

# Learning and Service in Engineering and Global Development

Donna Riley  
Assistant Professor  
Picker Engineering Program  
Smith College  
Northampton, MA 01063  
[driley@smith.edu](mailto:driley@smith.edu)

Alan H. Bloomgarden  
Director of Faculty Grants and Government Relations, Smith College and  
Ed.D. Candidate, University of Massachusetts at Amherst  
Northampton, MA 01063  
[abloomgarden@smith.edu](mailto:abloomgarden@smith.edu)

***Abstract*** - In Spring 2004, students in Smith College's new Picker Engineering Program teamed up with the community-based organization Nuestras Raices in Holyoke, MA to address the problem of wood-fired oven emissions posed by the successful and expanding operation of Nuestras' entrepreneurial project, the El Jardin Bakery<sup>1</sup>. This partnership between El Jardin and the Picker Engineering Program developed in the context of a new course, "Engineering and Global Development," which aimed to achieve such pedagogical goals as: developing an understanding and critical view of globalization and global development engineering; developing analytic and implementation skills related to the design and construction of technological solutions in developing settings; and critiquing the "expert" model learning relationships that operate both in the classroom and in the community. Though global in overall perspective, the course engaged multifaceted challenges of engineering, economic and human development. We found these challenges analogous across communities that are similarly distressed by pressures of globalization and human need, such as those affecting low-income, poorly-resourced communities worldwide. We also found the ambitious marriage among engineering education, development studies, and liberative pedagogies to provide profound challenges equaled by pedagogical, educational, and experiential rewards.

*Index Terms* – Global development engineering, appropriate technology, liberative pedagogy

## INTRODUCTION

Service learning pedagogies in higher education promise to prepare students to meet the needs of a rapidly changing economy and democratic society, while fostering an improved capacity for colleges and universities to respond to challenges of leadership, community development and social problems.<sup>2</sup> Globalization has become a widely-employed term that captures the breadth and depth of this changing socio-economic landscape.<sup>3</sup> Globalization at once draws our attention to the increasing connectivity between what is local and global, while highlighting expanding divides between dynamic growth in technology and retrenchant poverty, injustice and human suffering in developing communities. Service learning offers pedagogical and experiential

approaches to breaching these divides through intentional, reflective learning that connects disciplinary content to societal challenges.

Recent discussion in engineering has also 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. This article describes one approach to doing so via an interdisciplinary project-based course, an upper-level undergraduate elective within an engineering program at a liberal arts college. Open to students in a variety of disciplines, "Engineering and Global Development" seeks to initiate critical study of the technological, cultural, and policy aspects of international development through the lenses of critical and post-colonial theory, appropriate technology and critiques of neoliberalism, and sound engineering research and design. 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.

Furthermore, the course is constructed upon a semester-long, team-based collaborative service project that employs principles of engineering research and design to consider and redress a real-world problem. This dimension provides students both with a meaningful application of the social and technological critique they develop through readings and discussion, and an opportunity to engage in community partnerships we hope foster mutual understanding, personal transformation, collaboration that effects social change, and an expanded view of the purposes and practices of engineering as a discipline.

We begin by providing an overview of partners in this service-learning collaboration. We then present the Picker Program's "Engineering and Global Development" course approach to combining learning with service through the El Jardin bakery research and design project. Finally, we consider some of the challenges and lessons that emerged through the experience in the hopes these reflections will provide guidance to others who may similarly seek to develop educational approaches in engineering that tangle simultaneously with issues of design theory and practice, community service and partnership, inquiry-based and learner-centered pedagogy, and socio-economic development.

### **SMITH COLLEGE, THE PICKER ENGINEERING PROGRAM, AND SERVICE LEARNING**

Smith College in Northampton, Massachusetts is a women's liberal arts college with approximately 2,600 undergraduates. It is a member of the Five College Consortium, including Amherst, Mount Holyoke and Hampshire Colleges, and the University of Massachusetts at Amherst located in western Massachusetts. Smith's research-active science faculty, extensive undergraduate research programming, and track record of graduating significant numbers of students in the sciences who proceed to doctoral degrees create a backdrop for its recent decision to offer a B.S. in Engineering Science. In 1999, Smith became the first women's college to establish its own program in engineering science. The Accreditation Board for Engineering and Technology, Inc. (ABET) subsequently awarded accreditation to Smith's pioneering Picker Engineering Program in 2005, and the program has now seen three graduating classes totaling more than 80 students.

