managed by UVG. Some programs, like SIFE and AIESEC, are by nature self-sustaining and must generate their own funding. AIESEC ('Association internationale des étudiants en sciences économiques et commerciales' or the 'International Economic and Commercial Sciences Students Association') is the world's largest youth-run organization, present in over 110 countries and territories and with over 60,000 members. AIESEC has 60 years of experience in developing high-potential youth into globally minded responsible leaders. The organization focuses on providing a platform for youth leadership development, offering young people the opportunity to participate in international internships, experience leadership, and participate in a global learning environment. AIESEC is run by young people for young people, enabling a strong experience to all its stakeholders.

None of these projects are embedded into the curriculum. The SIFE students must organize themselves and assemble a "mentor committee" composed of SIFE alumni and industry people who will guide them in the execution of the particular project. All mentoring is volunteer, but as they are mostly SIFE alumni this increases the enthusiasm of the students.

These programs have largely been extracurricular activities and the students are encouraged to participate. However, since 2010, due to modifications in the accreditation processes, these activities have become part of the extension activities of our university and now they have become a graduation requirement for the School of Engineering requiring 10 hours of extension work per academic year. Most students clock many more hours than this. Our university does not have any formal certificates or minors officially available for service learning credit, but the students can take elective courses related to the projects. USAC students must participate in such programs and it is included in the curricula.

Our relationship with communities can be very close at times, or can be more distant at others. Our projects are focused mainly nearby to our campuses. If the relationship starts in a relaxed fashion, it leaves open the possibility of quickly growing more focused and closer as the community sees positive results from the projects. Our campus of UVG-Altiplano is a perfect example. It is located on a former military base. People would not go into that area under any circumstances because of bad memories. Through the years, it has become a place of gathering and exchanging of experiences and is open to all. We can attribute this in part of our efforts in engaging the community. UVG-Altiplano works mainly with very poor local people (mayan descendants) and our champion is our Community Liaison Officer. He is local and knows the people and how to speak to them in their own language. The UVG Central and UVG-Sur campuses work with more Hispanic people and the champions are the dedicated project leaders.

We strive to do more than simply engage in a project and then depart. UVG strives to make all aspects of our partnerships and our program sustainable. For instance, socially we strive to convince the people that following the project instructions/actions will be better for them. We use clear examples and make it directly applicable to their lives; for example, asking them to feed chickens with a different type of corn. The resulting stronger and larger chickens convince them that the corn was good food and it would be beneficial for humans. The development of trust is critical.

Economically, all of our enterprises must be economically self-sustaining. In fact, this is a requirement of our donors and also of the university. Our champions in these efforts are our SIFE partners. Part of the effort involves training the people on better practices, better products and how to obtain an additional value that would mean a price premium. Working together with different disciplines is a valuable experience for our students.

Environmentally, we strive to be very much oriented to protecting natural resources. Environmental impacts are evaluated in every project.

Just a few examples include:

a. Re-inventing a suburb: A very low class suburb with very bad reputation is shown how to recycle all sorts of materials (paper, plastic, aluminum, etc.) and profit from it. This project has been replicated in several other suburbs with equally good success.

b. Eco-weaving: Using leftover packaging material, the students teach community women how to weave it and prepare purses, wallets, bags, etc. and they also show the community where to sell them and obtain a profit from their activities.

c. Macro Tunnels: Many country people work with the sugar mills cropping sugar cane. This work is available for a 6 month period of time each year. The rest of the year the people have little income. Macro Tunnels is a protected agriculture technique that allows the families of these workers to have another income source by producing vegetables all year long. This has been a very successful project.

Our extension work is performed shoulder to shoulder with the marginalized communities as collaboration is essential for our success. The solutions proposed are customized to each community as they all have different particular needs and even the way of implementing them is different from one region to another. This is where the Liaison Officer of UVG-Altiplano comes in very handy to engage in frequent, direct communications with the communities themselves.

One area of concern is that of liability. We deal with some poorly educated people. They can be “handled” by ill-intended persons with personal interests. This is why the community has to be empowered within the framework of the project even before starting it. It must come from them instead of being imposed by our university. Lastly, we are constantly striving to incorporate entrepreneurship in all of our projects.

University of Pretoria

In 2005, the Faculty of Engineering, the Built Environment and Information Technology (EBIT) at the University of Pretoria, South Africa, implemented a new compulsory undergraduate module entitled *Community-based Project*. This initiative was a new endeavor for the faculty and was the first of its kind for EBIT students in South Africa. Community-based learning was not included in the existing modules at the time, and therefore the establishment of a new, separate module was necessary. The main aim of the module is to develop students' awareness of personal, social, and cultural values, as well as multidisciplinary and life skills, such as communication, interpersonal and leadership skills.

Community-based learning is a relative new field of learning. It is a form of experiential learning which aims to accomplish specific tasks which meets genuine human needs, as well as the execution of the tasks that serve as an educational and learning tool aimed at the acquisition of a number of important life skills by the students.

Students have the option of attempting the module in any one of their undergraduate years of study but preferably not during their final year. Depending on the nature of a specific project, it can be attempted in the course of a semester, during vacation time, or both, as long as they provide a service to the community. The module is compulsory and counts for 8 credits. That means that the students must work 80 hours on the module. The module is structured such that the students work 40 hours in the community and do assignments for the other 40 hours.

Projects may be executed by individual students or in teams. The condition for team projects is that a distinct task must be allocated to each team member. Multidisciplinary project teams that consist of team members from across the various schools and departments in the faculty are encouraged. There are certain set criteria that the project needs to comply to in the study manual.

Students have to choose projects in an area for which they feel passionate. This approach supports communities of practice on which the module is based. Students must also determine the community's needs before they choose a project. Learning opportunities are created in both work practices and in a social context. Through the projects, students have to solve problems in real-life learning situations. Students may form their own teams. These teams may include students from the various departments and schools (e.g. school for Engineering, the Built Environment and Information Technology) as long as the student(s) are enrolled for the module for that specific year. The main reason is that many of the students enrolled for this module are in their second year of study and are not yet qualified to conduct projects related to their specific field of study, such as electronic or mining engineering.

To engage in a project, the students first make an appointment with the lecturer and each project is discussed individually with the group. Students may form their own teams and may identify a project they are passionate about. There are various community projects where students are on the sites on a yearly basis. These community partners identify projects at the beginning of the academic year and submit it to the lecturer. New community partners also forward requests to the lecturer and these projects are assessed if it falls into the criteria of the outcomes of the module. Students also may identify their own project. Students from rural area always prefer to go back to their own communities for their outreach project.

