CHAPTER 3

Why Design for Industry Will Not Work as Design for Community

"With over four decades of experience with appropriate technology in the South, why do so many engineering-for-development initiatives still struggle to produce successful, sustained outcomes? One compelling answer to this question is, simply, that 'Development is difficult.' This claim is a truism for anyone experienced in development work, surely. But if this truth were widely known, we might expect to see fewer projects initiated with more investment dedicated to each. Instead, the past decade has seen a proliferation of engineering-for development projects, and this fact provokes a different answer to the question of why engineering-for-development projects struggle with success: 'Our models for development are wrong.'"

–Nieusma and Riley, "Designs on Development: Engineering, Globalization, and Social Justice."

3.1 INTRODUCTION

We care about design. Of all engineering activities, it is perhaps the one creative process where science, math, art, economics, function, form (and more) can come together in the conception, development, and implementation of a system, or artifact for a specific purpose. Design is at the heart of what engineers do. We agree with Bill Wulf, former president of the National Academy of Engineering, who describes engineering as "design under constraints." After participating in design workshops, teaching an engineering design course, and conducting ethnographic work on engineering design activities at large high-tech companies like Airbus, Boeing, and Honeywell, we have come to appreciate the challenges that engineers face when teaching, learning, and doing design. In short, we celebrate design!

Yet after conducting numerous interviews with students and faculty involved in design for community development or humanitarian engineering—which we will call "design for community" for the remainder of this book—we became concerned about how the assumptions, methods, concepts, and practices underlying many of their design projects come from practices born in industrial and corporate settings. As we continued to listen to students and faculty, read their design reports and syllabi, review engineering education journals, and participate in design conferences, we further confirmed that most in engineering design education still follow assumptions, methods, concepts, and practices that come from industry and corporate settings.

While teaching courses on Engineering for Sustainable Community Development (see Chapter 8) and Humanitarian Engineering Ethics, many of our students involved in design for community projects found a place, perhaps for the first time, to critically reflect and write about the problems that emerged when they brought industry-based assumptions and practices to design for community projects. Students' realizations, and more importantly their capacity to grow intellectually as they made these realizations, were both revealing and inspirational to us (see Chapter 8 to see how students changed by questioning design projects and practices). As we did for our own students, we want to help engineering students involved in design for community make these realizations and grow intellectually in their own terms. Hence, we invite you to read this chapter and patiently engage the issues and questions raised here. In short, we have sketched here an anatomy of senior engineering design with the following goal: **To help students identify and question the underlying assumptions, concepts, methods, and practices in their engineering design courses and projects so they can assess the appropriateness of these for design for community.**

We begin our anatomy of design by dissecting a design project that won an award for "Exceptional Student Humanitarian Prize." Winners for this competition were selected "based on the results achieved and their impact on humanity, or, on a community." Although this is only one project of design for community, it represents an exemplar within the engineering profession, as it was sponsored by the president of one of the largest and most influential engineering societies in the world. We understand that every design project is different, so the project presented here might not be similar to yours. The features, assumptions, methods, and procedures in this exemplar might not be representative of all design for community projects out there. In other words, our intent here is not to generalize from a sample of one. Yet this exemplar is significant and relevant because of the recognition that it received from an engineering society, how it reminded us of the dozens of design for community projects that we have come across over the years, and how it can help you learn to raise critical questions on a completed project before you begin yours.

Our intention here is not to blame or embarrass a particular design team or course, but to begin revealing the hidden assumptions that are often made in design for community projects. Hence, the quotations that follow are taken verbatim from the source material, but actual references are omitted, so that the focus can be on highlighting oversights, inconsistencies, and challenges that such groups face when practicing design for community. Although lengthy, we decided to include here the majority of the project description, broken in segments, to allow you to slowly read, pause, and reflect through the all the steps taken by a design team, asking with us difficult questions that might reveal problematic assumptions, concepts, methods, and processes often made or used in design for community. Here we go!

3.2 ONE DESIGN PROJECT: DESCRIPTION AND REFLECTION

The description of this particular group's design project begins this way:

Project Description: In the developing world, there is a need for technologies that make their lives easier. These technologies need to be inexpensive and the materials must be locally available. One of the needs is an efficient and inexpensive way to crush and dehusk grain. The grain crusher project arose from an Engineers Without Borders trip to Senegal. They said that the people there do have a grain crusher, but some cannot afford it due to the cost of diesel, which is the fuel used to power the crusher. Also, the hand method of mortar and pestal is very time consuming and hard on the body....

This description clearly and neatly lays out a defined problem, one that perhaps you agree needs to be addressed. At first glance, it seems this design team is working toward something worthwhile and necessary. Yet, this description takes many things for granted:

- What assumptions exist when students call a country "developing" or "Third World," while calling others "developed" or "First World"?
- Why do engineers in these types of projects focus on "needs?" How do they find out what a community might "need"? How can these students come to assess and understand a community's needs and define a problem after just one trip to Senegal, despite language and cultural barriers between the students and the locals?
- How and why did local villagers express their desire to and interest in working with the design team? Is the students' assumption, that hand techniques are "time consuming" and "hard on the body," fully accurate? Is it a perspective shared by the local community?

In fact, the project description provides a narrative describing, in some detail, how the project members came to a solution:

Solution: The human powered grain crusher project began in the Fall of 2006. The original design concept was for a rotary stone grinder called a quern. *It was decided* that the most reasonable device to fulfill the purposes of this project would be the quern which is essentially two circular stones, one on top of the other, with an axle in the center and a handle attached to the top stone. The grain to be ground is placed between the two stones and the top stone is rotated about the axle. On more advanced designs, a small hole in the top stone allows for the continual introduction of fresh grain into the space between the stones. It is very efficient, effective, and constructed of all natural materials, which require very little machining. The quern and its direct descendent, the millstone, were so effective that they were the primary means for all grain production until the late 1800's. Some small scale modern mills, in fact, still operate using high quality, electrically-turned millstones that produce flour which is said to have better baking qualities than commercially available flour which is produced using metal grinding devices. *Having chosen a design,* using circular cement "paver" stones and a steel rod as an axle, a working quern was assembled and tested. *It was tested* by grinding various types of grains and proved to be adequate as a working model. Then the group started to contemplate what improvements could be made to a device that had existed in various forms for thousands of years. It was at this time that *the realization was made* that the quern had very little development potential, while keeping the cost at a reasonable level (italics added).

You probably detected that all of the italicized words in the description above are in the passive voice, which is a typical communication strategy in technical writing. Yet, the use of the passive voice here—in a design for community project wherein communication and collaboration between design team and community members is important—leads us to ask several questions:

- What are the implications of the passive voice ("it was decided", "having chosen a design", "it was tested") in a description of a design project?
- What does the passive voice hide? What does it tell us about how decisions in a design project are made?
- Might the passive voice reveal how the perspectives of the community that the design is supposed to serve remain untapped?