The engineering program's philosophy emphasizes the integration of engineering with the liberal arts. This view depicts engineering as a bridge connecting the basic sciences to the social sciences and humanities, and aims through the curriculum to realize the discipline's promise to apply scientific and mathematical principles in the service of humanity and ecological sustainability. The program emphasizes developing strong communication and abstract reasoning skills, and broad study of the theoretical scientific underpinnings that govern the

practice of all engineering disciplines. In particular, the program emphasizes the use of engineering science principles in design, most prominently via the year-long capstone “Design Clinic” experience required of every graduate. This focus on the application of theory, social relevance, and the significance of design principles make a potentially good fit between program learning goals and service-learning pedagogies and practices. However, no special engineering or Smith College initiatives existed then or now to encourage or support service-learning approaches.

Nonetheless, during 2001-2003 and concurrent with the startup period for the Picker Engineering Program, two environmental conditions facilitated the initiation of the El Jardin-Smith collaboration. First, faculty and staff across Smith departments and programs were engaged in an informal, monthly seminar on community-based learning in this period. Both authors explored service-learning’s practical and pedagogical challenges and opportunities through this primarily networking and group-learning process – Riley as a participant and Bloomgarden as the group’s convener. Second, a revitalized Five College Community Based Learning Committee became increasingly focused upon moving from an “outreach” model of placing students individually in volunteer service positions within the community, to a “partnership” model involving cross-campus and campus-community collaboration among faculty, students, and community-based organizations. These efforts were centered especially upon the nearby community of Holyoke, Massachusetts, in large part out of the Committee’s concern to redress a checkered track record of college involvement in this physically near but culturally and socio-economically distant community.<sup>4</sup> Underlying the Five College CBL Committee work was an abiding commitment to redressing the very loaded question raised by service-learning pioneers Nadinne Cruz and Dwight Giles: “Where is the community in service learning?”<sup>5</sup> This environment and the interpersonal contacts that developed on campus, across campuses and in Holyoke enabled us to approach Nuestras Raices Executive Director Daniel Ross regarding potentially fruitful college-community collaboration in January, 2004.

### **HOLYOKE, NUESTRAS RAICES AND EL JARDIN BAKERY**

Holyoke is a small city in western Massachusetts of just under 40,000 residents. The city has both a substantial urban center and suburban neighborhoods, and is characterized by sharp divisions between low-income lower wards (in which the population is over 80% Latina/o) and more affluent upper wards (with predominantly white residents). Holyoke’s industrial legacy faced a major economic downturn when paper and textile mills closed between 1945 and 1970. The Puerto Rican community in South Holyoke since the 1950s is the largest concentration outside Puerto Rico, and has faced long-term unemployment, dilapidated housing and decaying schools, health and social services, and other social and physical infrastructure.

Nuestras Raíces is a grass-roots organization founded in 1992 located in the heart of south Holyoke’s Latina/o community that promotes economic, human and community development in Holyoke through projects relating to food and agriculture. Nuestras Raices builds membership and leadership from among the low-income, primarily Latina/o youth and families that participate in their network of community gardens and community kitchen. The organization has developed an extensive network of community gardens, a youth gardening and leadership program, a series of educational workshops and fieldtrips, an environmental justice program, a health library, and has constructed the Centro Agrícola community agricultural center for community education and business development. Executive Director Daniel Ross was a 1999

recipient of the Do Something Brick Award for Community Leadership, and received an Environmental Recognition from the City of Holyoke Conservation Commission in 2001.

El Jardin is an artisan bakery in Nuestras Raíces's building, opened in early 2003 as an entrepreneurial project of Nuestras Raíces with the goals of providing jobs, training and popular, high quality organic breads to support those goals primarily through wholesale distribution. From modest beginnings and a site in an economically stressed neighborhood, El Jardin now supplies many finer restaurants and quality retailers in the more affluent neighboring communities of Northampton, South Hadley, and Springfield daily. However, success resulted in a challenge as El Jardin increased production. Specifically, the wood-fired ovens baking El Jardin's terrific products became a source of smoke affecting the neighborhood's air quality. Surrounded by taller residential buildings, El Jardin's emissions affected residents, businesses, and most important, Nuestras' own offices. Because asthma was already very common in this community, it was essential to the credibility and sustainability of this project to solve the air pollution problem.

