Global Development Engineering and its Discontents: An interdisciplinary project-based course

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Abstract

Recent discussion in engineering has focused on the importance of preparing students for a global future, but rarely do we examine the profession's role in globalization with a critical eye. An interdisciplinary project-based course and upper-level engineering elective, open to students in a variety of disciplines, seeks to initiate critical study of the technological, cultural, and policy aspects of international development. Rather than working from a common base of introductory knowledge, this course requires students to share sophisticated knowledge in their discipline with others from different backgrounds.

Developed through a collaboration between an engineering professor and a sociology student/alumna, and taught by the engineering professor in the spring semester of 2003 and 2004, the course wrestles directly with the differences in perspective that create gulfs in understanding between social scientists and engineers, and between development workers and intended beneficiaries of development projects. Students grapple early on in the course with the promises and limitations of technology for development, with the meanings of capitalism, colonialism, and globalization, and with the implications of engaging in development work from places of privilege.

Case studies in appropriate technology highlight the importance of communication, leveling power relationships, anticipating the social impacts of technology, and meaningful involvement of end users in technology development. Cases address topics including water quantity and quality, food production and preparation, and energy. Through class discussion and short assignments students analyze the role of technological, economic, cultural, and governmental factors in helping or hindering the success of development projects. Two design projects were developed that allow multidisciplinary teams to construct prototypes (of a slow-sand water filter and a child's crutch) using hand tools and scavenged objects. Students experience in a very real way how technical, economic and social considerations are inextricably linked in design.

We are working to establish meaningful two-way relationships with communities both locally and abroad in hopes of creating a community-based project connected to the course. We discuss some of the concerns that have arisen to date and the ethical guidelines we believe are necessary for appropriate community collaborations.

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Introduction and Background

The phenomenon of globalization has been recognized within engineering education as a new business need, and (perhaps not often enough) as a professional or social responsibility concern. The Accreditation Board on Engineering and Technology (ABET) included in its Criteria 2000 "the broad education necessary to understand the impact of engineering solutions in a global and societal context.[1]" A recent trend in engineering education involves project-based courses in global development, often connected with projects overseas.[2,3]

Smith College's Picker Engineering Program has created a course in engineering and global development that is truly interdisciplinary, drawing students from the social sciences and engineering. In doing so, the course incorporates a critical view of globalization and global development engineering. The course was offered in spring 2003 with an enrollment of 9 students and in spring 2004 with an enrollment of 12. Course objectives include enabling students to:

- Design and build technology systems for use in developing countries
- Apply knowledge of what constitutes appropriate technology to design
- Critically analyze issues related to the use of technology in developing countries
- Demonstrate an understanding of the limitations of technology in addressing problems of development.

The course begins with an introduction to issues in global development, based primarily in the social science literature. Students are introduced to the ideas of appropriate technology and critiques of that approach. Through a number of case studies, students explore what it means to implement appropriate technology in trying to address problems in global development, including the pitfalls, promises, and limitations of this approach. Two projects were developed to accompany the course without connection to a community. However, a connection was established with a local economic development agency in an urban Puerto Rican community, so students in the spring of 2004 have the opportunity to apply their knowledge in a real community situation, which is preferable to learning with a ready-made project.

Background in Development and Appropriate Technology

Students begin with two very short readings that are packed with thought-provoking material for lively discussion. The first three pages of Arundhati Roy's nonfiction work *Power Politics*[4] gives students an initial exposure to an Indian woman's view of globalization. Juxtaposed with a piece entitled "Kofi Anan's Astonishing Facts" from the *New York Times* [5], students are immediately confronted with the enormous global inequities and the wastefulness of developed country consumers. Discussion helps students work through a variety of responses typical of those in power positions – defensiveness, guilt, denial, anger, an earnest yet sometimes patronizing desire to change the situation, etc.