The project solution description continues:

Having realized that making a quern would not allow any improvements beyond what already existed, the focus of the project shifted to a grinder that is produced in Uganda. The Ewing III grinder is produced in a manufacturing plant in Uganda that was set up by Compatible Technology International (CTI), an organization that helps to improve food processing operations throughout Africa. Discovering the Ewing III grinder allowed us to shift our focus from designing a complete grinder to developing improved methods to power an existing grinder. We attempted to contact CTI in an attempt to acquire a Ewing III but never received a response. As an alternative, we selected the Country Living Grain Mill as a comparable substitute to the Ewing III grinder. For powering a grain crusher, a device is needed to convert human power to mechanical power for the grinder. Designs brainstormed and researched included bicycles or stationary bicycles modified with a chain or drive belt used to turn a crank on a personal, kitchen type grinder. **The group decided that a bicycle stand for an existing bicycle would be the best idea for the scope of the project.** A bicycle stand *was constructed* with intentions to be attached to a pre existing grinder. Of critical importance to the design was a wide range of adjustability so that the final product could fit a variety of bicycles. The stand would need to fit bikes with tire diameters ranging from 20 inches to 26 inches, and also with varying rear axle widths. The design also had to allow for adjustment to the tension in the drive belt, so *it was decided* that the grain crusher's location would be adjustable to provide such tension. The only fixed components would be the center drive axle and its supports. Everything but the bolts and bearings is made of 6061 aluminum, because this is just a prototype. The rear bike wheel is held in place by two "pucks" with holes lathed into them so that it fits over the nut on the back axle. The support shafts that hold that puck are adjustable in height. The wheel rests on a roller once it is properly secured. The roller has 80 grit grip tape on it to ensure more friction. When the bike is pedaled, the roller turns a 3" v-belt pulley which is belted to a 12" pulley on the grain crusher itself. Slots are milled into the base so that the belt can be tensioned or replaced. *An effort was also made* to use as many off-the-shelf pieces as possible. This would limit machining time and product variability for the end-user. *It was also proposed* to include an electric motor that could be powered by solar energy. This would give users the option of human or electric power, so if they do not have electricity, they are still able to use the device (italics and bold added).

Although the active voice (e.g., "we selected," "The group decided") is encouraging, active decisions seem to be made only by the design team and not by local community members. Again, questions arise:

- Could it be problematic to assume that a grinder produced in Uganda, or one sold by Country Living Grain Mill through a US catalog company, would be appropriate in Senegal? After all, these three countries have vast differences in people, colonial past, geography, economy, and potentially beliefs about, and ways of using technology.
- What issues might emerge when assuming that "off-the-shelf" parts found in the US would be found on shelves in a community in Senegal?
- How did the engineers know that the potential users would want to pedal a bike as a source of energy for the grinder? Who did they have in mind when selecting a bike? Women? Children? The elderly?

The project solution description continues:

During the Fall 2007 semester, the objective of this project returned to the original objective with a focus on reducing cost and weight of the product. In order to accomplish this, the Spring 07 design was turned into a working model and analyzed to determine how best to reduce the cost. It was found that if the team could create its own grain crusher instead of ordering the Country Living Mill, the cost of the overall product would be greatly reduced by about $150. This change also reduced the weight of the product because the crusher has been made from aluminum instead of much heavier cast iron. The new crusher is designed to retro fit onto the previous base. It is the same width and roughly the same height. The method of grinding remains the same. The grain is fed in through the top of the grinder and is augured through a hole. That hole allows the grain to fall between two grinding plates. One plate is bolted down, and the other rotates and the shear force is what grinds the grain. Keeping the same idea of the prototype in mind, the total price of materials was a large difficulty. The pricing goes hand in hand with the conservation of materials, so when the excess material is trimmed down, the total cost of the product will have the same effect. The Spring '07 design had a Baldor motor ($225), Grain Crusher ($375), and construction materials ($200), so the cost of this design was approximately $800 to build. For the Fall '07 design, the cost of the materials to make the crusher itself is approximately $224, which shows that the objective of this project was reached. The new design costs $151 less than the old one, excluding the motor. The motor was also eliminated from the design, saving more on the cost of the project. This would be one of the designs taken to India for the pilot study.

By now, you might be asking with us:

- Why are cost and weight reduction the guiding design constraints? How would the design be different if the main constraints were community empowerment and respect for traditional grinding practices? How was the design tested and by whom?
- What does it mean when the design cost of a grinder is $800 for a country with an annual GDP per capita of $1600?
- Why would this design, intended for a Senegalese community, be appropriate for testing in communities in India? Is this testing in India motivated by a belief in the *universality of technological applications* highlighted in the Introduction?

The design group goes on to describe the testing for the project, and its potential implementation:

This design was tested for how long it would take to grind different types of grain and roughly how much energy was required to grind each type of grain. A simple test was done by tying weights to a string and then tying the string to the shaft of the crusher. The maximum weight that we could lift at a replicable rotational speed of about 1888 RPM was 44.85 N. Since a replicable design was available, [our] University Business Department showed interested in working with the project. After meeting with the group of business students to show them our drawings and explaining the concept of the project they decided to work on the marketing side of the project. At present, the business team is doing research on areas the finished project can be marketed in. They are also presenting to a group of possible entrepreneurs that might be interested in becoming involved in the project. In addition, the design team also investigated other market sources for the product. During spring break, the Engineers Without Borders [EWB] clinic team traveled to a community in Senegal. Presented with this opportunity, a list of questions was compiled for the team to ask the community that they stayed with. A great deal of information was brought back from the group.

From this description, important questions emerge:

- Where were potential users from the community during this testing stage?
- How extensive, reliable, and legitimate could the data be if it was gathered during a one-week visit? Was this the first time the team engaged the community's perspective?
- Who defined the questions to be asked of the community? What did the team learn from the community?