### **ENGINEERING AND GLOBAL DEVELOPMENT**

The phenomenon of globalization has been recognized within engineering education as both a new business need and 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.”<sup>6</sup> A recent trend in engineering education involves project-based courses in global development, often connected with projects overseas.<sup>7,8</sup>

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. “Engineering and Global Development” (EGR 330) objectives include enabling students to:

- Design and build technology systems for use in developing countries
- Apply knowledge of appropriate technology and its critiques 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 pedagogical approach to this course, furthermore, is to practice and embody a critique of the “expert” model increasingly problematic both to educators and engineers alike. Specifically, the instructor seeks to empower students to own their learning through an inquiry-driven model, enabling them to assist in selecting readings and exercises under the guidance and facilitation of the instructor. This approach encourages students to help define the relevant engineering and development studies concepts in relationship to the course technology project, rather than requiring them to follow a predetermined, rigid and yet only occasionally relevant set of readings and exercises. This Freirian<sup>9</sup> rejection of the “expert” role for the instructor in favor of the “facilitative” role is a pedagogical tool (and a value) pertinent to classroom practice – it is also a lesson and value pertinent to students' learning about what it means to practice engineering in the community. Namely, the aim of this approach beyond the classroom is to encourage students to learn and embody a critique of the “expert” model as they gain entry and cooperation from partners in the community. Empowering students and their community partners to become

responsible for and “own” the processes and agendas for learning are components of a “liberative” pedagogical approach, based on the critical works of Paulo Freire, Bell Hooks, and others.<sup>10</sup> These posed fundamental challenges but promised important educational gains go well beyond the obvious aim of practicing what was being “preached” about collaboration and equity across power and cultural boundaries.

The course began with an introduction to issues in global development, based primarily in the social science literature. Students were introduced to the ideas of appropriate technology and critiques of that approach. Through a number of case studies, students explored 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, because the connection with *Nuestras Raices* was established, students in the spring of 2004 had the opportunity to apply their knowledge in a real community situation, which was preferable to learning with a ready-made project.

Students began with two short readings packed with thought-provoking material for lively discussion. The first three pages of Arundhati Roy’s nonfiction work *Power Politics*<sup>11</sup> gave students an initial exposure to one Indian woman’s view of globalization. Juxtaposed with a piece entitled “Kofi Anan’s Astonishing Facts” from the *New York Times*<sup>12</sup>, students were immediately confronted with the enormous global inequities and the wastefulness of developed country consumers. Discussion helped students work through a variety of responses typical of those in power positions – defensiveness, guilt, denial, anger, and an earnest yet sometimes patronizing desire to change the situation.

Students read two histories of development – one policy oriented, explaining concepts such as structural adjustment, and an Afro-centric sociological critique of colonialism by Walter Rodney.<sup>13,14</sup> To understand Rodney, whose perspective is distinctly Marxist, students also tackled an excerpt of Max Weber’s *Protestant Ethic and the Spirit of Capitalism*, to understand why many in the world critique capitalism as an economic system.<sup>15</sup> While this can be threatening to some, it is vitally important that students engage the dialogue about globalization directly, which necessarily involves understanding arguments based on critiques of global capitalism. It is not possible to understand current critiques of neoliberal approaches that guide most student engineering projects overseas today without understanding these fundamental critiques of the overall framework under which development is taking place. This was a first introduction for most students in the course to these readings, so they were kept short with extensive time for discussion.

After reviewing development efforts from these perspectives, it was natural to examine more deeply what has caused the failures of past development projects. We supplemented the answers given by earlier readings with that of Hammer, an anthropologist who focuses on explanations rooted in a lack of attention to culture, power, and communication.<sup>16</sup> At this point students wrote 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 examined the role of technology in society through readings by Langdon Winner and Richard Sclove.<sup>17,18</sup> Students learned 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 on “the virtues of mundane science” that discusses the academic biases that prevent important breakthroughs in low-tech and low-cost solutions to some problems

of poverty and environment around the world.<sup>19</sup> Through these and previous readings, students examined some of the reasons for development efforts that have been disastrous for local communities economically, socially, or culturally.

Students were then introduced to the phenomenon of appropriate technology, both in its historical form and its resurgence with a neoliberal, entrepreneurial twist, driven largely by western engineers. Students read articles by proponents and critics of appropriate technology, and wrestled 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.<sup>20,21,22</sup>

At this point students wrote 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 was a short reflection intended to help students make the connections between the classroom and the field work. Most class work was directed toward the project and its deliverables, discussed below.

