ENGINEERING SELVES / Hiring In to a Contested Field of Education / Gary Lee Downey and Juan C. Lucena

ONE DAY IN AN ENGINEERING THERMODYNAMICS CLASS, the professor pulled out an Ann Landers column, titled "A Different Breed," from that morning's newspaper. He asked the seventy or so third-year students, "How many of you think this is reasonably accurate?" The column contained excerpts from letters, mostly from frustrated spouses, that portrayed engineers as technical, inflexible, and socially inept. The first provided a summary statement:

> Dear Ann: This letter, my first ever to a columnist, was sparked by your column about the engineer's wife who asked, "Are engineers really different?" The answer is ABSOLUTELY! My father was an engineer. My three brothers and four uncles are engineers. Engineers ARE a different breed. They are precise, logical, and great at problem solving, but they know very little about human interaction. My engineer husband makes a fine living, but when it comes to expressing emotions, on a scale of 10, he's about a 4. *A wife in Houston*

Three other letters added credibility to this characterization by attributing it even to the best engineers, describing the difficulties of living with such a person, and suggesting that things could be otherwise:

> FROM TUCSON, ARIZ: Engineers ARE different. My engineer husband (graduate of MIT) tells me when my skirt is ⅛ inch shorter in the back. If the floor in the bathroom looks uneven, he gets out a tape measure for "proof." A crooked window must be adjusted at once. If, however, I am crawling around the house with a killer migraine, he doesn't notice.

> SANTA BARBARA: My husband the engineer has no tolerance for the gray areas of life. He sees everything in absolutes. It's black or white,

right or wrong, yes or no. Never a maybe. He feels no joy, but he is never depressed either. Everything is in perfect order, or there is hell to pay. It is not easy to live with such a man.

NO CITY, PLEASE: Thirty years ago, I married an engineer. Our marriage was an emotional wasteland. He would have been a better father if our children had been robots he could program. Engineers can figure out everything except how to be human and caring.

The sole letter from a man removed gender as the determining feature:

CHICAGO: My wife is an engineer. She is precise, analytical, and definite in her views, and she always thinks before she speaks. She's as cold as ice and so sure of herself, she makes me sick. My next wife will be an empty-headed, bubbly moron, and it will be a relief.

Finally, letters from an optician and an interior designer established that the problems with engineers go beyond family relations, for engineers "are murder to work with" as well.

The only two letters expressing disagreement contested not that engineers were somehow a different breed but the judgment that this assessment is negative:

CARBONDALE, ILL: You're damned right engineers are different. I am still happily married to mine after 35 years. They tend to look before they leap and have stable marriages. By nature, they are problem solvers, sensitive, and caring. The woman who wrote to complain ended up with the wrong man, not the wrong profession.

INDIANAPOLIS: My engineer husband doesn't send me flowers. In fact, some days we don't even have a decent conversation, but I'll take this nerdy looking guy with his assortment of pens and eyeglass cases in his shirt pocket, his dull tie and wrinkled trousers over any of the men I've ever known. He is loyal, decent, dependable, and real. He'll never cheat or lie to me. That's worth a lot these days.

Prodded by the instructor to offer their own judgments, roughly a third of the students raised their hands to say they agreed that engineers were a different breed, nearly half said they disagreed, and the remainder did not respond. In sharp contrast with the usual practice when asking about today's homework or next week's test, not a single hand rose above shoulder level. The quick, low wave was the rule, as if students felt vulnerable and hoped to avoid calling attention to themselves. After all, why risk being wrong about something that would not be on the test? Despite the fact that the professor was a gentle man who was not afraid to discuss matters of the heart, he made no move to offer his own assessment. Did it even cross his mind to do so? To hear how he felt about things would have been interesting but unusual, and no one dared ask. Class began.

The two of us are interested in the making of engineers, the mechanisms of self-fashioning that take place in undergraduate engineering education. The professor and students in this class were grappling with what they understood

to be the stereotype that engineers regularly criticize as a preconceived and oversimplified idea of the characteristics of the typical engineer trained in the United States. Questioning its accuracy involves asking whether or not people called engineers actually conform to the stereotype. During the course of our fieldwork among engineering students and teachers at Virginia Tech, a land-grant university with roughly four thousand undergraduate engineering students, we heard many discussions about the stereotypical engineer. In every case, someone disputed the image by claiming that it did not characterize accurately many engineers and hence was not true, only partly true, or at least too narrow. Yet the image persists, and students seemed to take for granted its existence and its power.