Students read two histories of development – one policy oriented[6], explaining concepts such as structural adjustment, and an Afro-centric sociological critique of colonialism by Walter Rodney.[7] To understand Rodney, whose perspective is distinctly Marxist, students also tackle an excerpt of Max Weber's *Protestant Ethic and the Spirit of Capitalism*[8], to see why many in the world critique capitalism as an economic system. While this can be threatening to some, we believe it is vitally important that students engage the dialogue about globalization directly, which necessarily involves understanding arguments based on critiques of global capitalism.

This is a first introduction for most students in the course to these readings, so they are kept short with extensive time for discussion.

After reviewing development efforts from these perspectives, it is natural to examine more deeply what has caused the failure of development projects. We supplement the answers given by Rodney and Agunga with that of Hammer[9], an anthropologist who focuses on explanations rooted in a lack of attention to culture, power, and communication. At this point students write a short essay (2-3 pages) on one of two topics: whether or not aid should be given by developed nations to developing nations, or a reflection on pitfalls to avoid in their project based on why projects have failed in the past.

Students examine the role of technology in society through readings by Langdon Winner[10] and Richard Sclove.[11] Students learn about the tendency for engineers to find higher-tech solutions to problems, to over-design, without any social impact consideration. They read Kammen and Dove's piece[12] on "the virtues of mundane science" that discusses the academic biases that prevent important breakthroughs in low-tech solutions to problems of poverty and environment around the world. Through these and previous readings, students begin to understand some of the reasons for development efforts that have been disastrous for local communities economically, socially, or culturally.

Students are then introduced to the phenomenon of appropriate technology, both in its historical form and its resurgence with an entrepreneurial twist, driven largely by western engineers. Students read articles by proponents and critics of appropriate technology,[13,14,15] and wrestle directly with the question of whether western engineers, and even western-trained engineers, have a role to play in the developing world – and in what ways that role may necessarily be problematic due to (*inter alia*) present global inequities and the history of colonialism that contributed to their establishment.

At this point students write a second essay on the role of U.S. trained engineers in developing countries, the role of technology in development, and their role in the setting of the class project. Again, this is a short reflection intended to help students make the connections between the classroom and the field work. Most class work is directed toward the project and its deliverables, discussed below.

Students examine a number of case studies in appropriate and inappropriate uses of technology in developing countries, focused around the themes of water, food, and energy. Two short projects over the course of the semester were designed to challenge students to apply their knowledge to design. However, these projects (discussed below) have been put aside in order to engage students in a real-world and local community-based design project.

Case Studies

Throughout the course, students examine numerous case studies that highlight both the successes and failures of engineering in global development.

To accompany the background readings on development and economics, students read a case study about the distribution of vaccines, in which science has produced successful preventive technologies that are not delivered due to economic and policy barriers.[16]

Students examine three models of economic development. Yunus[17] describes the development of Grameen banking and Grameen telecomm in Pakistan, Albee and Gamage[18] describe a credit union cooperative owned and run by poor women in Bangladesh, and Stevens[19] describes the entrepreneurial efforts of an American engineer in marketing a pump in Africa with Approtec, arguing that the solution to poverty is a stronger middle class.

A classic success story from the 1970s appropriate technology movement is the Lorena cookstove.[20] Held as an ideal in many appropriate technology readings, the cook stove is the product of a well-coordinated community-based design process. The relationships between design considerations and social factors are transparent, and the engineering issues (heat transfer) are accessible to undergraduates. The technical analysis and the social analysis were combined to create a solution greater than the sum of the parts.

Students then consider what makes a technology indigenous, and what kinds of interactions development can have, for better or for worse, with indigenous technology. Thomasson[21] describes a Kpelle process for steelmaking in Liberia, detailing its demise and resurgence related to development policy and cultural attitudes toward indigenous vs. foreign technology. Rhyner-Pozak[22] describes an interaction in which architects from developed countries were able to share information to strengthen indigenous building technologies following the 1974 earthquake in Guatemala, rebuilding structures using traditional methods that would now be more stable in the face of an earthquake.