Students examined a number of case studies in appropriate and inappropriate uses of technology in developing countries, focused around the themes of water, food, and energy. Questions about when to use high –tech and when to use low-tech approaches, how to grapple with western cultural and economic power, and what makes a project successful, and for whom, were woven throughout. Case studies highlighted both the successes and failures of engineering in global development, as well as a case in which science succeeded in developing a vaccine, but economics and policy failed to create effective distribution.<sup>23</sup>

Students examined three case studies based in different models of economic development. Yunus describes the development of Grameen banking and Grameen telecomm in Pakistan, Albee and Gamage describe a credit union cooperative owned and run by poor women in Bangladesh, and Stevens 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.<sup>24,25,26</sup>

Students examined historical case studies of appropriate and indigenous technologies, including the Lorena cookstove in Guatemala,<sup>27</sup> Kpelle steelmaking in Liberia<sup>28</sup>, and indigenous architectural practices that integrated western approaches to strengthen buildings following the 1974 Guatemalan earthquake<sup>29</sup>. The complexities of these cases allow students to discuss factors that make such projects successful, and take apart assumptions that idealize or deride appropriate or indigenous technologies.

Capitalizing on local expertise in assistive technology at Hampshire College, students studied 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).<sup>32</sup> 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; a second article about working with wheelchair users illustrates the importance of community involvement and empowerment in the design process.<sup>33</sup>

Students examined the case of the Tehri Dam in India, which has caused widespread displacement of families, in order to provide electricity to wealthier citizens far away. In this case, we welcomed the local expertise of a Smith student who wrote on the topic.<sup>34</sup> Case studies in water included Rita Colwell et al. describing the reduction of cholera rates in Bangladesh through the use of simple filtration with sari cloth,<sup>35</sup> 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.<sup>36</sup> The role of women in water and sanitation enabled us to discuss gender and development, a recurring theme in the course.

Two short assignments provided practice problems for students to apply their engineering knowledge to the key areas of water and energy. The problems were simple enough that non-engineers could attempt them with some success, yet at the same time they challenged conventionally trained engineers to employ more big picture and common-sense thinking, with an emphasis on estimation and judgment.

### **El Jardin's Oven Emissions as a Service-Learning Project**

It was within this context of global development engineering and its critiques that students undertook a local service-learning project with the El Jardin Bakery. Globalization has certainly had its impact on the city of Holyoke, as textile production has been exported from Massachusetts toward cheaper labor markets, the economy in industrial mill towns like Holyoke has suffered, necessitating new forms of economic development. The bakery project is an interesting example of sustainable economic development in an urban setting, introducing locally grown and produced organic bread that changes the relationships among consumers, food, those who work to produce food, and the land. A particularly interesting aspect of their economic model is to provide a high-end market product to upscale stores and restaurants in the surrounding, more affluent communities, bring the fruits of this market back to Holyoke, and employ these profits in support of Nuestras' larger social change aims by creating jobs, subsidizing educational outreach and gardening projects regarding health and nutrition, etc..

A local project was chosen because geographic proximity created a greater likelihood for ongoing relationships, frequent communication between Nuestras Raices and project teams, proper project assessment, and accountability in continuing involvement. While working in Holyoke was definitely a cross-cultural experience for most students, it did not require the same level of acculturation, or logistical challenge as an overseas project in the developing world. On the semester time frame, this seemed appropriate.

The twelve students in the course met initially with Nuestras Raices to learn about the problems at the bakery and get to know the executive director and bakers with whom they would be working closely. Daniel Ross made it clear that the primary problem was related to the indoor air pollution in the Nuestras Raices offices, and while the outdoor pollution was a local neighborhood concern, residents were more troubled by large polluters in the region that were affecting Holyoke's outdoor air quality.

The students met as a large group to define the problem and identify general approaches to explore over the semester. Taking a systems perspective, they identified three control approaches: (1) preventing pollution at the source by focusing on fuel and combustion; (2) preventing smoke from entering the Nuestras Raices offices by improving the exhaust; and (3) addressing indoor air quality in the building through filtration or HVAC modifications. A group of three students developed design ideas for each of these approaches.

The students wrote an initial proposal outlining their work for the semester, including Problem Definition, Solution Criteria, Design Options, and Evaluation methods. This was presented to Nuestras Raices for feedback. A progress report was due a few weeks later detailing the work the team had accomplished to date. At the end of the semester a final written report was due, and an oral presentation made to Nuestras Raices. Rubrics were used to clarify expectations

and structure students' work. The project was worth 50% of the grade overall, apportioned across these assignments and peer and self evaluations which took place at midterm and the end of the semester.