The students attend compulsory orientation sessions and then submit their projects in the form of a proposal for evaluation and approval. The students set up a project proposal meeting with the lecturer. During this hour session the project is discussed, the community is contacted to confirm that the students may work on/in their site, and a meeting between the students and the community is set. The student's project is loaded on the e-learning management system, the finances for the project are discussed, and how they will go about to utilize it. In the case where they will use University transport, the transport costs and bookings will be done. The student's blog report will be created.

If the project falls in the criteria set by the module, the students may continue with the project. They may not start with the project before they discussed it with the lecturer. Each student receives an amount of R300 – R500 (± $37- $61) for their expenses, including transport. Students may only use the money for transport and materials and not lodging or food. Most of the money allocated to the module comes from the University budget, but there are also various sponsors involved, e.g. Telkom, Denel, the City of Delft (The Netherlands).

Students may request the money in advance as flat rate. If they use University transport, the cost of renting will be deducted from their allocated funds. Many students also find donors and sponsors for their project. (e.g. a group found a sponsor for R22 000.00 ($2699.00) in 2011).

Students then begin their fieldwork in the community of at least 40 hours. After the students have done their fieldwork they report on their experiences and lessons learned via a presentation and report in the form of a blog.

Most of the participating students are only in their second year and as such undertake very elementary "engineering" projects. Very few big constructional projects are done. For example, students may repair jungle gyms or build a hoist feeder for the giraffe in the zoo. Prime partners in these efforts include the National Zoological gardens of Pretoria and the Johannesburg Zoo as well as the Air Force Museum and Military History Museum. Also, South Africa has a huge problem with a lack of qualified mathematics and science teachers. Therefore, one of the most popular projects has students, especially from rural areas, going back to their own schools and assisting learners with math and science.

A person in the community has to assess the students at the end of the project and sign off on the project that they are satisfied that the work is satisfactory. In the case where the community is not satisfied with the work, the student may not pass the module. The lecturer discourages students to undertake design and construction of complex structures as it may lead to liability issues.

Table 8.1 Number Of Students Enrolled For The Module

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
JCP 201* (School for the Built Environment)	103	156	250	226	248	262	264	261
JCP 202* (School of Information Technology)	14	165	218	258	231	316	367	321
JCP 203* (School of Engineering)	121	417	742	1213	816**	919	960	1001
TOTAL JCP-students	238	738	1213	1697**	1295	1495	1591	1583

*Code of the module
**Students initially had the option of choosing between two modules. From 2009, this choice has not been available, hence the lower enrolment figures.

The Community-Based Project Module office has only one permanent staff member. Former Community-Based Project Module students are employed as office assistants and drivers to handle the huge number of students and the various administrative tasks, including basic administration, booking transport, and organizing drivers. They interview applicants for posts and train them, thereby taking ownership of the process. Students are preferably appointed as assistants in their third year so that they are available for two more consecutive years. The lector appointed to manage the module is responsible for the following:

- Orientating students of the expectations of the module and their field work
- Identifying possible projects for the students
- Identifying and establishing community-campus partnerships
- Assessing the students on the outcomes and reflections of their field work

Managing the logistics of the module includes the transport of the students to their community sites as well as handling the funding received to execute the projects. There is one full-time lecturer responsible only for this one module. The lecturer visits communities before the academic year to establish needs in various communities and the communities also forward requests for assistance to the lecturer. Lecturers, in collaboration with communities, may choose the projects. Students may also identify projects themselves. Often times the communities request assistance.

Table 8.2 Number Of Projects And Community Partners From 2005 To 2011.

	2005	2006	2007	2008	2009	2010	2011
Number of projects	47	244	345	475	445	432	545
Number of community partners	31	186	267	381	288	265	402

As can be expected, the number of projects increased as the number of students increased. The average size of the groups is two to four students.

Sustainability is attained through **s**tudents handing projects over to following year's students, through the mentors assisting new students, and via agreements with communities to continue projects at site. Funding for travel to the sites is only provided if there is again a project taken place by the JCP-students on the specific site. It differs from project to project. Students sustain the websites they build for the communities; or the outdoor playthings of a pre-school are fixed again the next year. Unfortunately, the students only work 40 hours during the whole of the academic year and social entrepreneurial projects needs continues support. The projects therefore are intensive short outreach efforts that address a specific need of a community.

Both research and design projects are undertaken, as well as entrepreneurial efforts. However, these are very difficult to implement in the community-engagement module as students only work 40 hours a week and the best option for a successful entrepreneurial project is a champion on site.

The following assessments are required from the students to complete the module successfully. Most of the assignment are done on the e-learning management system (Blackboard) that is used on the campus:

- An assignment on the first contact session
- An assignment on the second contact session
- Opinion Polls 1,2 and 3
- A reflection assignment using De Bono's thinking caps
- An assignment on HIV/AIDs in the workplace
- An assignment on gender awareness
- The assessment of the community
- A log statement indicating the hours worked
- A presentation to the lecturer
- A report in the form of a blog that is assessable from the Universities website http://blogs.up.ac.za/jcp2011/index.php

There are definite changes in attitude in the students with regard to their outreach projects from the first opinion poll before they start with their project to the final opinion poll (completed after their projects conclude. The students are also required to reflect on their experiences in the blog report, a presentation, and the reflection assignment. A high percentage of the students show a positive attitude change from the start of the project to the end of the project. This may also be attributed to the fact that they may identify a project according to the set criteria and work with a team they feel comfortable with. The module's outcomes concentrate on the development of soft skills, creating a better understanding of the socio-economic issues in a post-apartheid South Africa and creating of citizenship by the students. The assessments done by the communities give feedback on the performance of the students via an assessment form. They are also required to indicate that the students worked the set hours required for the module.

Students that receive sponsorship from various industries must confirm on a yearly basis that they did work at least 40 hours in the communities. A "bursary" is a sponsor to assist with their study fees. Some students are employed, e.g. Air Force. They work during the recess (holidays) for the companies. Most companies prefer to sponsor the student, but do not employ the student at that time. However, the student will work for the company after they completed their studies. They have to complete the module as part of the undergraduate course to receive the degree but it is not necessary for the employment contract.

Various industries, for example Exxaro, get involved in the modules and industry does contribute to the support of the program and fund projects.

