2006-1657: THE ROLE OF ENGINEERING EDUCATION IN INTERNATIONAL DEVELOPMENT

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THE ROLE OF ENGINEERING EDUCATION IN INTERNATIONAL DEVELOPMENT

Abstract

The role of science, technology, and innovation in international development has been the focus of several recent studies, including ones produced by the National Academy of Science, the World Bank, The RAND Corporation, the Interacademy Panel and the United Nations Millennium Project. These studies all cite the importance of science and technology in addressing development challenges. A number of the issues are engineering related and thus require engineering solutions.

This is especially relevant to engineering education in the U.S. As our students in the U.S. will now be faced with finding viable relevant solutions to problems faced not just by the approximately 300 million people in the U.S., nor by the 1.2 billion people living in developed countries, but by the majority of the world's population living in developing countries which is projected to outnumber the population in developed countries by six to one by 2050.

This paper presents some of the challenges faced by developing countries and how engineering and engineering educators around the world are finding ways to address these issues. This is not a comprehensive list, however presented are a cross section issues that the U.S. Agency for International Development and a host of other organization are facing. Also presented are ways these organizations are coping with these issues and ways in which engineering education in the U.S. is answering and can answer the call for help to find solutions.

Introduction

The role of science, technology, and innovation in international development has been the focus of several recent studies, including ones produced by the National Academy of Science,¹ the World Bank,² The RAND Corporation,³ the InterAcademy Council⁴ and the United Nations Millennium Project.⁵ These studies all cite the importance of science and technology in addressing development challenges. A number of the issues are engineering related and thus require engineering solutions. In addition there are a number of engineering competitions in which development problems are proposed and engineering solutions sought including the Grainger Challenge,⁶ the Modialogo Engineering Award⁷ and the Ashden Awards for Sustainable Energy.⁸ Non-profit organizations like Engineers Without Borders,⁹ Engineers for a Sustainable World,¹⁰ and academic programs such as Engineering for Developing Communities¹¹ at University of Colorado Boulder and the Master's International Civil and Environmental Engineering¹² program at Michigan Tech all present approaches to how engineering and engineering education can play a vital role in international development.

The students in the United States are now presented with the challenge of finding viable relevant solutions to problems faced not just by the approximately 300 million people in the US, nor by the 1.2 billion people living in developed countries, but by the majority of the world's population living in developing countries which is projected to outnumber the population in developed countries by six to one by 2050. There are two aspects to this issue, one introducing sustainable development into engineering education which applies to both developing and other countries, and two, tackling problems that are very specific to developing countries. The Human Development Report in 2001: Making New Technologies Work for Human Development¹³ presented a table of some of the deprivations that are experienced in developing countries and ones that are experienced by Organisation for Economic Co-operation and Development (OECD) countries.

<i>Developing countries</i>
968 million people without access to improved water sources (1998)
2.4 billion people without access to basic sanitation (1998)
34 million people living with HIV/AIDS (end of 2000)
2.2 million people dying annually from indoor air pollution (1996)
<i>Education</i>
854 million illiterate adults, 543 million of them women (2000)
325 million children out of school at the primary and secondary levels, 183 million of them girls (2000)
<i>Income poverty</i>
1.2 billion people living on less than \$1 a day (1993 PPP US\$), 2.8 billion on less than \$2 a day (1998)
<i>Children</i>
163 million underweight children under age five (1998)
11 million children under five dying annually from preventable causes (1998)
<i>OECD countries</i>
15% of adults lacking functional literacy skills (1994–98)
130 million people in income poverty (with less than 50% of median income) (1999)

8 million undernourished people (1996–98)
 1.5 million people living with HIV/AIDS (2000)

Table 1. Serious deprivations to many aspects of life as presented in the 2001 Human Development Report.¹³

In addition this report also presents a four top priority areas in which research is needed, the latter two are directly related to engineering:

1. Vaccines for malaria, HIV and tuberculosis as well as lesser-known diseases like sleeping sickness and river blindness
2. New varieties of sorghum, cassava, maize and other staple foods of Sub-Saharan Africa
3. Low-cost computers and wireless connectivity as well as prepaid chip-card software for ecommerce without credit cards and
4. Low-cost fuel cells and photovoltaics for decentralized electricity supply.