Students traveled to Holyoke many times over the course of the semester to engage in data collection, discussions with Nuestras Raices staff, and testing of design ideas. Students pursued different kinds of engineering knowledge driven by each of their projects, including combustion chemistry and thermodynamics, heat transfer, passive solar technology, indoor air quality modeling, mass transfer, statics, and strength of materials.

The combustion/source group recommended strategies for burning wood more cleanly, including construction of a solar wood dryer, design changes to the oven door, and alterations to the fire-building process in the oven itself. The dispersion group recommended extending the exhaust stack by adding a steel pipe to allow smoke to exhaust from the building rather than being forced back into the building by downdrafts in the urban corridor. Their report included summaries of wind data collected on the roof of the bakery that helped identify and characterize the down-drafting problem. Additional potential enhancements to the stack, if needed after initial implementation, included installation of a chimney fan to help draw air up the chimney, and a catalytic combustor to address local outdoor air pollution concerns if they remained. Finally, the indoor air quality group provided data on fate and transport of pollutants from the bakery to the offices and recommended the use of conventional air filtration units to reduce exposure to bakers and workers in the adjacent offices.

Nuestras Raices was most interested in building the taller stack. However, complications arose in the organization's dealings with the city, in which the city required a permit and professional engineers' certification on the project. While the students had worked with both the city and local professional engineers to enable this work to go forward, this collapsed on both ends. When the semester ended, students' enthusiasm dwindled. Although the class had discussed at length the problems with the semester's artificial time line and students had committed to continue to see the project through to completion, each student reneged on this commitment for various reasons having to do with competing demands on their time. Further complicating this was some ambivalence on the part of Nuestras/El Jardin toward pursuing the student recommendations. We did not know this at the time, but in their own efforts to determine potentially practicable and affordable solutions, the staff had identified a potential solution from a catalogue that they believed might resolve the internal air quality issue at an acceptable cost. They were reluctant to bring this to the instructor's or student's attention mainly because they were hesitant to slow or redirect the learning and research processes underway.

Students end of course evaluations asked for their assessment of the fulfillment of course objectives, the quality of readings, assignments, activities, and instruction, and overall impressions. A five-point Likert-type scale was used to evaluate each element of interest, with invitations for open-ended comments throughout. The course objective with the highest rating (mean=4.72) was the ability to critically analyze issues related to the use of technology in developing countries and local communities, followed by understanding technology's limitations in addressing problems of development (4.54) and the ability to apply knowledge of community-based design in a real-world situation (4.36). The objective with a much lower rating (sample size too small for statistical analysis) was the ability to design and build technology systems (3.18). Judging from students written comments, this rating is low in part because the project did not reach a fabrication stage, and in part because non-engineers perceived this as something they were not capable of doing. When asked to critique the objectives, one student suggested that

students be required to develop a more solid position or set of personal beliefs about appropriate technology and its use in development.

When asked to rate the contribution of course elements to learning, students ranked the community collaborators the highest (4.45) and the hands-on work with Nuestras Raices second-highest (4.36). The project deliverables (progress report and proposal ranked next highest at 4.00 and 3.90 respectively). Other elements including the homework assignments and in-class discussion and activities were ranked much lower (3.09 each) and with a wide variance. Students clearly recognized the importance of the project to their learning. Their critiques of project included that groupwork is stressful, and that it was not “low-tech” enough. They said they wanted a project that dealt more with basic human needs and appropriate technology; however, we view this as a failure to communicate the purposes of the bakery, which clearly does support a basic human need (food), and does so in a sustainable way that fundamentally changes relationships among people and resources in the region.

Students were reflective about the ways that power dynamics played out on the project, and how academic achievement goals sometimes competed with Nuestras Raices’s goals. As one student put it:

We came across as the token college class that steps just a little bit off of the ivory tower to work with a community organization. We spent more time with the assignments to prove our progress and formalize the process than we actually did thinking about the issues here. I don't mean to say that we didn't think about what it meant to be doing a real project. You brought up the topic a lot, did a good job getting us to remember that our project had real implications for building relationships or creating tension....but we didn't internalize that in our processes nearly enough. That's my critique. I DO feel like I could recognize some of this in a future project, and to me that means that I am learning well.

## CONCLUSIONS AND REFLECTIONS

The instructor’s *a priori* commitment to an expertless classroom or at least a non-expert relationship between faculty and students drew upon a deep commitment to both teaching about and embodying in practice equitable approaches to differential power relationships in service and learning. Riley wanted students from the outset to own their learning, and asked them to explore engineering technical pieces as needed rather than as a complete, intentional problem set. Yet students needed more context for understanding why this framework that they perceived as open-ended and less structured was appropriate both to the subject and the processes with which they were engaging. It is clear that greater clarity about the purposes and responsibilities embedded for both student and faculty member in these approaches would have been beneficial, and subsequent courses based on this approach will attend to articulating and communicating these matters better.