The design team then describes some of the EWB traveling team's findings:

They found that there is already an existing grain crusher that can be used, but the cost of the diesel to run the crusher prohibits some of the communities from using the grain crusher. Also, the women of the community are the ones who crush the grain everyday, and to do so, they wake up around 4:30 am to produce enough grain for the day. The EWB team found that if an easier and less expensive way was available for crushing grain, the members of the community would be very interested. To provide visibility for the product being designed, a website was assembled to showcase the Grain Crusher project …It also gives links to the types of products used to create the grain crusher device. The site is currently up and running and has been updated recently with a photo gallery and video clip of the working model. In the beginning of the Fall 2008 semester, it was decided that the grain crusher assembly should be made to be more reliable and user-friendly. The idea behind redesigning is that the current design may not be acceptable to all bicycles, such as mountain bikes or bikes with pegs. Also, it was decided that the grain crusher could be made cheaper and lighter, but still be very sturdy by using steel. The new design still uses pedal power to turn the crusher, but it is self contained so that you will not need to attach a bicycle. To save money, the new design is made primarily out of steel. Steel is less expensive than aluminum, but it is stronger so fewer support components will be needed…It is also chain driven instead of belt driven. Another great benefit of this design is it not only reduced the cost of the crusher to $250 all together, the weight also dropped from about 40 lbs to 32 lbs. The design has the same grinder plates and loading system as the Fall 2007 design, except an auger was added to increase the feed rate of the grain that is being ground up. The seat has 6 adjustable height levels to make useable to a wide variety of people. The gear ratio is slightly greater than 1:1, but is still relatively easy to pedal. Energy calculations still have to be done on this design, but from observation the speed is slower, but it is easier to pedal than the Fall 2007 design. This design does have a slight learning curve when it comes to finding the correct height and getting used to pedaling while sitting directly above the axis of pedal rotation. The cross member that runs perpendicular to the chain direction is bent 5 degrees on both ends to reduce the "rock" effect and provide greater stability. With two designs completed, preparation began for the pilot study. One slight modification to newer design was made. In order to save money, each design was brought as luggage on the flight. The one end of the base had to be trimmed an inch and a half in order to fit the airline's luggage size regulation. This did not affect the balance or the performance of the crusher.

Salient questions emerge:

- What does it suggest about current design for community projects when students, *after* defining the problem and brainstorming solutions, find that the community already had a working grinder?
- If a key problem with the existing grinder is the cost of diesel, could engineers envision simpler *economic* solutions (e.g., subsidies or increased efficiency in diesel transportation, etc.)?
- What if most or all bicycles used in this community are needed for essential transportation between villages and are unlikely to be given up for grinding (see Figure 3.1)?

The description goes on to provide information about the village and the process of dehusking. Oddly, this information appears late in the description, long after the problem and solution have seemingly been decided upon, by the design team itself:

Sengalpaddai was the village in which the pilot study was conducted. The first part of the pilot study involved investigating, first hand, the current methods used to grind grain. One aspect that was not known was that they use a quern to "dehusk" lentils. Dehusking is the process in which the outer skin is removed and the lentil itself is broken in half. Once they separate the skin from the grain, they grind it up using a long stick and a bowl, a dry mortar, and pestle, or a wet mortar and pestle (for flour). The next step of the pilot study was to demonstrate how to use the Fall 2008 design. Once it was assembled, and a short demonstration was given, they took turns using the crusher. Once they had done that, we repeated the process for the Fall 2007 design. There were several major aspects that were observed. The first is that when adjusted properly, the crusher also removed the skin of the lentils very well. Also, not many of them wanted to sit on the seat and pedal, especially the women, because they did not want their clothes being caught up in the chain. Instead, they sat down behind

Figure 3.1: Health care workers in Senegal, Namibia, and other African nations use bikes to deliver food, medicine, and companionship to people with HIV/AIDS.
(Source: `http://www.rd.com/content/printContent.do?contentId=58758` Author unknown.)

the crusher and pedaled by hand. Another noteworthy observation is that the Fall 2007 may be a little faster, but it is difficult to collect the crushed grain. Overall, the newer design was much better received than the older design. Once the trial was done, a roundtable discussion was had in order to receive feedback and suggestions to improve upon the design. They said that when they wanted the grain fine, it took too long so they wanted larger grinding plates to improve capacity. They also said that the grain tended to get caught up in the plates and just repeatedly cycling around, so they suggested making the plates horizontally oriented, in hopes of expelling the crushed grain faster. Another design change is to make it spin faster to increase output, but also keep in mind it needs to be easy to use. Another suggestion was to make one hand powered handle, instead of the foot pedals. They also wanted a better collection system.

Key questions continue to emerge:

- What does it mean for a community when a pilot design is demonstrated to them after their voices seem to have been excluded from all prior steps in the design process?
- What can we tell about the way engineering students are being trained in design when they find out at this stage of the design process that "not many of them [villagers] wanted to sit on the seat and pedal, especially the women, because they did not want their clothes being caught up in the chain"?
- How could a "roundtable discussion" yield trustworthy information when there has not been enough time or opportunities for the community to develop trust with the design team? How

well-equipped are the engineers to discern the community's diversity of voices, hidden tensions, and conflict from a "roundtable discussion"?

The design team goes on to describe the current status of the project, and how team members envision future work:

Current and Future Work: Currently, the newest design is being contemplated. The objective is to incorporate as many of the suggested design changes as possible. Price is still a parameter, but since only the design drawings will be sent to India, size and weight is not as large of a concern. One change that will be implemented is larger grinding plates. Madurai Mill Stores (www.maduraimillstores.com) sells much larger grinding plates. Currently, they have yet to send us technical information about the plates. Once the new design is completed, and a prototype built, performance calculations will be done. The energy calculations for the new design will make sure it still is relatively easy to grind the grain. Now that it is known what the villagers want in the design, the newest design should be the most ideal. If the prototype works well, the drawings will be sent the DHAN foundation where they will distribute the device to villages that need it in the effort to make them self sustaining.

Such a description leads to several questions:

- What does it say about our current practices in design for community when it took this long for students to readily write "now that it is known what the villagers want in the design"?
- Could the reception of the new prototype by the villagers in Sengalpaddai be affected by the quantity and quality of time the design team dedicated to establishing rapport and trust with them?
- What could be problematic about assuming that a prototype will be distributed to villages across cultures, adopted, and become sustainable in the long term?

The team briefly describes the impact of the project:

Impact: By providing a better device for crushing grain, they can produce more of it for the community. Not only that, but the devices, once distributed, should provide entrepreneurial opportunities to the villages and people running them. This should alleviate poverty to an extent in the developing world and improve the quality of life. Once the grain crusher is finished, other prototypes will be developed that address other needs in the developing world. These prototypes should have the same result.

Summary Questions:

- What could possibly be wrong with a design meant to "alleviate poverty" in the "developing" world?
- What if good intentions are not enough to produce effective technologies?
- Instead of "helping" people, could technology end up reproducing inequalities such as those of development projects described elsewhere in this book?

3.3 DESIGN COURSES AND DESIGN INSTRUCTION

Perhaps, after wrestling with the questions above, you have become somewhat skeptical about design for community projects like this. Now we want to turn your attention to a design course, the site where projects like these are conceptualized, planned, developed, tested and written up, all activities for which students receive a grade. Furthermore, the design course is the place where most students come to learn and do design for the first time. By dissecting the constitutive elements of a design course and asking you to conduct some exercises along the way, we hope to facilitate critical reflection about the potential origins of the assumptions, methods, processes and concepts in many engineering design for community projects. After all, the problematic assumptions made by the student team above had to come from somewhere.

3.3.1 SYLLABUS

Syllabi are social contracts between professors and students, for they spell out what a course is about, what students are expected to learn and do, how they are going to be graded, what will be covered, and what is accepted behavior, writing guidelines, etc. Hence, syllabi constitute important evidence of how faculty understand a topic, how they are planning to teach it, and how they expect the students to learn it.