The project efforts are very often multidisciplinary. Even though a module may be a separate module in the curriculum of the Faculty, it is still strongly linked with the outcomes of the other modules.

The champions at the university who provides oversight are the lecturer for the module and the Dean of the Faculty. The community champions include: leaders in communities, NGOs, NPO's, schools, and government departments.

The University is legally responsible for the projects and is handled differently from project to project and community to community.

Some of the insights and lessons learned by student are captured in remarks such as the following:

"The JCP experience was very interesting, it took us out of our comfort zones and made us realize that poverty is a reality. We actually saw that there are people who have far less and are far happier with it (or at least appreciate it more) than we are with all our privileges. It was a lot of fun to build the vegetable garden, especially since we knew someone else was going to benefit from it. Hopefully we made life a little easier for the children and the people who take care of them."

"Having done this really opened my eyes to what we have and what we should be grateful for. What we might have as a luxury, these kids need as a necessity. These kids crept into our hearts. The work was hard and it took some time, but with perseverance, we finished the job with exceedingly great results. We made the vegetable garden with the thought that in the future, it will benefit them. It will feed them and help them grow, not only physically, but as a unit. This experience has been life changing and helped me grow as a person."

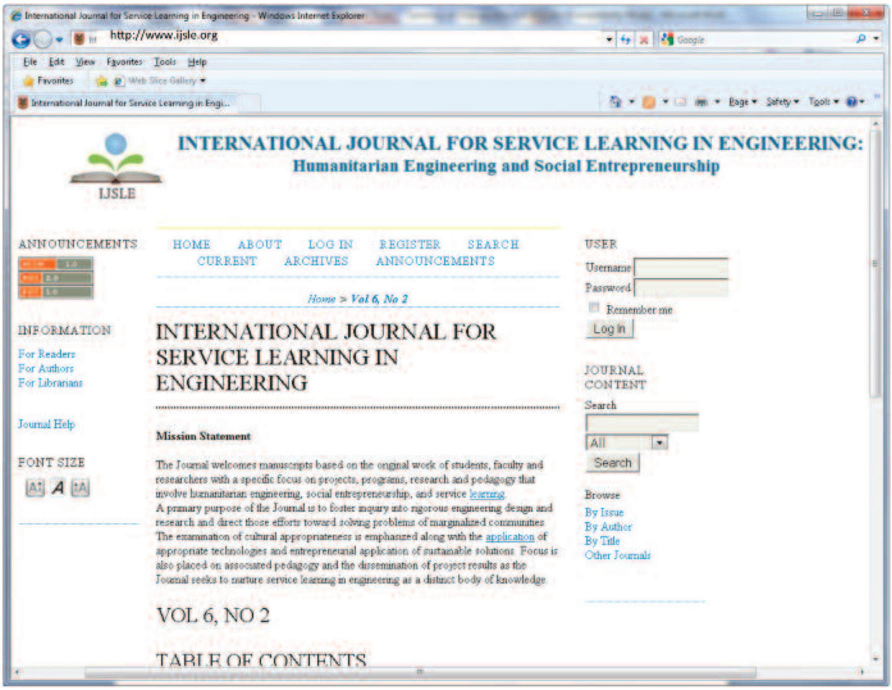
Summary

As evidenced by the comments made above from four different universities' perspectives, many of the same issues related to the LTS efforts at universities in the United States are experienced by universities around the world. What stands out first and foremost is that all of the universities consider the engagement by students in real world projects which impact the community as valuable. Each of the programs felt immersion and interaction with the communities was critical. Sustainability was key in all responses. A focus on the social, environmental, and economic sustainability aspects of the projects was important. In particular, each mentioned how corporate and businesses see value in the efforts and are incorporating such activities into their corporate missions to engage societies in positive ways. There were obviously different methods of implementing such programs. Whether the academy embeds the projects in the curriculum, does not embed in the curriculum yet requires such engagement as a graduation requirement, mandates an entire program dedicated to all students engaging in LTS, or, relies on volunteers, what was consistently expressed was the need to have the students engage in a fashion to utilize their academic skills and create positive benefits for the communities.

Liability was mentioned as a concern by all, but nothing that has arisen has caused major problems with projects. Likewise, entrepreneurship was mentioned by each institution's representative as useful, but there were not formally structured programs to integrate this effort for all participants.

In comparing the efforts from these universities to those located in the United States, some common areas stand out. First, the level of interdisciplinary engagement is valued but not necessarily inherent in formal programs. Second, the level of academic rigor is often not maximized, instead focusing on the 'softer skill' benefits for the students. Third, little or no research efforts into the problems of marginalized communities was evidenced. And lastly, entrepreneurial interventions to take technologically appropriate products and processes to market and ensure their economic sustainability were not central to many of the discussions.

However, the similarities and predispositions from all concerned indicate that a critical point has been reached. There is a strong recognition that students and faculty located at institutions of higher learning around the world perceive that they have the ability, the responsibility, the means, and the inclination to step forward and begin to make a difference. As these many differing approaches to integrating academia, industry, community, social, and economic concerns evolve, the path is clear - a convergence of interests from many stakeholders to 'do good while doing well' is expressing itself around the world.



"Every time our ability to access information and to communicate it to others is improved, in some sense we have achieved an increase over natural intelligence."

— Vernor Vinge

CHAPTER 9
Open Access Scholarly Knowledge: a Common Wealth

Usman Mushtaq
Queen's University

Background

The debate about open access of academic research is old news for some[1,2] but it is worth revisiting here in this forum. The *International Journal for Service-Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship* (*IJSLE*) is committed to recognizing and disseminating scholarship in the areas of humanitarian engineering, social entrepreneurship, frugal engineering, and service learning in engineering and the associated collaboration with marginalized communities. The journal serves as a platform for communities, students, academics, and practitioners to share their experiences in humanitarian engineering, social entrepreneurship, frugal innovation and service-learning in engineering; and to learn from one another. Through this, the editors of the journal hope to encourage more students to demand more meaningful and beneficial projects in their curriculum, for faculty to connect students with complex "real-world" issues, and for communities to see the action potential of engineering students. This means not only providing open access of knowledge to fellow academics, but also to students, communities, and professionals outside academia. Without this open access, the journal would not be financially or physically accessible to many of the audiences outside of traditional academia.

The journal recognizes the Open Society Institute's definition of open source:

> *"By "open access" to this literature, we mean its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining*

> *access to the internet itself. The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited"*[3].