The 2005 United Nations' Millennium Project Task Force 10 report "Innovation: Applying Knowledge in Development"⁵ presents four platform technologies: *information and communications technology, biotechnology, nanotechnology, and new materials*, which will be crucial in achieving the eight Millennium Development Goals.¹⁴ The paper also discusses the importance of adequate infrastructure and education in the sciences and engineering in conjunction with these technologies to achieve the desired results by 2015 of:

1. Eradicating extreme poverty and hunger
2. Achieving universal primary education
3. Promoting gender equality and empower women
4. Reducing child mortality
5. Improving maternal health
6. Combating HIV/AIDS, malaria and other diseases
7. Ensuring environmental sustainability, and
8. Developing a global partnership for development

The challenge to engineering education is eloquently stated The National Academy of Engineering report "The Engineer of 2020".¹⁵

Engineering will increasingly be applied in ways that achieve synergy between technical and social systems.... Technical systems will leverage all available resources, including human and social infrastructures, to achieve desired outcomes and to better ensure sustainability. Thus, the engineer of 2020 will be actively involved in political and community arenas. ...Engineering will need to expand its reach and thought patterns and political influence if it is to fulfill its potential to help create a better world for our children and grandchildren.

How Academia, Agencies, and Individuals are Addressing the Problem

There are a number of agencies, institutions and individuals addressing the problems stated in the Introduction Section of this paper; each utilizing its own expertise in the most suitable manner. The U.S. Agency for International Development (USAID) is the lead U.S. government agency

devoted to international development. Through programs in its missions around the world in 70+ developing countries and a number of programs in non-presence countries, USAID has a number of programs related to science and technology in the areas of health including infectious diseases, population, child and maternal health, energy, agriculture,¹⁶ natural resource management, environment and science policy, biotechnology, engineering and infrastructure, and disaster assistance. It also applies technologies to address issues in democracy and governance, education, and economic growth. The agency funds research and applied research both in the U.S. and in foreign countries, examples of this include the Consultative Group on International Agriculture Research¹⁷ (CGIAR), the Collaborative Research Support Programs¹⁸ (CRSP), and the Higher Education for Development Program¹⁹ (formerly the Association Liaison Office). Additionally the Agency has teamed with private industry on a number of public/private partnerships to leverage government funds against private funds to yield significant results examples include partnerships with Nokia, Chevron/Texaco, Microsoft, and Cisco. It also has funded engineering programs at universities, for example EARTH University in Costa Rica and the American University in Yerevan Armenia. USAID often works with other government agencies including the Department of Energy, Department of Health, the Centers for Disease Control, the National Institutes of Health, the Department of State, and the Department of Agriculture in country to achieve US foreign assistance goals. These activities sponsored by the US government are just one way to address the global challenges poverty, health, equity, and education.

Other institutions have risen to the challenge too. One example of this is the Kigali Institute of Science, Technology and Management²⁰ (KIST), in Kigali Rwanda, initially funded with money from the United Nations Development Program (UNDP). KIST is the first public technological institute of higher learning in Rwanda. The goal of the university is to contribute to Rwanda's economic renewal through the creation of highly skilled manpower and providing technical assistance and services to all sections of the community. KIST has embraced service learning and has participated in number of community based educational engineering service projects, including constructing the first pedestrian suspended bridge in Rwanda, developing efficient community cooking stoves, and developing biogas cooking and lighting technology.

Along with KIST, programs like Engineers Without Borders, Engineers for a Sustainable World, and academic programs such as Engineering for Developing Communities at University of Colorado Boulder and the Master's International Civil and Environmental Engineering program at Michigan Tech all present models and approaches to how engineering and engineering education can play a vital role in international development. The World Federation of Engineering Organizations (WFEO) Committee on Capacity Building²¹ (CCB) focuses its efforts on developing strategies and programs to build engineering capacities in developing countries.