We were initially drawn to study engineering education by our own experiences as engineering students. Both of us completed undergraduate degrees but felt somehow that the sort of people we were being asked to become did not fit with the sort of people that we already were or wanted to be. Above all, we felt constrained. Over the years we have observed that people who left engineering, including ourselves, seemed to feel a need to explain why. It was not that they couldn't "hack it"—the engineering student's term for not having what it takes—but that somehow there was a lack of fit. Understanding learning solely as the transmission of knowledge from the heads of faculty to the heads of students did not begin to account for the bodily experiences of constraint so many of us experienced. How might we make these and similar feelings more visible? And might doing so suggest ways to shift engineering toward a place where people like us would want to be?

As a cultural anthropologist teaching in a graduate program in science and technology studies (STS) and a Ph.D. student in STS interested in cultural and anthropological studies, we organized a research project that would follow engineering students through their curricula to explore the changing demands they experienced as persons.[1] Do stereotypes count? How was the knowledge content of engineering related to the social dimensions of engineering personhood? Long-term participant-observation and extensive interviewing and document collection became strategies to explore students' experiences.

We quickly learned, however, that this work involved more than just studying students. As we elaborate below, we had organized our project in the midst of great debate among engineers over the contents of engineering education. Our study was even funded by the National Science Foundation, which had emerged as one of the leaders in this debate. Unless our written work appeared entirely irrelevant or uninteresting to engineers, it would likely be captured and positioned by this debate (see Rapp on abortion and Hess on capturing, this volume). Not only did running away or hiding seem pointless; we also wanted very much to participate in the process of retheorizing engineering education. We sorted out a pathway we call "hiring in."

Hiring In

As a metaphor of employment, hiring in indicates a willingness on the part of social researchers to allow their work to be assessed and evaluated in the theoretical terms current in the field of analysis and intervention. It means

becoming employees in a sense, whether paid or unpaid. Although one need not accept at face value what people say about themselves and what they consider desirable or worthwhile, hiring in involves, at minimum, acknowledging that established modes of theorizing constitute established power relations and that contributing new theorizing captures one within those relations. Maximally, hiring in involves following all the pathways to critical participation that one can identify and attending to all the details and doing all the work necessary to position, assess, and, if warranted, try to achieve a theoretical shift.[2]

Accepting the responsibility of hiring in, as many researchers studying science and technology, including anthropologists, have already done, may provide an opportunity to contribute directly and genuinely to the theorizing that takes place in a contested field. It offers the possibility of convincing people to shift their modes of theorizing from here to there by acknowledging and emphasizing that one can only start where one is. As a practice for researchers combining cultural perspectives and ethnographic fieldwork, hiring in can involve making visible modes of theorizing that are otherwise hidden, thus possibly legitimizing alternate perspectives that are rooted in the field itself.

However, complementary risks of cooptation and social engineering are substantial, each leading in its own way to marginalized ineffectiveness and self-delusion. The cooptation of a project involves its transformation into something indistinguishable from that which it studies. More than gaining participation or otherwise becoming located as part of the field, cooptation dissolves the identity of the researcher(s) entirely into the field. A coopted project not only goes native; it is nothing else. Social engineering involves presuming that one's expertise warrants the authority to legislate change through a research project. The arrogance of social engineering keeps a project permanently outside the door, preventing it from participating critically in that which it studies. A social engineer in the field never leaves the hotel.

We locate hiring in as one approach to a more general academic practice that one of us has elsewhere called "partner theorizing" (Downey and Rogers 1995), limiting it to those situations in which one is not already located in the field of intervention but seeks to gain entry. Hiring in contrasts with debates, for example, whose interlocutors are presumably located within the field of intervention. The main goal of partner theorizing is to encourage the growth of collaborative relations in academic work and relocate the agonistic politics of rebuttal from a necessity to an option in the everyday practices of academic researchers. It asserts that the practice of theorizing neither can nor should be a proprietary feature of academic work, for much theorizing, in fact the major proportion of theorizing, takes place outside the institutionalized Western academy. Alongside the anthropological perspectives represented in this volume and elsewhere, partner theorizing thus reconceptualizes relationships within and between academic disciplines, as well as between modes of academic and popular theorizing, as flows of metaphors in all directions rather than the necessary diffusion of truthful knowledge and power from the inside out.