All engineering courses and their syllabi have at one point or another been justified in relationship to ABET accreditation criteria. Design courses are no exception. We found the following definition of engineering design from ABET in the course syllabus that we analyzed for this chapter:

> "…the process of devising a system, component, or process to meet desired *needs*. It is a decision-making process (often iterative), in which the *basic sciences, mathematics, and engineering sciences* are applied to convert resources optimally to meet a stated objective. Among *fundamental elements* of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation." (italics added)

This definition reaffirms "needs," but does not explicitly mention the concerns or aspirations of those to be served by the technology. This view of need may implicitly reaffirm a problematic assumption that communities are deficient in something and that engineers are endowed with special knowledge and skills to come in and fulfill those needs (see Chapter 4). We invite you to question this assumption throughout the book.

This description also places higher value to knowledge coming from scientific analysis, testing, and evaluation. But what if you want to begin a design by seeking input from community members who have knowledge about their own locale and circumstances that might be considered non-scientific or too subjective? Is it possible to take them seriously and still be true to the definition? Also, how could this definition be appropriate for design for community given that, for example, it leaves out contributions that social sciences (such as anthropology), participatory techniques, or even aesthetics can make to designs responsive to community's concerns? This can help explain why the design project analyzed above did not include any of these perspectives throughout the research and development of the grinder. The fundamental elements of the design process in this definition do not include finding out community concerns and aspirations, defining problems with communities, or making iterative exchanges with community throughout the design process. Might this omission help explain why none of these important considerations were included in the design of the grinder?

3.3.2 OBJECTIVES

The syllabus that we analyzed for this chapter continues: "This course has been designed to comply with the ABET guidelines that require the engineering design component of a curriculum to include at least some of the following features…". The left column Table 3.1 lists these features, while the right column includes features not listed in the syllabus but that could be appropriate for design-for-community projects.

3.3.3 CONSTRAINTS

Likely your design faculty view engineering as "design under constraints." Hence, they might include a list of constraints that students must consider during their projects. The main constraints often included are the following: economic factors (e.g., time, cost), weight, safety, reliability, aesthetics, ethics, and social impact.

These constraints come to engineering design from a number of sources such as economic considerations, codes of engineering ethics, industrial practices, corporate values, and fear of liability. While these factors may be suited to industrial design projects, how appropriate is it to assume that these constraints easily apply or are equally relevant to design for community? We pose a number of questions here:

Table 3.1: Design objectives for industry and for community.

Features actually listed in the syllabus	Additional proposed features that might make the course appropriate for design for community (not listed in syllabus)
“development of student creativity”	development of students’ *empathy* for and understanding of a community’s capacities
“use of open-ended problems”	defining problems with communities by *listening* to multiple community perspectives
“development and use of design methodology”	development and use of participatory practices and methods
“formulation of design problem statements and specifications”	formulation of circumstances that allow communities to articulate their own problems (concerns), specifications, and desires
“consideration of alternative solutions”	ensure that potential solutions include those generated by the community or by both community and team working collaboratively
“feasibility considerations” (often defined in terms of time, cost, weight, ease of manufacturing, legal and safety requirements)	allowing input from the community to weigh its own considerations and decide which are most important
“detailed system descriptions”	include a detailed socio-cultural description of the community to be served

- **First**, whose economy? What kind of economy? Budgets for design projects in the for-profit sector assume that everything can be bought and sold at a price (labor, tools, materials, land, permits, consulting, etc.) and that at the end there should be a profit. But what if a project is carried out in a different kind of economy where the most important assets defy simple quantification (e.g., local knowledges), others defy simple valuation (e.g., land), while others can be obtained for free (e.g., volunteer labor)? As one engineering design professor confessed to us,

  > [u]nfortunately, by the time engineering students are seniors–it seems as though they are totally convinced that what matters is cost, cost, and cost. This may be because cost is easily quantifiable—and therefore appears in many engineering problems given throughout their education.... Design is always about finding a solution that simultaneously satisfies (imperfectly) multiple goals at once.

  Design for community challenges engineers to consider multiple goals, many of which reside in the community and defy quantification. We understand that projects ultimately have to be economically feasible, but design-for-community projects require engineers to place community goals first. These goals may very well include making a profit, but would likely also include issues of justice and participation. At the end, the community should be the one establishing priorities.

- **Second,** whose safety? Safety depends heavily on cultural notions of "risk." What is an acceptable risk in one community might not be acceptable in others (Douglas and Wildavsky, 1983). Many water-related projects begin with the assumption that it is "risky," hence unsafe, for a community to drink water with certain levels of contaminants or bacteria. Quickly engineers assume that there is a "need" for cleaner water in that community, perhaps overlooking more serious community concerns. (See the case study in Chapter 6 to see what happened to a pre-defined water sanitation project when engineers began to listen to concerns instead of assuming needs). At the same time, different understandings of risk across cultural boundaries raise important, yet unexplored, ethical questions for engineers. Should an engineer accept a lower threshold of protection for a community willing to accept the additional risk?

- **Third,** reliability in technical systems is usually desirable. After all, it is great when things do not break often. But reliability comes at a cost. To ensure reliability, engineers might overspec a design or chose materials or parts with longer working lives but unavailable or too costly for a specific locality. A community might be willing to accept a significant degree of unreliability in exchange for local control over parts and maintenance. But those in charge of development projects seem to miss this lesson. After \$53 billion of US taxpayer dollars spent in development reconstruction projects in Iraq between 2002-9, most of them failures, the US government is beginning to realize that high-tech or overspec projects may be less reliable and desirable than low-tech solutions (Adnan, D., 2009).

- **Fourth**, aesthetics present additional challenges to engineers working in "design-for-community"-projects. For US engineers, form and function are usually separate characteristics in the design of artifacts and systems. As engineering professor Louis Bucciarelli found out in his extensive ethnography titled *Designing Engineers*, "Though appearances can be central to the people specifically responsible for a product's looks, most participants in the design process worry primarily about how things 'perform' or 'behave.' Looks are secondary; function is primary. Designing in this sense is about how things work" (Bucciarelli, L., 1994, p. 1). Yet in many places outside the US or in fields such as fashion design, form and function are inseparable characteristics of an artifact, as lines, symbols, colors, textures, etc., have deep meanings and perform important cultural functions.

- **Fifth**, engineering ethics, usually contained in codes of ethics published by engineering societies, prescribe certain practices (what should be done) while proscribing others (what should not be done). For example, US engineers know too well that receiving gifts from a client could be easily interpreted as bribery. Most codes are very clear about this. But what if gift-giving is an essential act in building trust between a community and its outsiders who are coming to perform a service? In the book *Three Cups of Tea*, widely popular in the community development and humanitarian worlds, Greg Mortenson describes how important it was for him to receive gifts from a village before they will let him begin construction of a school. No gifts, no trust (Mortenson and Relin, 2006).