As such, the *International Journal for Service-Learning in Engineering* remains open to both authors and readers. No author fees are charged for publication nor are subscription fees charged. The journal allows (and encourages) the distribution, sharing, and copying of the articles in the Journal through use of the CC-BY-SA copyleft license[4]. Keeping in mind the commitment to be fully accessible to all stakeholders, yet maintain the financial sustainability of the journal, the editors of *IJSLE* have fully adopted the open access model by employing the Open Journal System (OJS), an open-source journal management system developed by the publicly funded Public Knowledge Project[5]. However, the *IJSLE* is not by any means a forerunner in adopting the open-access model.

History of Open Access

Academic journals like the *Electronic Journal of Communication*, a peer-reviewed journal published by the Communication Institute for Online Scholarship, have been freely accessible online since the early 1990s[6,7]. Over the course of the 1990s, many other peer-reviewed open access journals were created, many from editorial staff leaving already established journals[7]. Still, these journals could not shake off perceptions of low-quality and low-impact among traditional academics, leading many of them to flounder and eventually disappear[8]. To challenge these perceptions, the Open Society Institute in Budapest called a meeting in 2001 on open access. In this meeting, participants from academia, government, and civil society created the Open Access Initiative, which called for open access to peer-reviewed journal literature through both open-access journals and self-archiving[3]. While some of the more negative perceptions remain, open access journals over the course of the last few years have come to be seen by many authors to be just as impactful and quality-driven as their toll access brethren[9]. Coupled together with rising fees for libraries to access journals and increasing monopolies in academic publishing[10], more authors and academic institutions are beginning to see open access as a viable option than ever before even though some barriers remain[11].

In January 2010, an expert panel on academic publishing submitted a report to the U.S. House Committee on Science and Technology requesting that all research-funding agencies develop explicit public-access policies[12]. Today, the Directory of Open Access Journals (DOAJ), a collection of scholarly peer-reviewed open journals, lists 4,801 journals in fields from agriculture to archaeology to philosophy[1].

Debating Open Access

Yet, the debate about open access of scholarly knowledge is still ongoing. Critics of open access argue that open access merely shifts the financial responsibility from the reader-subscriber to the author[13]. For example, Public Library of Science (PLoS) journals, an open access academic publishing non-profit, charges authors fees to publish; however, the publication is freely accessible to all readers[14]. This author-pays model is especially problematic for authors from low-income communities who have neither the personal income nor the institutional funding to afford authorship. In this case, publications would be biased towards authors from the Global North[13]. On the other hand, supporters of open access claim that authors in the Global South often struggle more with a lack of knowledge of open access and its benefits rather than authorship charges, as many open access journals will waive author charges for deserving authors[15]. This is a failing not of open access but of outreach from the open access community. In fact, open access archiving has been argued to be a "fast-track" to building research capacity in India[16]. Other studies have shown that authorship charges were actually a common practice since the early 1980s, even in the traditional academic publishing world[15], demonstrating that this model has worked quite well for traditional publishers.

In addition, critics of open access claim the author-pays model would create incentives for open access journals to be less selective of accepted articles in their publication as more articles would mean more profit[17]. BioMed Central, an open access publisher, debunks that by arguing that toll access journals have just as much motivation to include more articles to justify their high prices. In any case, a journal that does not publish excellent peer-reviewed content will see its reputation harmed[18]. The peer-reviewed system is self-correcting in that sense. Meanwhile, established publishing houses argue that the rising costs of toll access journals actually lead to profit that can be invested into the creation of research/publication tools or better editing that creates added value[17]. In a more "bare-bones" open access model, that same investment into publication and editing could not be made leading to a loss of value.

The biggest argument against open access, of course, is that the model is financially unsustainable even if authors pay[19]. The model is even more financially unsustainable if content is free to be published and accessed. These subsidized journals must rely on volunteer staff, institutional commitment, or funding agencies making it unsustainable to create a consistent product[20]. Open access supporters counter this argument by pointing out the variety of business models that have sprung up to tackle the issue of financial sustainability[21]. There is no one fixed open access business model. Many journals "mix and match" models to maximize access to the public. Bigger open access publishing houses like PLoS and BioMed Central are even able to make considerable investments into editorial and publishing tools that make their journals highly ranked in their respective fields.

Finally, there is the debate around impact, on which considerable literature has been devoted. Without going into too much detail, open access has been shown in multiple studies to increase impact by increasing access to literature either through open access publication or open archives[22,23,24]. However, this impact increase differs from field to field and from journal to journal. Peter Suber, an open source advocate, explains the high rate of high impact toll access journals by pointing out that many open access journals are new while many toll access journals have been established for quite some time[25]. If given some time to develop a reputation, open access journals should have just as much of an impact as already established toll access journals.

The debate around open access is by no means over. However, in the opinion of the *IJSLE* editors, the debate has shifted from whether open access is a viable option to that of "how can we use the full potential of open access", while keeping in mind the limitations of online access, financial sustainability, and public understanding of academic jargon.

With that in mind, the journal seeks to facilitate student learning, faculty scholarship, and community engagement via open access. By keeping the educational aspects in mind, we believe the open access community can start thinking about using the action potential of open access and proceed towards more community-oriented access.

Learning and Open Access

Those unfamiliar with the debate around open access often confuse the term open access with free access. However, free access is not open access[26]. An article that can be accessed without cost by the reader-subscriber is just the first part of open access. The second part of open access must be that the reader-subscriber has the full ability to share, reproduce (with attribution), and otherwise distribute the article free of cost over any medium to any audience. A journal that provides access to publications for free but does not allow authors to retain copyright or for reader-subscribers to distribute the publication cannot be considered open access[27]. However, this definition of open access is incomplete if the goal of open access journals is to provide access to scholarly knowledge to the proverbial "man on the street". After all, the desire for this "man on the street" to read the *Journal of Molecular Podiatry* has not "been subverted for the past century by the mercenary interests and narrow–mindedness of publishers"[28]. While Esposito says that ironically, there is some truth to the fact that many journals produce esoteric knowledge that is intellectually inaccessible to a wider audience of practitioners and students even in the field. As a journal that shows viewers how to connect with the needs of their communities and technology developers how to create in an appropriate context, the editors of *IJSLE* believe that our journal should be physically, financially, and, most importantly, intellectually accessible to a wider audience of students, community members, technology developers, educators, and community development practitioners. As such, our journal attempts to be relevant and accessible to this wide audience and that full open access is a prerequisite in addressing the "last mile problem"[29].