Capitalizing on local expertise in assistive technology at Hampshire College, students study community-based design processes for a number of assistive technologies as described by David Werner and the Program of Rehabilitation Organized by Disabled Youth of Western Mexico (PROJIMO). A case in wheelchair design for four women with spinal cord injuries in Bangladesh, Mexico, the Philippines, and Egypt illustrates the need to adapt technologies to local situations and individual needs; [23] a second article about working with wheelchair users illustrates the importance of community involvement and empowerment in the design process.[24]

One case study of inappropriate technology for energy production is the case of the Tehri Dam in India, which has already caused widespread displacement of families, in order to provide electricity to wealthier citizens far away. In this case, we welcome the local expertise of a Smith student on this topic. Students read an article she wrote on the topic.[25]

Case studies in water include Rita Colwell et al.[26] describing the reduction of cholera rates in Bangladesh though the use of simple filtration with sari cloth. Another study examines the role of women in water and sanitation. Written by the United Nations International Research and Training Institute for the Advancement of Women (INSTRAW),[27] the article discusses the Decade of Water in the 1980s and highlights some of the lessons learned about the importance of involving women in water projects, and presents two case studies: an Indonesian woman who

single-handedly built an irrigation system to bring water to her village, and the use of indigenous technology in India for water purification.

Two short assignments provide practice problems for students to apply their engineering knowledge to the key areas of water and energy. In the first offering of the course, problems were taken largely from the Hazeltine and Bull text[15], and emphasize design considerations in social context. The problems are simple enough that non-engineers can attempt them with some success, yet at the same time they challenge conventionally trained engineers to employ more big picture and common-sense thinking, with an emphasis on estimation and judgment. Students did not readily connect this work to their projects however, making these assignments the least popular element of the course. In the second offering of the course in spring 2004, problem assignments were more closely linked to project work.

Projects

In addition to case studies, students apply their knowledge from the course to a hands-on project. The project is the centerpiece of the course, requiring most (at least two thirds) of the students' time and energy. We found it important to pare down the work load so that students can focus primarily on the project, with the readings and other short assignments clearly connected to and supportive of the project work.

In the first offering the course, students were asked to come up with their own design projects. In teams of three, they worked on an improved cook stove for use in a community in northern India, a household water reuse system for irrigation of a residential garden in Botswana, and a water collection and filtration system for use in Panama. In the first two cases, one student in each team had first-hand knowledge of the community in which the design was to be implemented, through either study abroad or childhood experience. Unanimous student and instructor feedback after the first year indicated that students needed more structure for the project, and that choosing a community and/or project would help focus the class and make the projects more successful.

Thus, two short-term projects were developed for the spring 2004 class, intended to work independent of a connection to a community. While this was seen as a second or backup choice, we spent the time to develop satisfying projects so that we could use these in the absence of a good community-based project.

The first project we developed involves building a small-scale slow sand filter using hand tools and found objects. Social factors in design for this project primarily relate to the decision of how safe is safe enough, and disparities in drinking water standards among countries. Students design, season, and test their filters over the course of several weeks. Testing can be accomplished through the use of standard laboratory methods if they are available and convenient, or through the use of fairly inexpensive synthetic agar substitute gels – where one places the water sample and counts the number of colonies of coliform bacteria that develop. While the latter method is less precise, it should allow students to have some measure of the effectiveness of their filter, and to track its improvement over the seasoning period.

A second, more involved project is the product of collaboration among faculty who teach courses in global development engineering at several schools. The project was developed last summer at

a workshop hosted by MIT. Students are asked to design a crutch for a 12-year old child who has lost part of a limb in a land mine accident. Design and societal/individual considerations here are more inter-related. For example, the size of the child, and the child's typical daily activities will be determined by the cultural and physical conditions in which the child lives. While students would be allowed to use any scavenged materials for the exercise, students reflect on what materials would be available in the community of focus, as well as what tools would be available. Without being able to interact with the child or the community, student designers need to make a number of assumptions and develop a set of questions they would like to answer in collaboration with the user of the crutch and the community. Articulating these well is essential to a successful project.