- **Sixth**, social impact, often treated in design courses as the "anything goes in here" constraint, is equally problematic, especially because often neither students nor faculty have the knowledge to understand and assess the social impacts of a technology. This kind of assessment requires education in areas like science and technology studies (STS), technology policy, or technology assessment, rarely found in engineering design courses (with few notable exceptions such as the Design, Innovation and Society Program at Rensselaer Polytechnic Institute). The hundreds of design projects that we have witnessed have never included long-term assessment of how the artifact or system in question impacts (for better or for worse) the socio-cultural environment in which it will live. Note that the project described at the beginning of this chapter did not include any kind of assessment of social impacts. In most written reports or final presentations that we have witnessed, students often make up something about the performance of the technology in the future, always portraying their design in the best possible light.

Exercise 8 *Can you develop a new list of design constraints, or modify the ones above, that might be more appropriate for design-for-community projects?*

3.3.4 EXPECTATIONS FROM STUDENTS

Like most syllabi, design syllabi include a set of expectations that faculty demand from students in order to give them a passing grade. These expectations are important because they socialize students to behaviors proper of most US engineering professional settings (e.g., corporations, government agencies). For example, the syllabi that we have studied for this chapter include *individual* expectations such as the following:

- "be on time and attend all class meetings, lectures, and team meetings;"
- "be respectful at all times of your teammates and faculty;"
- "maintain a well documented project notebook;"
- "submit professionally written progress reports;"
- "make professional oral presentations (each team member must present at least once during each semester);"
- "participate on all team assignments and functions (peer evaluations will be incorporated into the individual grade at the end of each semester);"
- "complete a one-on-one personal interview with the Team Project Manager;"

and *team* expectations such as:

- "formally document all client interactions (meetings, letters, memos, calls, emails, etc.);"
- "maintain a well documented team project notebook;"
- "demonstrate team effort on all team assignments and develop professionally organized oral presentations;"
- "work as a team toward a final product which is an effectively communicated team project proposal."

These expectations reflect professional norms and behaviors in corporate engineering settings. However, how do they relate to work with communities? We do not want to imply that communities deserve less respect from you, but we should remember that respect comes in different forms. For example, note the emphasis on "being on time," highly valued in US engineering settings. After all, in US settings, time is money. But how about in community development settings where "spending time" with and "being with" community members might be more important than "being on time" to a presentation? Learning to listen and building trust take time, an investment that defies quantification in terms of hours and dollars. Or how about communities where the pre-eminence of oral traditions precludes most attempts at documentation? Or where instead of presentations *directed to* a group (which might reaffirm assumptions about an expert talking to non-experts) what is valued is *conversations with* a group? In such instances, the above expectations seem to be misguided.

Exercise 9 *Develop a set of individual and team expectations that might be more appropriate for design projects in sustainable community development.*

3.4 COURSE CONTENT

3.4.1 DESIGN PROCESS

Engineering design courses introduce students to some form of design process. In most courses that we have looked at, the process is presented as a sequential model and visually represented as a step-by-step diagram that looks something like Figure 3.2.

Clearly, this is an elegant and clear depiction of design. It is hard to imagine, at first glance, what could be problematic with this model. However, engineering professor Bucciarelli describes the shortcomings of this *ideal* representation of design, and the possible motivation that faculty might have in continuing to reproduce this view of design in front of students, as follows:

> Such abstract figures express an ideal—an object-world creation of engineering faculty. Their intent is to *establish control* over the design process by breaking it down into discrete elements or subtasks, sharply bounding these subtasks by enclosing them in boxes or circles and then connecting them sequentially with straight lines. But while [this] figure and its kin may be useful pedagogically, in keeping with the reductionist tenor of such tools, as models of practical design activity they are deficient. If we allow the figure to direct our thinking about the people engaged in all the tasks contained in the boxes, we might conclude that design practice is an *extremely orderly, rational process* in which creative thought can be contained in a single box that yields a conceptual design or designs, which after detailed evaluation and analysis within some more boxes can be given real substance, tested, put into production, and then marketed for profit and the benefit of all humankind (italics added) (Bucciarelli, L., 1994, p. 111).

In his in-depth ethnography of engineering design, Bucciarelli actually found out that the design process is quite messy, far from orderly, and sometimes even irrational. After all, design is a human and social process of *negotiation and exchange.*

> To students, these diagrams shed very little light on how design acts are actually carried out or on who is responsible for each of the tasks within the various boxes. Nor is it apparent what these participants need know, what resources they must bring to their task, and, *most important, how they must work with others*. The lines with arrows hardly represent the *negotiation and exchange* that go on within designing…. As a reductionist, mythical, object-world representation, [this kind of] figure might be useful in the *indoctrination of students into the ways of thinking of the world of the firm*, but it misses the uncertainty and ambiguity of what really goes on in designing. Unlike the kinematics of particles, designing is not lawlike or deterministic. It is not a process of nature, nor can it be made to mimic nature (italics added) (Bucciarelli, L., 1994, p. 113).

As we will see in the chapters that follow, the processes of negotiation and exchange (of knowledge, skills, resources, etc.) when working with communities are perhaps more complex than when working with likeminded engineers within the same firm or from the same school. This may