The "last mile problem" of knowledge is the two-step problem of gaining access to scholarly knowledge once it's published and then using it to answer questions[29]. Open access addresses the first issue of gaining access to scholarly knowledge. Under the open access model, all reader-subscribers have access to scholarly knowledge. However, just because a reader-subscriber can access and share scholarly knowledge does not mean they can apply it or understand it. Not only does scholarly knowledge need to be physically and financially accessible, but that knowledge needs to be shared and distributed in a way so that a wide audience can access it at a level of historical knowledge, language, academic jargon/culture, and theoretical background to use the knowledge in answering their questions. Otherwise, academic knowledge is merely,to draw an analogy from internet connectivity, the high speed cable line to the local dial-up network. That is the "last mile problem". While open access does not directly address the second part of the problem, it is a prerequisite to solving the issue entirely. The *IJSLE*'s editors believe, in our case, the definition of open access must be refined to include intellectual accessibility in both the issues discussed in our Journal (relevant not just to service-learning engineering educators) and the language/academic, culture/history/theory of our journal. Otherwise, our Journal will not be truly accessible to much of our audience.

As proof of the accessibility of our journal, a considerable part of our audience is students. In fact, the *IJSLE* includes quite a few publications from students by themselves or with faculty support. We believe open-access can be a powerful tool in connecting students with each other and with the latest knowledge in their field. An example of that can be found on the PLoS website, where many students provide comments/feedback on posted articles and essays[30]. It comes as no surprise then that students are among the most vocal advocates of open access recognizing that open access improves the education experience by providing them access to publications[31]. Through open access, students can access the latest scholarly knowledge regardless of geographic location, socio-economic status, or institutional support. As a journal dedicated to education, we want to make sure that the knowledge in our Journal is accessible to all students. Open access is one proven way forward.

In fact, open access is a necessary tool in the democratization of knowledge for all[32]. *IJSLE* is committed to bringing in voices that have been traditionally absent in engineering education. This can only be done though if the journal creates inclusive methods of contributing and sharing knowledge. Open access allows for that inclusivity. With that in mind, *IJSLE* remains committed to open access in the fullest sense and our move to the Open Journal System is part of that commitment.

The Open Journal System

The Budapest Open Access initiative describes two different approaches to open access[3]. The first path is the "gold" path of journals immediately releasing published material at no cost to the user-subscriber. The second path is the "green" path of authors choosing to archive their published material in the publicly accessible repositories of their institutions or journals after a time delay. *IJSLE* provides open access to both current published articles as well as archived material.

Due to this commitment to open access, the editors of *IJSLE* found that maintaining our own journal management and publication website was too burdensome. Therefore, we switched to the Open Journal System (OJS) in the summer of 2009. OJS is an open-source journal management and publication system specifically designed for newer peer-reviewed open access journals[2]. It is a creation of the Public Knowledge Project, a publicly funded initiative to improve the quality of research[33]. Taking the lead from other successful open access journals[34], we chose to move to the OJS platform for several reasons.

OJS was specifically designed to facilitate the work processes of an open access journal. Therefore, OJS is an ideal platform for the *International Journal for Service-Learning in Engineering* management and publication, not only for the editors but also for authors, reviewers, and readers. The platform simplifies and consolidates the work flow of a journal into easy steps, which can then be followed by the reviewers, authors, and editors. In addition, OJS has a simple easy to-use interface for user-subscribers to our journal. They can quickly and efficiently access any of our published material and, more importantly, share it with others.

At the same time, OJS allows our journal to keep costs down as the platform is available for free. *IJSLE* only "pays" for the OJS platform through the IT support and hardware provided by Queen's University in

Kingston, Ontario, Canada. The platform is also open source. This means it can be modified to meet the needs of every individual journal. In our case, we have slightly modified the OJS platform to meet the unique needs of *IJSLE*. That the OJS platform is a publicly accessible open source platform is a benefit that meshes nicely with our commitment to inclusivity and open access.

The editors of *IJSLE* have found the OJS platform to be a useful tool in improving the services provided by our journal, whether those are editing or publishing services. Most importantly, the move to the OJS platform has decreased the burden of managing and operating an open access journal. In turn, we can dedicate more of our time and energy into making *IJSLE* a high impact journal, while keeping it as open as possible.

REFERENCES

[1] Directory of open access journals. (2010). . Retrieved March 7, 2010, from http://www.doaj.org/.

[2] Open-Access License. (n.d.). *PLoS Biology*. Retrieved March 7, 2010, from http://www.plosbiology.org/static/license.action.

[3] Budapest Open Access Initiative. (2002, February 14). Retrieved March 7, 2010, from http://www.soros.org/openaccess/read.shtml.

[4] Attribution-Share Alike 3.0 Unported. (2010). *Creative Commons*. Retrieved March 10, 2010, from http://creativecommons.org/licenses/by-sa/3.0/.

[5] Open Journal Systems. (January 2010). *Public Knowledge Project*. Retrieved March 10, 2010, from http://pkp.sfu.ca/?q=ojs.

[6] Harrison, T. M., Stephen, T., & Winter, J. (1991). Online Journals: Disciplinary Designs for Electronic Scholarship. *The Public-Access Computer Systems Review*, *2*(1), 25-38.

[7] Suber, P. (2009, February 9). Open-Access Timeline. *The SPARC Open Access Newsletter*. Retrieved March 10, 2010, from http://www.earlham.edu/~peters/fos/timeline.htm.

[8] Wells, A. (1999). *Exploring the development of the independent, electronic, scholarly journal*. Master's, University of Sheffield. Retrieved March 10, 2010, from http://panizzi.shef.ac.uk/elecdiss/edl0001/index.html.

[9] Swan, A., & Brown, S. (2004). Authors and open access publishing. *Learned Publishing*, *17*, 219-224.

[10] Edlin, A. S., & Rubinfeld, D. L. (2004). Exclusion or efficient pricing? The "big deal" bundling of academic journals. *Antitrust Law Journal*, *72*(1), 119-157.

[11] Bjork, B. (2004). Open access to scientific publications - an analysis of the barriers to change? *Information Research*, *9*(2). Retrieved March 10, 2010, from http://informationr.net/ir/9-2/paper170.

[12] News Briefing. (2010). *Nature*, *463*, 274-275.

[13] Gadagkar, R. (2008). Open-access more harm than good in developing world. *Nature*, *453*(7194), 450. doi: 10.1038/453450c.