Our project on engineering education illustrates three different moments of partner theorizing. First, it envisions all acts of theorizing as undertaken in partner relations with their interlocutors in collective, but temporary, negotiations

of knowledge production. We are thinking of partner theorizing not as a market activity, a business partnership, but as a variety of activities of exchange among committed cohabitants, married or otherwise. One's work always intervenes in the context of other theoretical agendas. Competing theorists, both academic and popular, live together.[3]

The dominant theoretical agenda with which our project has to contend is the doctrine of "competitiveness." Since the early 1980s official United States dogma has redefined international struggle from a political and military to an economic idiom, transforming understandings of the nation from a site within which individual interests compete into a single economic actor maximizing a collective interest. The power of patriotic commitment to this economic call to arms became concentrated in the slogan of competitiveness and its logic of productivity, which locates humans alongside technology and capital as resources for the production of consumer goods. Popular theorizing about competitiveness seems to reach into everyday lives and selves much more than the military logic of the Cold War did, because it turns every action into an economic defense of the nation. Something is good if it enhances competitiveness and bad if it does not. Engineering education has gained particular salience in these developments because engineers figure as key participants in virtually every image of increased national productivity (see Business-Higher Education Forum 1983; National Academy of Engineering 1986; President's Commission on Industrial Competitiveness 1985).

National visibility is new for engineering education (Lucena 1996). In the years after World War II and before Sputnik (October 1957), engineering education stood alongside other forms of technical and scientific education as an integral component of a military struggle against communism. "Our schools are strong points in our national defense," said President Eisenhower early in 1957, "more important than our Nike batteries, more necessary than our radar warning nets, and more powerful even than the energy of the atom" (US Congress 1957). Sputnik shifted concerns somewhat because it was read as a shocking accomplishment of science rather than of engineering, and nationalist interest in education during the 1960s narrowed to an exclusive focus on science and the production of scientists for basic and applied research. The National Science Foundation took Edward Teller's advice that emphasizing engineering education would miss the point:

> It is my belief that it [engineering] should not be considered a weak link in our scientific and technological effort [and therefore has sufficient funding]. We should put the greatest possible emphasis on higher education in applied science. (National Academy of Sciences 1965:259)

The 1970s maintained an emphasis on basic and applied science but expanded the range of legitimate problems to include energy, transportation, pollution control, and other nonmilitary arenas, through such programs as NSF's Research Applied to National Needs.

The nationalist reinterpretation of economic competition as national struggle and strategic risk in the 1980s was sudden and dramatic, embodied and epitomized in the Reagan election. Engineers gained the opportunity to become

121

leaders on the battlefield, as when President Reagan called upon the National Academy of Engineering in 1985 to

> marshal the nation's technical engineering-based expertise in a campaign that will ensure America's scientific, technological and engineering leadership into the 21st century. . . . These efforts . . . are essential to the goal of helping American businesses and workers to modernize and compete. (National Academy of Engineering 1986:3)

The NAE began by mapping engineering "education and utilization" visually in a computer-printed model that looked like a dense piping diagram. Tracing flows in from secondary school on the left to flows out through "death," "disability," "emigration," and so forth on the right, the model linked education and employment together in infrastructural movement with lots of connections and feedback loops. Education became a flow of bodies through engineering schools whose primary problems were, accordingly, "recruitment" and "retention."

The piping image stuck. Tracking flows of engineers made it possible to reimagine education and utilization in the economic terms of supply and demand and establish the goal of enabling supply to respond more flexibly to demand. The National Science Board, which sets NSF policy, said in 1988:

> If compelled to single out one determinant of US competitiveness in the era of the global, technology-based economy, we would have to choose education, for in the end people are the ultimate asset in global competition. . . . Economic performance and competitiveness will be particularly affected by undergraduate engineering education. (National Science Board 1988)

By 1988, NSF had not only explicitly adopted the pipeline image but also transformed it into a linear image that defined continuity of flow as the goal and leaks as the problem.