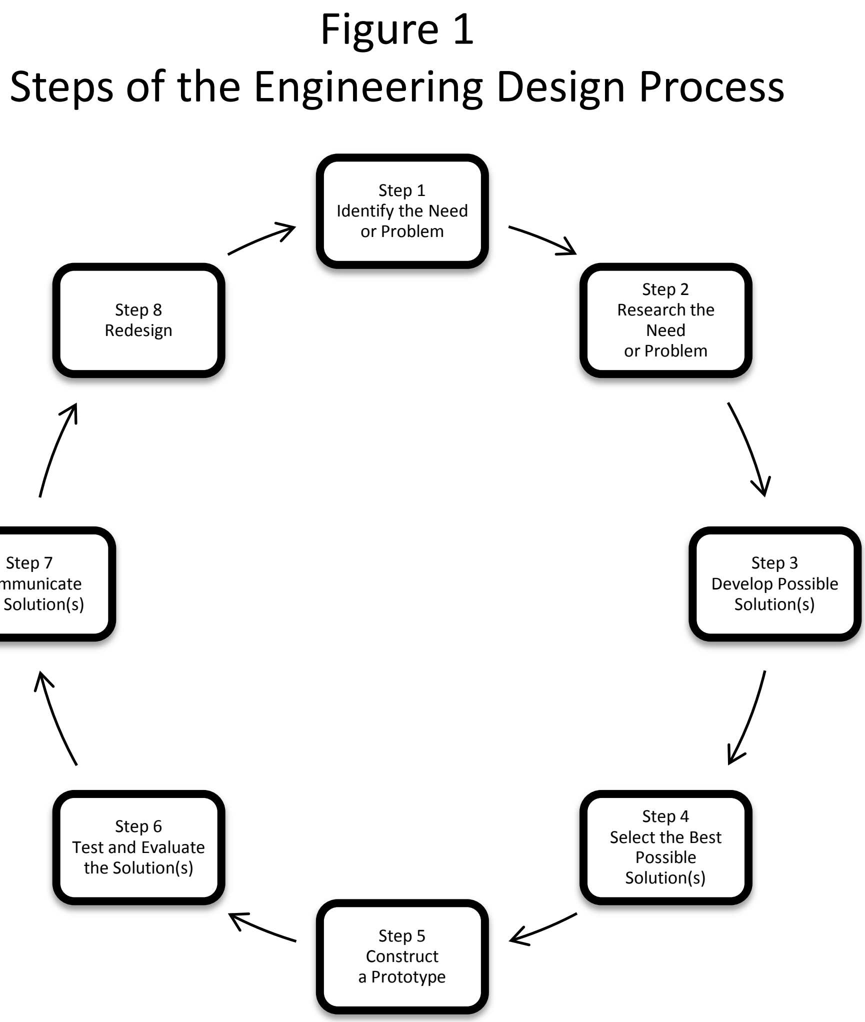

Figure 3.2: Sequential and step-by-step model of design found in many engineering design courses. (Source: `http://www.doe.mass.edu/frameworks/scitech/2001/standards/strand42.gif` Credit: Massachusetts Department of Education.)

explain in part why the description of the humanitarian design project above used the passive voice, hiding human agency, and social negotiation, and followed a step-by-step format that resembled the ideal model often presented to students. It seems that the students in that project were appropriately responding to a sequential model that they learned in class.

Exercise 10 *Share the sequential model and Bucciarelli's quotes above with your design faculty and discuss with them how these compare with what is taught in engineering design class. If this proves to be difficult, because you do not know your faculty well, share it with friends who have taken engineering design already. Invite them to think hard through their design experiences. How do they compare with the steps in the sequential model? What different groups of people or individuals emerged in each step? What kind of agreements and disagreements did they have? How did these human interactions and negotiations alter the course of the design? Try not to include "working with communities" just yet. Save that discussion for after you read Chapters 4 and 5.*

3.4.2 LEADERSHIP AND TEAMWORK DYNAMICS

Design courses often include presentations and readings on leadership and team work. Often engineering faculty (or visiting engineers from industry) in charge of those presentations have had extensive experience in corporate and/or military organizations. Given engineering's long historical association with the corporate and military sectors, this should come as no surprise (see Chapter 2). Hence, portrayals of leadership often include references to leaders in management/business and military (see Riley, D., 2008, Ch. 2 for a comprehensive analysis of how this historical association shapes engineers' "mindsets"). In some places, quotes on leadership often come from the works of management gurus like Peter Drucker and historical invocations of military leaders like Patton, Eisenhower, and Powell. Often in these presentations, students receive a portrayal of leadership as a desired set of characteristics of *individuals* who

- know how to take charge,
- move quickly to seize opportunities,
- have a vision and strive to have others share it as well,
- understand and respect their and other's strengths and limitations,
- listen more and talk less,
- and have passion for what they do.

As the story goes, design teams (or armies or business groups) with good leaders often succeed while those with mediocre leaders falter. The dynamic established is that between an *individual* who leads and a group of *individuals* who follow. Although there are variations on the treatment of leadership and teamwork from course to course and from school to school, the message here is clear: the human dimensions of design are centered in a leader who knows how to lead and a group that knows how to follow.

So what should be the appropriate approach when working with communities? Given the powerful message on leadership and teamwork, students might be left to conclude that the right thing to do is to "march on," seize a perceived problem in a community (e.g., their "need" for clean water), work as a group under effective leadership to solve the problem, and deliver a solution to the community. So what could possibly be wrong with that? As we will see in Chapters 4-7, this kind of approach has a long history of failures, especially under the umbrella of international development, and will likely fail again in design for community projects. Design for community requires a new kind of leadership (see Chapters 4 and 5).

Exercise 11 *Begin envisioning a type of leadership and team work required for engineering work in community development. After reading Chapters 4 and 5, put your own list of qualifications required of a leader working with communities in their own development.*

3.4.3 DESIGN TOOLS AND APPROACHES

Engineering design courses also include arrays of project management tools such as Work Breakdown Structure, Project Evaluation and Review Technique (PERT), and Critical Path Methods, to name a few. Among approaches to design, Quality Function Deployment (QFD) has gained popularity since the "quality movement" scaled up its incursion into US engineering practices since the mid-1980s. (Quality methods were one among many responses that US engineers put in place to address the challenge of Japanese technology in the 1980s). First developed in Japan in 1966, QFD was first used at the Bridgestone Tire Co. and Mitsubishi Heavy Industries "to identify each customer requirement (effect) and to identify the design substitute quality characteristics and process factors (causes) needed to control and measure it." According to the QFD Institute, QFD "was developed to bring [a close] personal interface to modern manufacturing and business. In today's industrial society, where the growing distance between producers and users is a concern, QFD links the needs of the customer (end user) with design, development, engineering, manufacturing, and service functions." QFD is now endorsed by a number of think-tanks dedicated to improve the quality of businesses (Mazur, G., 2009).

While we do not doubt the contributions that these tools and approaches have made to business and government in delivering higher-quality goods and services to customers, we wonder how appropriate these might be for design for community projects. What could possibly be problematic for community development about linking "customer needs" with engineering metrics or exposing trade offs between conflicting goals as QFD does? Well, all tools or methods developed for particular purposes and under specific circumstances (historical, political, economic) bring with them assumptions about the world around them and the people using them. Hence, tools developed for business bring with them assumptions (*inscriptions)* about markets where "customers" demand better products from "producers." In this world, customers exercise the power of their wallets (in the for-profit sector) or the power of their taxes and/or votes (in the public sector) to which producers try to respond with better products or services. But how appropriate is it to superimpose these assumptions on the realm of community development? What if the communities in question do not have the purchasing power to vote with their wallets or the citizen rights to vote with their votes? Furthermore, what issues are associated with treating community members as "customers" and engineering students as "quality experts" in community development? As we will see in the next few chapters, transferring assumptions from the business worlds (e.g., community = customers) is perhaps one of the most problematic issues confronting engineers in design for community projects.