[14] Publication Fees for PLoS Journals. (n.d.). *Public Library of Science*. Retrieved March 10, 2010, from http://www.plos.org/journals/pubfees.php.

[15] Papin-Ramcharan, J. I., & Dawe, R. A. (2006). Open access publishing: a developing country view. *First Monday*, *11*(6).

[16] Sahu, D. (2006). *Open access: unrestricted access to published research*. 93rd Indian Science Congress, Hyderabad, India.

[17] Worlock, K. (2004, September 13). The pros and cons of Open Access. *Nature Web Focus*. Retrieved March 10, 2010, from http://www.nature.com/nature/focus/accessdebate/34.html.

[18] BioMed Central. (2004). *(Mis)leading Open Access Myths*. Submission to House of Commons Science and Technology Committee Inquiry into Scientific Publications, BioMed Central. Retrieved from http://www.biomedcentral.com/openaccess/inquiry/myths.pdf.

[19] Editorial Staff. (2004). Experiments in publishing. *Nature*, *431*(111). Retrieved March 10, 2010, from 22 Antelman, K. (2004). Do Open-Access Articles Have a Greater Research Impact? *College & Research Libraries*, 372-382.

[20] Solomon, D. J. (2006). Strategies for developing sustainable open access scholarly journals. *First Monday*, *11*(6). Retrieved March 10, 2010, from http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1335/1255.

[21] Willinsky, J. (2003). The Nine Flavours of Open Access Scholarly Publishing . *J Postgrad Med*, *49*(3), 263-267.

[22] Antelman, K. (2004). Do Open-Access Articles Have a Greater Research Impact? *College & Research Libraries*, 372-382.

[23] Eysenbach, G. (2006). Citation Advantage of Open Access Articles. *PLoS Biol*, *4*(5), e157.

[24] Harnad, S., Brody, T., Vallieres, F., Carr, L., Hitchcock, S., Gingras, Y., et al. (2004). The Access/Impact Problem and the Green and Gold Roads to Open Access: An Update. *Serials Review*, *34*, 36-40.

[25] Suber, P. (2008a). *SPARC Open Access Newsletter*. SPARC. Retrieved from http://www.earlham.edu/~peters/fos/newsletter/09-02-08.htm.

[26] Weitzman, J. (2003, July 28). Free access is not open access. *Open Access now*, 1.

[27] Bethesda Principles. (2003, April 11). *Open Access Now*. Retrieved March 11, 2010, from http://www.biomedcentral.com/openaccess/ bethesda/.

[28] Esposito, J. (2004). The devil you don't know: The unexpected future of Open Access publishing. *First Monday*, *9*(8). Retrieved March 11, 2010, from http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/ fm/article/view/1163/1083.

[29] Suber, P. (2008b). *SPARC Open Access Newsletter*. SPARC. Retrieved from http://www.earlham.edu/~peters/fos/newsletter/07-02-08.htm#lastmile.

[30] Chinnock, P. (2007, October 14). Using open-access articles for student projects. *Public Library of Science*. Retrieved March 12, 2010, from http://www.plos.org/cms/node/271.

[31] Student Statement on The Right to Research. (2008). *The Right to Research Coalition*. Retrieved March 12, 2010, from http://www.righttoresearch.org/students/ statement.shtml.

[32] Pyati, A. (2007). A critical theory of open access: Libraries and electronic publishing. *First Monday*, *12*(10). Retrieved March 13, 2010, from http://firstmonday.org/ htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1970/1845.

[33] About PKP. (n.d.). *Public Knowledge Project*. Retrieved March 13, 2010, from http://pkp.sfu.ca/about.

[34] Case, M. M., & John, N. R. (2007). Opening up scholarly information at the University of Illinois at Chicago. *First Monday*, *12*(10). Retrieved March 13, 2010, from http://www.uic.edu/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/1956/1833. http://www.nature.com/nature/focus/accessdebate/35.html.

CHAPTER 10
Stakeholders

Service Learning in Engineering

Student Competitions with a Purpose

Human Powered Vehicle Challenge (HPVC) – The HPVC, held annually at selected East and West U.S. locations and in Latin America, challenges teams to engineer and build aerodynamically efficient land vehicles that run on human power.
http://www.asme.org/Events/Contests/HPV/Human_Powered_Vehicle.cfm

ASME IShow (Innovation Showcase) – Inspiring students to be product innovators and entrepreneurs, the ASME Innovation Showcase provides a platform for top collegiate teams to compete for seed money to further develop their product. While demonstrating their technical creativity, winners must prove that they have a sustainable business model to a judging panel of successful innovators, industry experts, venture capitalists, and intellectual property specialists. ***Photo:*** *One of the IShow 2009 winners, the Solar ORC engine from MIT is a novel small-scale solar thermal technology engine.* Click link below for details!
http://www.asme.org/Communities/Entrepreneur/Innovation_Showcase_IShow.cfm

EARTH SAVER

SDC Earth Saver Competition – The ASME Student Design Competition (SDC), with funding from Boeing, provides a platform for ASME Student Members to present their solutions to a range of design problems. A recent design problem was the design of a recycled material sorter.
http://www.asme.org/Events/Contests/DesignContest/Student_Design_Competition.cfm

Student Design Expositions – Providing a platform for all engineering students to showcase their innovative design and build projects to a broad audience. Bringing practicing engineers, faculty and students into one venue, this program also provides educational and professional development opportunities for exhibitors as well as spectators.
http://www.asme.org/Events/Contests/Student_Design_Expo.cfm