What Can U.S. University Engineering Programs Do?

There is an ever increasing demand for the engineer to play a greater role in poverty reduction and sustainable development. There is need therefore for more holistic training of the engineering student, thereby integrating the social, environmental, political, global and economic contexts within the application of engineering. One way in which engineering programs in the US can address issues of sustainability and international development is to introduce new

requirements/outcomes into the curriculum. Or they can take existing outcomes and mold the educational methods used to achieve these outcomes, in such a manner so that sustainability and international development engineering problems are addressed. ABET has established a list of program outcomes under Criterion 3: Program Outcomes and Assessment for accrediting engineering programs. Outcomes “3c,” “3f,” “3h,” and “3j”

- 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
- f. an understanding of professional and ethical responsibility
- h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- j. a knowledge of contemporary issues

are directly related to the issues proposed in this paper.²²

Incorporating international development within a service learning context in the engineering curriculum provides a learning/teaching paradigm by which engineering programs can demonstrate they are addressing ABET Criteria 3c, 3f, 3h, and 3j. Civil, systems, environmental, agricultural and power engineering programs are engineering majors most suited to address these issues. However, chemical, biomedical, electrical and mechanical engineering along with material science and computer science can also incorporate development issues into the curriculum. At the undergraduate level the Senior/Capstone design project is one way to incorporate international development service learning projects. Even at the freshman level students can postulate and research possible engineering solutions to development problems. Students can be steered to take general education classes in the social sciences in international relations, trade, public policy, international development, urban planning, social systems, rural development, etc.

Other engineering educational examples include the University of Colorado Boulder Engineering for Developing Communities¹¹ (EDC) program which “educates globally responsible engineering students and professionals who can offer sustainable and appropriate solutions to the endemic problems faced by developing communities worldwide.” At Tokyo Tech the International Development Engineering²³ was established in 1995 to meet growing needs to train professional engineers with the skills needed to respond to the recent global changes and opportunities such as rapid economical growth in Asian region and internationalization of technology. Their program covers broad areas of engineering (Chemical Engineering, Mechanical Engineering, Electrical Engineering, Computer Science, Civil Engineering) that are necessary especially for Asian countries including Japan to further develop their industry. They especially focus their training so that their engineers can actively play important roles in international cooperation between countries. At Michigan Tech the Master’s International Program combines a graduate degree in civil or environmental engineering with 2+ years of training and engineering service with the U.S. Peace Corps. It is the only program of its kind in the United States, students have served in 16 countries and have worked on a variety of engineering projects related to water supply and treatment, wastewater treatment, solid waste management, public health training, construction, and water resource planning and management.

Engineering programs can also promote study abroad programs during which students spend a semester or summer abroad in a developing country. Additionally they can be encouraged to apply for internships with multinational companies that offer that work opportunities in developing countries. Finally student organizations such as Engineers Without Borders and Engineers for a Sustainable World and GEEK Corps provide students with other opportunities to take on projects for developing communities.

Examples of USAID Funded University Partnerships

USAID promotes partnerships between US higher education institutions and those in developing countries, some of which address curriculum and training issues, others which address research problems and others which apply information and communication technologies to the delivery of course content and materials. Engineering schools can develop synergistic and complementary partnerships with engineering programs in developing countries. Three of their partnerships are described below.

In 2002 Purdue University, Kabul University, Kabul Polytechnic and Kabul Education University were awarded a grant to establish a rapid training program at the universities in Kabul in order to generate an immediate flow of skilled workers and trainers into Afghanistan's rebuilding effort, with a focus on agriculture, education, engineering, and technology. The partners targeted their efforts on training in the use of distance learning (DL), and establishing four DL laboratories at three universities in Kabul. Four Kabul faculty members have been trained at Purdue in DL and curriculum development in agriculture and in computer maintenance. Three additional Kabul faculty members have received training at Purdue's School of Education in curriculum development and distance learning. Agriculture professors from Purdue have traveled to Afghanistan to work with the faculty on the agriculture curriculum and the research farm. Partners have assembled a draft proposal to modernize the curriculum into three tracks (crop science, animal science, and farm management) with a marketing/entrepreneurship component. Purdue has donated textbooks and an additional 60 computers (for a total of 100) to the Kabul computer laboratories and has established four laboratories.²⁴