Community-Based Learning

While developing these projects, we explored possible community projects in affiliation with Engineers without Borders and Engineers without Frontiers, two organizations that seek to match engineering students with international development projects. We have deep concerns about the quality of the experience for both the students and the communities involved. The primary problem with any project that sends students for only a few weeks to a country with which they have no prior cultural experience is that it is impossible for students to develop an adequate knowledge or sense of the community in which they are working. Therefore, if the project is to fit the definition of "appropriate technology" someone else with greater knowledge of and experience in the community must do the creative design work, in collaboration with community members. Students then become little more than construction workers paying several thousand dollars to transport and feed themselves, when a local person could be hired to do the same work, with money left over to meet other needs in the community.

Additionally the authors were left with specific questions about certain projects that appeared to be inappropriate due to the types of relationships developed. For example, work in an indigenous community was done without working directly with the tribal leadership, or even with an NGO that works with that community, but instead through Christian missionaries, who have a reputation in the region for tying development aid to religious conversion and destroying the culture of that indigenous group, placing children of living parents in orphanages, teaching them a new language and religion, without regard for that community's traditions related to extended families.[28] The mere appearance of involvement in such a situation, where our work could however unwittingly be used in such an abusive fashion is simply unacceptable. The apparent lack of post-implementation assessment or in-depth community research as part of the design process raised additional red flags.

We continue to consider it problematic for students to read many case studies about how important the role of the community is in appropriate design, only to work in isolation. Finding that this problem has not been well solved through other programs, because it is not practical for engineering teams to spend enough time in the communities that will ultimately implement and be responsible for maintaining the technology, we concluded that a true collaboration requires engineers to be on location for longer periods of time. Perhaps a study abroad program could provide sufficient time and familiarity with a community.

One possibility we are currently pursuing is to implement appropriate technology approaches locally. Hampshire College does this with assistive technology initiatives. Through Smith College's community-based learning initiative, our class connected with Nuestras Raices[29], a community organization in inner city Holyoke, MA. The grass-roots organization promotes economic, human, and community development through projects relating to food and agriculture. Nuestras Raices approached us with a particular problem they have related to a new project, the El Jardín bakery, which uses a brick oven to bake organic loaves that are sold throughout the region. Because the building is located next to a much taller building, smoke from the chimney is forced down toward the street, causing localized air pollution in the adjacent offices and nearby homes. Because asthma is very common in this community, an important aspect of the sustainability of this business is solving the air pollution problem. In spring 2004, Smith students will work on this problem in three teams. This is an engineering project that meets community needs, involves community members in design, and provides students with an important educational experience. By working locally, the potential for true collaboration increases significantly. Throughout this project, students will confront the problems posed by global development projects in their own community: for example, how high-tech a solution is appropriate in this context, with economic constraints around what the organization can afford. What does it mean if this community has a less effective environmental control technology on their stack, and is that acceptable?

Student Feedback

A mid-semester minute paper and end of course survey were used to gather student feedback, in addition to informal mechanisms. In general, results were quite positive for this course (see Table 1).

In open comments, students praised the class environment: its flexibility and openness, its small size, its seminar structure, and the tenor of class discussion (every student listed something related to this class environment as a favorite aspect of the course). Three students praised the project and three praised the guest lectures (Barret Hazeltine on nut farming in Africa; Judy Cardell on renewable energy). Other highlights students mentioned included the reasonable work load, the interdisciplinary aspects of the course, instructor accessibility, and an interesting course topic.

The most frequently mentioned improvement to the course (mentioned by three students) was connecting the course to a real-world problem in a community. Other suggestions included the incorporation of more on the theory of development, intensifying discussions, shortening the readings, and assigning fewer or no problems from the text. All of these were incorporated into the second offering of the course.