In Support of Humanitarian Engineering

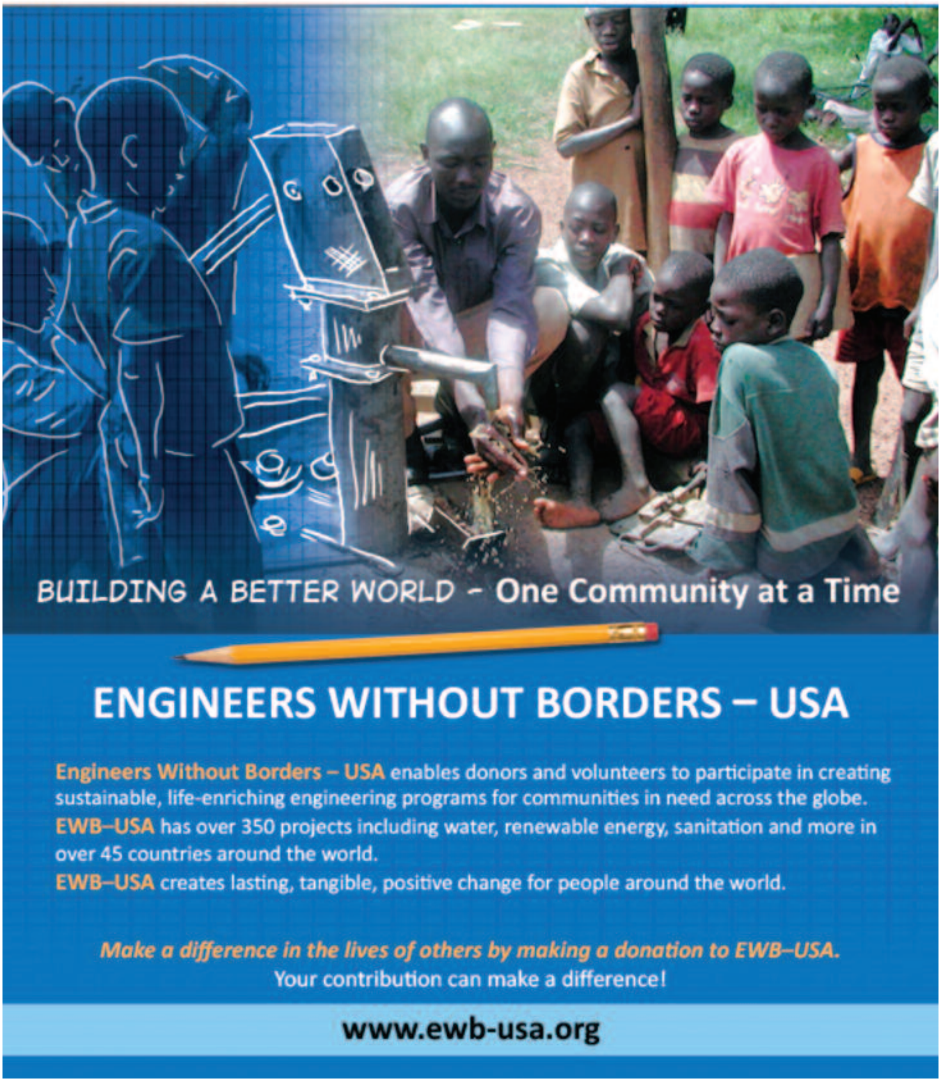
Engineering 4 Change (E4C) – Engineering for Change is an online environment bringing together engineers and other problem solvers with NGOs and local communities to address basic quality of life issues such as access to clean water, electricity and proper sanitation.
http://www.engineeringforchange.org

Engineers Without Borders - USA (EWB-USA) is a non-profit humanitarian organization established to partner with developing communities worldwide in order to improve their quality of life. This partnership involves the implementation of sustainable engineering projects, while involving and training internationally responsible engineers and engineering students. *https://www.ewb-usa.org/index.php*

ENGINEERS WITHOUT BORDERS USA

IN PARTNERSHIP WITH ASME

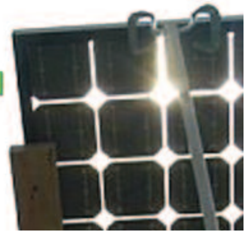
Human Powered Open-Source Water Purification Project – Engineering students from around the world collaborate first in a virtual research environment, then in person to build a prototype of a hybrid human/solar-powered water purification system for providing potable water for developing countries and disaster areas.
http://www.asme.org/communities/open_source_design.cfm


BUILDING A BETTER WORLD - One Community at a Time
ENGINEERS WITHOUT BORDERS – USA
Engineers Without Borders – USA enables donors and volunteers to participate in creating sustainable, life-enriching engineering programs for communities in need across the globe.
EWB–USA has over 350 projects including water, renewable energy, sanitation and more in over 45 countries around the world.
EWB–USA creates lasting, tangible, positive change for people around the world.
Make a difference in the lives of others by making a donation to EWB–USA.
Your contribution can make a difference!
www.ewb-usa.org

Engineers for a Sustainable World

Building today's solutions,
Building tomorrow's leaders

www.eswusa.org



our vision

ESW envisions a world in which engineering fosters environmental, social, and economic sustainability to improve both the quality of life and the condition of our planet

our approach

Today's students are tomorrow's leaders for combating global problems. ESW brings together technically minded people to learn, lead, and impact local and global problems in sustainability. Our most visible results are the projects that our 25+ student-driven chapters are accomplishing - everything from installing biodigesters in rural Nicaragua to helping local towns rennovate old buildings to performing energy audits on fraternity homes on campus.

Less visible to the public are the educational parts of ESW, both in and out of the classroom, which give ESW members the background in sustainability issues as well as the leadership skills they need in today's connected and information-dense world. Our members enter whatever career they choose, able to help steer their corporate community towards a more sustainable path.

our members...

...lead engineering projects

ESW members gain hands-on experience solving sustainability problems through participating in and leading local and international engineering projects.

...build knowledge of sustainability

ESW members learn about today's sustainability challenges through a year-long education curriculum, including monthly national webinars and an annual conference.

...engage their communities

ESW members educate community members about sustainability issues and engage them to act through partnerships with projects and outreach events.

Engineers Without Borders – International (EWB-I)

Ingenjörer och Naturvetare utan Gränser
Ingenieros Sin Fronteras
Ingeniører uden Grænser
Ingénieurs Sans Frontières
Ingenieurs Zonder Grenzen
Ingenieure Ohne Grenzen
Engineers Without Borders
Engineers Without Frontiers
Engenheiros sem Fronteiras
Ingegneria Senza Frontiere
Inzeneri bez Granici
Μηχανικοί Χωρίς Σύνορα
מהנדסים ללא גבולות
مهندسون بلا حدود

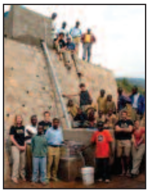
Web site: www.ewb-international.org

Engineers Without Borders - International (EWB-I) is an international association of national EWB/ISF groups whose mission is to facilitate collaboration, exchange of information, and assistance among its member groups that have applied to become part of the association. EWB-I helps the member groups develop their capacity to assist poor communities in their respective countries and around the world. The main office of EWB-I resides in the USA with regional offices in Mexico, India, Belgium, and Egypt.