Exercise 12 *Although we cannot analyze here every single topic covered in a senior design course, we invite you to think through other topics (safety, proposal writing, budgeting, reliability, ethics, intellectual property, etc.) and begin to question, to what extent are these topics appropriate for design for community projects?*

3.5 THE ACTUAL COURSE

3.5.1 LOCATION

Since design courses are scheduled like other courses, most design courses take place on campus in lab or conference rooms dedicated to design activities. Lecture presentations take place in large rooms or auditoriums with theatre-like set up. As the semester progresses, lectures begin to subside and classroom meetings might no longer be required. Often students move their project meetings to the library, an empty conference or classroom, or their own dorms. In any case, these settings are far removed from the community that is supposed to be served by the project. All designs are shaped by the environment in which they are conceived, the materials available nearby, and the colors, shapes, and textures around the design activity. All these factors influence designers in their choices and the outcomes of design (Rothschild and Cheng, 1999).

During a visit to the engineering design center of the French car manufacturer Renault, one of us witnessed how the entire facility was adorned with themes, pictures, colors and patterns from Brazil. Even the food and drinks served in the cafeteria were Brazilian. Renault engineers were getting ready to design a new car for the Brazilian market. When asked about this transformation of the design facilities, the engineer in charge of the tour explained that engineers/designers need to internalize, as much as possible, elements of the Brazilian landscape to able to generate designs that would appeal to Brazilians. They knew that the Renault facility would never be like the real Brazil, but at least the engineers understood the connection between design and place. So how can design for community projects be designed in a classroom or lab distant from the communities they are supposed to serve? As shown in Figure 3.2, important lessons can be learned from graphic designers who often surround themselves with artifacts, patterns, colors from the communities that they are intended to serve.

Exercise 13 *Survey the physical spaces where student groups are learning about, conceiving, and developing their designs for community. What do these environments tell you about the communities that the designs are supposed to serve? If travel to the community is impossible for you during the early stages of design, what could you possibly do to begin internalizing elements of the community and landscape where the design will eventually live?*

Figure 3.3: Design students at Drexel University Antoinette Westphal College of Media Arts and Design are challenged to design marketing materials to support the success of the Sunflower Oil Cooperative in the Ruggerero Genocide Survivors Village in Western Rwanda. Although no substitute for being in the actual place, students brainstorm over patterns, colors and textures of objects belonging to the community from which students derived inspiration. (Source: `http://blog.xcd.aiga.org/?p=502` Credit: AIGA XCD CrossCultural Junction Blog and Alan Jacobson).

3.5.2 COURSE PRACTICES

In spite of the problems with the sequential model of design, students in design courses quickly learn to follow these steps. After a number of introductory classes or activities, students move quickly to **problem definition** (steps 1 and 2 in the linear model discussed above). Through our interactions with students and faculty involved in design projects, we found out that most problems are defined *a priori* by others outside the communities to be served by the designs. These others often include professors, a representative of an NGO working near the community, a religious missionary, or sometimes the students themselves. In some complex cases, individuals or leaders in a community may make a decision without consulting others in their group. Such cases can be difficult to navigate. Reporting on how a design problem was defined for a design-for-community project, one student who analyzed one such project in a South American country said,

> [the professor] met [the leader of the ecotourism organization] at a sustainable resource conference in Boulder, Colorado. The two clicked and began working together. These two individuals laid the groundwork for the entire project, including all project goals

> and constraints. [The leader of the ecotourism organization] was the sole representative of the students from [South American country], as was the professor for the students in [the US school]…. A senior design student [from this project] observed that [the leader of the ecotourism organization] may have only been after personal recognition and achievement as [his organization] has won numerous awards (Note: names of people and specific countries were removed for confidentiality).

After problem definition, students quickly move to **choose design alternatives** that might solve the problem (step 3 in the sequential model above). Students often do lots of brainstorming on paper and/or computer software and search for parts and specs in hardware catalogs and/or stores available to them but perhaps unavailable to most communities that they are hoping to serve. Recall the selection of circular cement pavers, bicycles, and the Country Living Mill for the grinder design at beginning of this chapter. Unfortunately, students made problematic assumptions about the transfer of technology here. As the proponents of appropriate technology found out more than three decades ago, materials and parts for technologies to be used in "developing" communities need to be available (and ideally made) in the communities where the technologies will be used (Mason, K., 2001). If new technologies, dependent on parts and know-how from donor countries, are introduced (e.g., a water pump), these would likely disrupt community social relations such as those created by the women who often have the responsibility for collecting water. If the technologies eventually fail and cannot be repaired, the community ends up with both broken technologies and social relations.

In **selecting the best possible solution**, students follow the grade. If their faculty, either explicitly through the grading criteria or implicitly through conversations with students, emphasize *cost, weight, and timeliness* while undervaluing, if not completely neglecting, community empowerment, students would logically choose a design that reduces cost and weight and would be completed on time. Remember how in the grinder design above, the reduction of cost and weight became a priority for students during Fall 2007 even before they have checked their design with the community. We have yet to find grading criteria in a senior engineering design course that gives significant points for community empowerment.

Constructing and testing a design prototype (steps 5 and 6 in the sequential model above) are usually done in a lab or workshop on campus. Rightly so, faculty and students want to test a prototype under controlled conditions. After all, if the prototype fails in the lab, it will likely fail in the field. As one engineering design professor told us

> Actually, I would encourage students to build and test prototypes in a lab setting before testing on the ground. Frankly, if the prototype doesn't work in the lab, under controlled conditions, it is highly unlikely to work in the field. Since engineering design is about using science and math to predict the performance of the design as it is developed—experimental data from the lab also is often a necessary supplement to theory. It is not and should not be the end result—and a prototype that functions in the lab may yet fail in the field—but this step should not be dismissed readily. It is a valuable part of the messy design process.

Yet questions for design for communities still remain. What are the limits of lab testing? The history of technology is replete with examples of how lab testing differs significantly from testing on the ground in the reliability, performance, and usefulness of a prototype. For example, engineers who developed a copper-cooled engine for GM in the 1920s found that the prototype performed well in the dynamometer but failed dramatically when tested in actual chassis and roads (Leslie, S., 1979). How much are students likely to get fixated on a design after prototyping and before they seek input from the community? How does prototyping in a lab reaffirm for students the belief that data coming from instruments are more dependable and reliable than input from the community? In the humanitarian design case study above, how might emphasis on testing and prototyping have obscured the fact that the Senegalese community had acquired extensive user knowledge from years of mill grinding experience?

Exercise 14 *Reflect on your interactions and practices of your design project. When and how might community input be included in multiple stages of the process, rather than simply at the very beginning or end?*

3.5.3 TEAMWORK

Often the division of labor among students in design for community projects is done according to engineering disciplines. As professors (or someone else besides members of a community) define the problem a priori, those involved in the management of student groups envision solutions and select team members according to engineering disciplines. Even those teams labeled as "interdisciplinary" or "multidisciplinary" are frequently made up only of engineering disciplines (Pierrakos et al., 2007).

A final report requirement in a design course actually challenges students to

- "segment the design into technical subsystems and implementation phases…"
- "assign responsibilities to each of the design team members for appropriate technical development and implementation milestones…"
- "include one-page resumes that highlight the design team members' technical capabilities corresponding to the Division of Responsibility."