Breaching the cultural/race/class divide was an aim typical of many service-learning projects that we imported to this project. Yet communication broke down between students and the bakers. Students were not as consultative and present among the staff of El Jardin and Nuestras as either they would have liked, or as we would have preferred, from a participatory perspective. For example, after learning that the wood fires for the oven could be constructed in several different possible configurations and procedures, we wonder why didn’t students ask the bakers about how fires are made? They felt they could not ask about practice because they feared presenting their question as a critique of local practice. They were sensitive enough to be

concerned about coming across as judgmental, but perhaps not skilled enough as communicators to overcome this cultural challenge. We see this as a lack of experience in addressing culturally sensitive issues that perhaps we could assist with through some role play and preparation.

Similarly, we did not succeed in sustaining a relationship that could address either long-range social change goals or develop additional axes upon which mutually beneficial learning and service collaborations could develop. We sought transformation among students in their perspectives on the power, race and class divides, but it seems the results were at best one-sided (with students as “tourists” experiencing an expansion of their cultural horizons). In one sense a more ambitious, reciprocal gain was out of our control because the transformation of community views regarding students, engineers and colleges can only happen in the community when the community members and organizations involved can anticipate and trust that there will be an ongoing relationship worth investing in. The particular transformation we would have anticipated – about the expert relationship in engineering both in the classroom and in the community – could not occur on the community end without expectation of an ongoing partnership. This was instead an intervention. Each of these are key aspects of community-based research projects as identified by the literature, and they are regrets we have that stem somewhat from the ambivalence we encounter among our institutional colleagues for this work.<sup>38</sup>

Ultimately, the model in which engineering students act as engineers on a project to benefit a community client imposes expertise onto students in a way that can undercut some of the pedagogical goals of service learning. Setting up a “cult of the expert” implicitly devalues the knowledge and expertise held by community members and creates expectations that engineering students may not be able to fulfill. Different models may be more effective – for example, ones in which students act as apprentices to community members, so community knowledge is formally recognized. Students then can share what specialized knowledge they have from a more appropriate place – one that facilitates two-way transfers of knowledge so that communities come away with engineering knowledge, and engineering students come away with practical and project-specific knowledge. Even in our project where the “cult of the expert” was resisted, the expectations persisted, perhaps because of public perceptions of engineers – can engineering students ever be just students, if they are working on a community project involving technology?

Clearly the differential in time scales for action that is a well-documented problem in campus-community work was a problem for the service-learning component in several ways. First, it is clear that the extensive learning goals for the students to acquire knowledge and data regarding the specific engineering challenges took up a portion of time that perhaps the El Jardin staff may have felt delayed their arrival at potential solutions. In some ways this is perhaps inevitable, and it was never an option to abandon the inquiry-based learning and field research as educational dimensions in favor of a scan through product catalogues to identify possible solutions. Second, the requirement for students to extend their commitment beyond the credit-rewarded semester may have simply been a bridge too far. Both issues lead us to ask: how can we effectively combine the two purposes (learning and service) within the confines of high institutional expectations for learning coupled to relatively traditional modes for classroom-based learning. More models in which engineers and others are engaged in ongoing service outside of a classroom context yet which connect with the curriculum more seamlessly might be more sustainable by both benefiting learning, and allowing community organizations to benefit more from the collaboration by extending the impact and the relationship, beyond what can be achieved within the artificial time frame of the semester or academic year.

It was perhaps overly ambitious to take on a course that simultaneously attempted to (1) alter power relationships in the classroom; (2) engage students in social critiques of technology in global development in a fashion that directly challenged globalization; (3) participate in a community project that locally and practically applied academic themes around power relationships, technology, society, and economic development; and (4) use engineering design principles to solve an urban and indoor air quality problem for the bakery. We have made critiques of our overall model as well as the details of its implementation. Future projects should pay more attention to communicating pedagogical goals and demystify the cult of the expert in both classroom and community. We need to improve the collaboration and communication process and creatively work around the artificial time constraints of the academic calendar. By making social analysis of technology-based development projects a central part of the course, students were able to identify and learn from the imperfections in our own project. Involving the community group more in this evaluation process is likely to reap similar rewards and enable us to move forward with more effective service learning projects that better meet academic and community goals.

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