Conclusion

A course in global development at Smith College takes a critical view of appropriate technology and seeks to apply this knowledge to design in a real-world, community-based project setting. There are a number of challenges involved in designing a course on engineering and global development. The first is one of expertise. Because Donna Riley has an interdisciplinary doctorate in Engineering and Public Policy, she is perhaps better equipped than many engineering professors to conduct in-class discussions of social science topics. However, this

topic is not her area of research, and it is a daunting challenge to anyone to get a handle on the vast literature related to development. The angle of appropriate technology made this investigation much more manageable and served as a logical springboard for subsequent explorations.

Table 1: Results from end of semester survey, spring 2003 (n=9)		
Item	**Mean**	**Median**
Fulfillment of Course Objectives		
Design and build technology systems for use in developing countries	4.1	4
Apply knowledge of what constitutes appropriate technology to design	4.4	5
Critically analyze issues related to the use of technology in developing countries	4.6	5
Demonstrate an understanding of the limitations of technology in addressing problems of development	4.4	4.5
Quality of Readings		
Readings on reserve	3.8	4
Stolen Harvest	4.4	5
Appropriate Technology	4.6	5
Process of individual readings and presentations	4.1	4
Instructor's Performance		
Instructor explained things clearly.	3.9	4
Instructor facilitated discussions well.	4.1	4
Instructor increased my interest in course material.	4.7	5
Instructor increased my confidence in my abilities in this field.	4.6	5
Instructor fostered critical thinking.	4.0	4
Instructor was accessible.	4.7	5
Instructor gave good feedback on assignments.	4.1	4
Instructor was responsive to student feedback.	4.9	5
Quality of assignments and Course Activities		
Contribution of Homework Assignments to your learning:	3.4	3.5
Contribution of hands-on work to learning	4.0	4
Availability of help on project when I needed it:	4.4	4
Helpfulness of Initial Meeting with Greg Young and Prof. Riley	3.4	4
Helpfulness/Contribution to learning of Project Proposal/Outline	4.1	5
Helpfulness/Contribution to learning of Project Progress Report:	3.7	4
Overall Assessment		
Course	4.3	4
Instructor	4.3	4
I would recommend this course to a friend.	4.4	4

The time and effort required to put together any community-based course is daunting. The development of this course was supported by a summer student, travel funds and a faculty stipend provided by the College, and a staff member who has part-time responsibilities in establishing service learning at Smith. This course, or a similar course, could easily be adapted to another institution, but the logistics involved in setting up a community-based project are always time-consuming.

A second set of challenges relates to the ethical aspects of this work, which inevitably raises a number of complex and important questions. Community-based projects create additional challenges with many very real ethical problems that students and faculty alike must confront and resolve. We have discussed some of the ethical concerns in selecting a project in the

previous section, as well as issues students may confront that have an ethical dimension. In general, we rely on the ethical training our students have received as part of the engineering curriculum[30] and supply an additional reading specifically on engineering professionalism overseas.[31] Other course readings described above also ask many questions related to engineering ethics that are discussed and integrated into student writing assignments over the course of the semester.

There is a certain pressure on students not to let the client down and not to make poor ethical decisions in working in the community, because the consequences are quite real. New ethical questions, for example, related to funding for the engineering project, must also be anticipated and addressed. Students will share responsibility for some fundraising associated with the project, which raises issues of ownership and control. While these are addressed in other contexts through reading, the encounter in a real-world situation is a valuable educational opportunity, substantially different from classroom experience. The institutional coordinator of community-based projects -- who is experienced in working with our particular client and is knowledgeable about the history of students working collaboratively in the area -- served as an additional role model and resource.

The course is currently designed to anticipate as many challenges as possible related to engineers' involvement in community development work, and to meet these challenges with course readings, discussions, and reflections, as well as with student action.

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