Within American industry, becoming more competitive meant becoming more flexible. The flexible accumulation of capital in a struggling nation needs flexible people, lots of them (see Martin 1994). NSF is now at work reengineering engineers, supported by the National Research Council:

> We have to be thinking now what we want to see 10 and 15 years from now in terms of what is coming out of the pipeline with respect to science and engineering . . . human resources that will be flexible enough in terms of their training so that if they don't quite match what is at that time the need for their skills, they can be retooled very quickly. (Task Force on Science Policy 1985:43, 64–65)

NSF has pumped more than $200 million into research and innovations in engineering education to build more flexibility into engineering curricula and produce more graduates, mainly under its flagship program, the Engineering Coalitions.

Hiring in to engineering education in the 1990s thus involves recognizing that engineering educators in the United States can fairly easily construe what

they do as being centrally in the national interest. Engineering education is widely understood not only as a place where good students prepare themselves for career tracks that promise financial stability and upward mobility but also as a test site for the refiguring of patriotism. Research that seeks participation in the fashioning of engineering selves risks simply contributing to this nationalistic fervor by improving students' abilities to pursue the goals of competitiveness without critically examining its contents. At the same time, it risks giving the impression that one seeks to prescribe change, to fix people who are presumably broken. One could easily come across as antiknowledge, anti-engineering, and anti-American. Images count.

A second moment in partner theorizing involves viewing all theorizing as totalizing in content but not necessarily totalitarian in effect, in the sense that theorizing depends for its insights on a metanarrative, or background story, that builds a world within which its interpretations have meaning and power. From this perspective, the metaphor "temporary" may serve better than "partial" to describe the limited claims of totalizing theories participating in exchange relations. That is, the value of any form of theorizing is temporary, connected to changing circumstances.[4] If all forms of theorizing are temporary, then hiring in involves a historically and culturally specific encounter between distinct modes of theorizing.

The point of contact between our project and the ongoing retheorizing of engineering education lies in images of personhood. With the background story of competitiveness, we have to deal in particular with theorizing about "under-representation" and "flexibility." Because the pipeline model is an aggregate mathematical image, it counts people as individuals grouped according to distinct statistical categories. Sorting out persons biologically by sex and race, for example, the pipeline called attention to categories that were statistically underrepresented in engineering, namely women and minorities.

"If we want to supply our industries and government and our universities with the human power that we need in the future," NSF director Erich Bloch told Congress in 1987, "we need to concentrate on the groups which are under-represented today in the scientific engineering areas—women and minorities" (US Congress 1987:9). Echoed the National Science Board, "From the perspective of economic competitiveness (as well as other perspectives), NSF programs and management efforts designed to help bring women, minorities, and the economically, socially, and educationally disadvantaged into the mainstream of science and engineering deserve continued focus" (National Science Board 1988).

By the late 1980s the dominant argument was that the country needed more engineers, but the pool of college-age people was declining, compounded by a declining interest in engineering among first-year college students (roughly 8% of college degrees). Since approximately three-quarters of the engineering bachelor's degrees are granted to white males, "greater participation on the part of women and underrepresented minorities in engineering studies would be one way of addressing the supply-side problem" (Bowen 1988:734). While constituting 51 percent of the population, women make up roughly 15 percent of first-year engineering students. Blacks make up 12 percent of the population but

only 6 percent of first-year students, Hispanics 10 percent and 4 percent, and American Indians 0.7 percent and 0.5 percent, accordingly. In addition, while retention rates for white males hovered around 70 percent, retention rates for women were roughly 40 to 50 percent, 30 percent for blacks, 48 percent for Hispanics, and 33 percent for American Indians. Students of Asian descent were not considered a problem in this demographic profile, for with 3 percent of the population, they accounted for 6 percent of first-year students. Also, their retention rate exceeded 100 percent as more students subsequently transferred into engineering programs than departed (National Science Foundation 1990).

The nagging problem for engineers in theorizing underrepresentation concerns how to explain it in the first place. If students enroll in engineering programs because of innate capabilities and dispositions, then are nonwhites and females less capable or otherwise naturally predisposed away from this career track? From our perspective, the problem of underrepresentation is a citadel effect, an effect of theorizing learning entirely in terms of a diffusion model of knowledge. Colleges of engineering have been able to respond only by establishing new recruiting strategies and support systems for minorities and women students to increase enrollments and retention rates. These must struggle to maintain legitimacy since providing support programs for students does not fit the dominant model of challenging students to prove they belong.