The member groups of EWB-I share a similar mission, which is to partner with disadvantaged communities to improve their quality of life through education and implementation of sustainable engineering projects, while promoting new dimensions of experience for engineers, engineering students, and similarly motivated non-engineers. EWB-I creates links between like-minded organizations and cuts across national borders. It works in collaboration with various partner organizations affiliated with its member organizations. Projects conducted by individual EWB/ISF member groups are grassroots and small and are not usually addressed by in-country consulting firms. It is a matter of policy that prior to taking on projects, EWB-I member groups make sure that they are not competing with private engineering firms.

EWB-I member groups and partner organizations contribute to meeting the UN Millennium Development Goals through capacity building in their projects. They have endorsed the Earth Charter and the Universal Declaration of Human Rights.

EWB-I consists of member groups, provisional member groups, and start-up groups. All groups function autonomously. Membership requires that all members adhere to high professional and ethical standards as stated in the EWB-I By-Laws. EWB-I provides a unique platform for the different organizations to:



- Contribute to meeting the MDGs through capacity building in local projects
- Collaborate on projects and studies worldwide
- Share ideas, experiences, technical knowledge, and documentation
- Develop partnerships on community projects
- Address more global issues and projects
- Coordinate student exchanges, internships, and professional volunteers
- Advertise meetings and events
- Train and connect engineering professionals and students around the world
- Create synergy between their members

EWB-I is host of the ***Humanitarian Engineers' Registry and EWB-I Database.*** This register of skills links those in needs with those who can provide services, technologies, and solutions to eradicate poverty in communities around the world.

For more information, contact Prof. Bernard Amadei, EWB-I Executive Director, E-mail: bamadei@gmail.com, Tel:1-303-929-8167, Skype: bamadei

Disclaimer: EWB-I is not in any way affiliated with Doctors Without Borders. Doctors Without Borders is a registered trademark of Bureau International de Médecins Sans Frontieres.

P^3- People, Prosperity and the Planet-a National Student Design Competition for Sustainability

EPA's P3 award
people
prosperity
planet

What is P^3?

P^3 is a sustainability research design competition for students enrolled at U.S. colleges and universities to develop innovative designs that address challenges to sustainability anywhere in the world. The solicitation for new P^3 proposals is open in the fall of every year.

What types of designs are we looking for?

Projects can be in the following areas: Water, Energy, Agriculture, Built Environment, and Materials & Chemicals

Where does the competition come in?

Teams prepare a grant proposal for a P^3 Phase I grant of \$10,000 to develop their design. Phase I teams attend the National Sustainable Design Expo in Washington, DC, in the spring where they compete for a P^3 Award and a \$75,000 Phase II grant to further develop their designs or move them to the marketplace.

Want more information?

Go to the P^3 website

www.epa.gov/p3

Campus-Community Partnership Foundation

C2P

Community Academic-Service Entrepreneur Grant

About C2P: The Foundation (C2PF.org) has conducted programs in 27 US states and on four continents. Under the direction of a board of world-class educators, business leaders, technologists, philanthropists and community officials, the Foundation continues to develop and apply programs to link students' academic programs to community service and social entrepreneurship.

The Community Academic Service Entrepreneur grant competition empowers and motivates students to apply their classroom learning in real life. The student receives a C2P Certificate of Merit and micro-grant funding to implement the project. The whole process is generally completed in a single semester. Projects and proposals can be seen at ServiceBook.org, where the Foundation receives applications and administers the selection process. Examples include:

Lori Hanna, University of Dayton

CASE Grant: Solar Autoclave Development

Technology – CASE participants bring their own disciplines to social entrepreneurship, often creating technology breakthroughs in the process

■ Students at the University of Texas built an online, virtual simulation of SafePlace, the nation's largest domestic violence shelter, where trainees learn to diagnose and deal with problems as avatars in hypothetical cases, safely apart from the actual shelter.

■ A non-profit is building a school in Uganda based on "cookie cutter" blue prints. University of Notre Dame architecture students used a CASE grant and Skype to engage villagers in the design process and bring their knowledge of local weather patterns, materials and building techniques into an improved design.

Economic Development – CASE community projects help create jobs and prepare a better educated work force.

■ A student at the University of Nebraska, Omaha, used the grant to help a local charity develop, pilot and assess job readiness modules including interviewing, employer expectations, the job application process, customer service and other skills.

■ A Virginia Tech ag-economics major used the grant in Kenya to develop a production, marketing, distribution and education program to convince local farmers to grow soy beans for a better, more secure income and to combat malnutrition.

Whitney Prose, Otterbein College, Ohio

CASE Grant: Otterbein Lake, restoration of a waste pit

Education – College students work to find opportunities to inspire anc educate younger students. CASE grants help capture those opportunities.

■ In communities around Georgia Southwestern State University up to 30% of students are below standard in reading because their caregivers also do not read. A GSSU student used a CASE grant to give children "take home" books and train caregivers in reading skills, thus helping the caregiver and the child teach each other to read.

■ A mechanical engineering student at Dayton University in Ohio used a CASE grant to purchase Lego Mindstorms as the basis for a day camp where college students taught math and science to younger, inner-city students while building robots and other mechanical devices.

"The roots of humanitarian criticism, or of restricted forms of community and the promotion of equity or equality among humans, are many……

…..One root stems from the cosmopolitanism of Greek and Roman philosophy. Some ancient philosophers argued that all human beings are members of a single community…..

…..Another root is Christian theology; insofar as all human beings are created by and equal in the sight of God, they are members of a common community with obligations to care for one another…..

…..A third root is to be found in the moral principles of Enlightenment philosophy. David Hume defended sympathy as the foundational moral sentiment. Immanuel Kant argued for recognition of a categorical obligation to treat all humans as ends in themselves….."

—David R. Muñoz and Carl Mitcham
(authors, Chapter 3)

"The miracle is not that we do this work, but that we are happy to do it"
—Mother Theresa

IJSLE

International Journal for Service Learning in Engineering:
Humanitarian Engineering and Social Entrepreneurship (IJSLE)

Dissemination

Publication

Journals

Outreach

Research

Collaboration

Scholarship

IJSLE is a peer reviewed journal which publishes the original work of practitioners and researchers involved in Humanitarian Engineering, Social Entrepreneurship, Frugal Engineering and Service Learning in Engineering and seeks to nurture such efforts as a distinct body of knowledge.

The primary purpose of the journal is to foster inquiry into rigorous engineering design, research and entrepreneurship efforts which are directed toward addressing problems of marginalized communities.

www.ijsle.org