With the grade at stake, students have little choice but to compose a team in this way. Also, since engineering design courses are usually available only to engineering students (with some noteworthy exceptions such as EPICS at Purdue or Stanford's Design Program), there are few opportunities for the inclusion of non-engineering perspectives. Even when faculty and students, either from engineering or non-engineering departments, want to include non-engineering perspectives in design projects, strict pre-requisites for engineering design courses get in the way.

Once the groups are formed according to an ideal engineering disciplinary mix, students become very pragmatic about this division of labor and what needs to get done. With serious time constraints and a grade on the line, they seek to maximize points earned, giving priority to the preparation and presentation of a final report, not to the people of a community. As one graduate student reported in an in-depth analysis of a design for community project, "[during the entire project] students' interactions with the village tend to be very brief and hurried, while their design, although brief as well, still receives the majority of their attention throughout the school year. This suggests that students, due to the limitations of the problem-solving-based curriculum and the overall time spent on design sans in situ, are *more likely to be aligned with the project than with the people*" (italics added).

Exercise 15 *If the priority of a design team is empowering a community by facilitating the solution of problems that the community defines on its own, how would you go about configuring a design team? What kind of talents, skills, and expertise are needed? Make sure to repeat this exercise after reading Chapters 4 and 5 of this book.*

3.6 THE WRITTEN REPORT

Students in design projects spend a great deal of time preparing and writing a written report for which they receive a substantial part of the course's grade. Although formats vary from place to place, here is a list of the sections that our students are expected to include in their reports:

- Letter of Transmittal
- Title Page
- Executive Summary
- Table of Contents and Lists of Figures
- Introduction
- Design Objectives
- Requirements, Constraints, and Criteria
- QFD Explanation & Summary
- Product, System, or Process Definition
- Deliverables
- Design Specifications
- Safety Analysis & FMEA
- Testing and/or Modeling procedures
- Division of Responsibility
- Project Schedule and Budget

- Qualifications
- Bibliography, Appendices, and Glossary

Although we could make an extensive analysis of format, style, and content, we will limit our observations here to a few questions:

- **First**, the format clearly reflects the sequential conception of design described above and reinforces corporate practices of communication and documentation. But how appropriate is this format to encompass the complex dimensions of designing and working with communities?
- **Second**, with very few exceptions, all the reports that we have read, including the project summary at the beginning of this chapter, are written in passive voice. Passive voice hides agency, hence precluding engineers' from responsibility and further decreasing the possibility to make community perspectives visible.
- **Third,** by appearing to be scientific and objective, in format and style, these reports limit their audience to those who value scientific writing and content. But how about those who do not, yet whose livelihoods might be directly affected by the design in the report?

Exercise 16 *If the priority of design for community is sustainable community development, how would you go about organizing reports of design for community projects? What kind of language would you use? What kind of sections would you deem essential to be included in a report? Repeat this exercise after reading Chapters 4 and 5.*

3.7 THE FINAL PRESENTATION

This is usually the concluding event for a project team's participation in a design course. It is an important ritual where students dress up, often wearing suits and dresses, compose impressive Power Point presentations, and often display professional behavior appropriate to corporate environments. Largely for practical reasons, teams present to faculty, students, and industrial clients but almost never to the communities that they are supposed to serve with their designs; hence, the questions and concerns raised during the presentations usually come from those in the audience (engineers), not from the community-recipients.

During presentations of designs for community development, students quite often present pictures of their brief visits to the community that give some degree of legitimacy to the team in relationship to their connection to the community (after all, they want to show that they went there). These pictures often include children smiling to and playing with team members, community members looking at the design prototype (perhaps for the first time ever), and students working on the installation of the artifact or system in question. Although well intentioned, these pictures hide and/or trivialize complex dimensions of community life. Rarely do these pictures show disagreements about the design, existing local technologies, knowledges, and practices that could have been considered instead of the design, or the long-term impact of the design in a community. Understandably, students are going after a good grade and want to show their design in the best light possible. Unfortunately, in the grading structures that we have found, there are no incentives for failures (although failure might be a greater teacher of design, (Petroski, H., 1985), controversies, or for acknowledging that existing technologies in the community might be more appropriate and effective than the students'. What would have happened to the grade of the humanitarian student project at the beginning of the chapter if from the onset the team had discovered and reported that the people of Sengalpaddai already had a technique to dehusk lentils?

Q&A sessions following the presentations often focus on technical details. In many cases, we have witnessed faculty, who in an effort to show that their students' projects are not fluff, ask highly technical questions, focusing on calculations, data reliability, and procedures. Although this questioning is the faculty's prerogative and responsibility, this behavior sends the message that technical details are more important than community matters. Perhaps this interaction is to be expected since there is rarely anyone with community-development expertise in these presentations.

Exercise 17 *If the priority of design for community projects is empowering communities, how would you go about presenting reports of designs for community development? What kind of format, language, and visuals would you use? What kind of interactions and audiences would you deem essential to be included in this presentation? Make sure to repeat this exercise after reading Chapters 4 and 5 of this book.*

3.8 CONCLUSIONS: WHAT CAN YOU DO?

Hopefully, this chapter has helped you identify and question underlying assumptions, concepts, methods, and practices in your engineering design courses, and projects so you can assess their appropriateness for design for community. Perhaps, you might be wondering "what now?" We would like to conclude this chapter with a number of recommendations that perhaps you can consider in order to reform those design practices that you have found problematic in your own educational context:

- **First**, take the exercises in this chapter as a starting point to begin sharpening your critical thinking about design for community. Try to complete these with project teammates and peers in order to elicit fruitful discussion and critical thinking about your own design practices.

- **Second,** begin implementing the lessons that make sense to you and your project. Whether you are about to begin a design-for-community project, or you are in the middle or end, there are plenty of opportunities to incorporate design-for-community lessons throughout. For example, if you are prototyping your design, you can acknowledge and report that the community has not provided input yet and hence the prototype has significant limitations. This acknowledgement is a good start because it puts the design in its proper place and reveals that the community's perspective, perhaps the most important, is still missing from the design.

- **Third,** constructively invite your faculty and peers to consider these questions and issues seriously. You might find resistance and skepticism but also more welcoming attitudes than you expect. We have found many engineering students and faculty that are ready and eager to begin reforming engineering design to make it meaningfully relevant to communities. Work with them in constructing alternative syllabi and new formats for written reports and final presentations.

- **Fourth,** take the questions and lessons from this chapter and book to sites outside the curriculum where engineers try to do design for community. For example, it is very likely that your school has at least one student organization dedicated to community development or humanitarian work (e.g., Engineers Without Borders, Engineers for a Sustainable World, Engineering World Health, Youth With a Mission, etc.). Engage them with the questions and issues that we have raised in this chapter.

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