In 2004 Duke University's Pratt School of Engineering and Effat College in Saudi Arabia were awarded a Middle East Partnership Initiative (MEPI) award to establish a new and innovative curriculum in computer engineering at the Bachelor of Science level at Effat College. The new curriculum is to include instruction in information processing, information technology and networks. Partners are developing a curriculum through the: (1) identification of an appropriate curricular theme; (2) development of a theme-based introductory course and major curriculum that includes fundamental concepts of electrical and computer engineering (ECE); (3) development of theme-based design courses that integrate core technical competencies; and (4) use of MATLAB throughout the curriculum. Design concepts and hands-on learning are integrated within the entire curriculum from the earliest stages of a student's education through senior design projects, and team-based learning will be an important method of education delivery. The program includes curricula development, student internship/practicum experience, faculty training, and evaluation and accreditation assessment.²⁵

The Tribhuvan University in Nepal has two engineering related project-partnerships, one with University of Colorado Boulder and the second with Red Rocks Community College. The University of Colorado program, completed in 2003, developed a master's-level curriculum in renewable energy technologies. The partners launched the M.S. program with an inaugural class of 16 students. They were involved in building a laboratory for training and research at Tribhuvan University's Institute of Engineering (IOE) and Center for Energy Studies. Partners also collaborated on the planning and fund raising for a new Energy Park and Zero Energy Building, which serves as a focal point for the renewable energies technology program and a laboratory for graduate students. Faculty members from the partner institutions shared expertise on renewable energy technology, toured renewable energy sites in Nepal, and met with Nepalese engineers as well as government and utility officials from 11 institutions. The partners trained 269 Nepalese, including Members of Parliament, village officials, health workers, and school teachers, in renewable energy technologies. The Red Rocks Community College partnership, awarded in 2002, focused on preparing diploma and pre-engineering students to continue their studies in the environmental sciences. One Red Rocks Community College faculty member has taught mathematics at IOE and has worked with other IOE faculty to develop/use alternative instructional methods. Four IOE faculty attended seminars at Red Rocks and met with officials from the Colorado School of Mines and the National Renewable Energy Laboratory. Partners collected data on failure rates among students at the IOE's three campuses. The partners then developed an introductory environmental science curriculum, including labs, and introduced the use of the TI-83 calculator as part of the overall goal of improving the performance of students in upper-level courses.²⁶

Conclusion

The Cambridge University Engineering department believes sustainable development should not be considered a separate issue to be addressed by special courses, but that the needs of sustainable development should become embedded in the thought processes and methodologies of all practicing engineers and engineering designers.²⁷ Likewise, the paper proposes that just as ethics and engineering in a global societal context are woven throughout engineering curricula in the U.S., issues in international development should also be woven throughout the curriculum. This should be done not only because engineering can find solutions to some development challenges, but also because a large number of engineering graduates will find themselves working in multi-national companies that have interests throughout the world, not just in developed countries, but also in developing countries. These students should be aware of issues facing developing countries and how engineering can and is finding solutions to these issues.

There are various ways engineering programs are addressing engineering related development issues, but they fall primarily into three categories, capacity building, engineering projects, and service learning. The USAID university partnerships presented and WFEO CCB focus on building capacities in developing countries. Programs such as EWB and GEEK Corps focus on engineering projects and programs at Colorado-Boulder and Michigan Tech focus on service learning. All approaches provide a valuable contribution to this global issue.

This paper presents some of the challenges faced by developing countries and how engineering and engineering educators around the world are finding ways to address these issues. This is not

a comprehensive list, however presented are a cross section issues that the US Agency for International Development and a host of other organization are facing. Also presented are ways these organizations are coping with these issues and ways in which engineering education in the US is answering and can answer the call for help to find solutions.

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