Statistical calculations turn biological groupings into socially significant objects, making each woman stand for all women and each African American stand for all blacks. An anthropologist might be inclined to challenge this essentialist view of the person because it seems to reduce people to biology by showing these biological categories themselves to be historically and culturally specific constructions. Maybe the problem of underrepresentation would simply dissolve away as a misleading construct. Although this pathway to critique and opposition is fairly straightforward conceptually, it is likely incomplete as an approach to intervening, at least in the near term. One might be able to alter the importance engineers attribute to biological categories, but the categories themselves are probably here to stay.

Furthermore, the allocation of resources through the pipeline image, which draws on biological categories, actually provided new access to the corridors of power for interest groups that explicitly defined themselves as representing women and minorities. One newly funded female professor gleefully told us, "I can't believe I'm so deeply involved in this. I'm making connections all over the place. We're building an old girls' network." Similarly, the National Association of Minority Engineering Programs Administrators (NAMEPA) proudly announced the theme, "Partners in the Pipeline," for its 1994 meeting in Washington, which included scheduled lobbying trips to Capitol Hill. Congress itself authorized formation of the Task Force on Women, Minorities, and Disabled in Science and Engineering. In other words, classifying students by race and sex made some people visible who were otherwise hidden (Lucena 1996:180–81). As Donna Haraway (1989, 1991a) has shown us, biology can be useful.

In order for our work to hire in to the problem of underrepresentation, or have any role at all, must we force our data into artificial, predefined groups of women, minorities, whites, nonwhites, etc.? For us, these are interesting as cul-

tural categories of persons that people apply to themselves rather than as distinct types or categories of humans that should be taken as real because based in biology. What sorts of categories might following students' experiences produce, and would these help to account for underrepresentation as an outcome without dividing up the world by race and sex at the outset? Applied in this case, partner theorizing thus involves going beyond showing that students' experiences cannot easily be parceled up by race and sex and, hence, making the problem of underrepresentation seem illegitimate. We must also try to account for how students themselves identify people by race and sex and ask if this process has any implications for statistical underrepresentation.

The problem of "flexibility" raises different issues. At present, engineering policy makers are at a loss to establish what flexibility means in curricular terms, although many different groups, from NSF officials to Boeing engineers, are vying to control its definition. Generally, flexibility seems to mean "malleable," as in making the bodies of engineers sufficiently malleable to fit changing job definitions. Because no single mode of theorizing flexibility has become established, we have the opportunity to contest what flexibility could mean rather than having to limit ourselves to accounting for the effects of a given model.

A third moment in partner theorizing is that it focuses attention on the power relations between alternate modes of theorizing by accepting that knowledge is never simply knowledge *of something* but is also knowledge *for someone*. Accordingly, the practice of partner theorizing encourages one to look for ways of factoring into one's own thinking the views of others in the field of intervention without necessarily seeking the consensus that is often unrealizable. Rather, by looking for reasons to accept the legitimacy of others, even if one finds limitations in their perspectives, partner theorizing shifts the goal from simply advancing one position in a debate to advancing or replacing the debate as a whole. One theorizes in terms of both one's siblings and ancestors—the traditional mode of defining a theoretical stance—and one's interlocutors or the positions one is trying to engage. Together these locate one's theoretical position at the start of an analysis. Advancing a new mode of theorizing in a contested field through partner theorizing thus involves greater entanglement in existing power relations than either mastery through truth or opposition through resistance. Furthermore, when the goal is to hire in from an outside position, paying attention to the power dimensions of theorizing is crucial to make sure that one even gains the legitimacy to participate.

Our first step in hiring in to engineering education is to make visible the experiences of students as they move through their curricula, thus confining our intervention to what happens within engineering education. Were our own experiences idiosyncratic? Do the students themselves offer alternative ways of thinking about learning? The next section briefly summarizes a handful of these experiences, drawing material especially from three students labeled minority in order to engage theorizing about underrepresentation and flexibility. We then search for pathways for intervention that take account of the current structure of engineering education and do not demand the resources that would be necessary to redesign curricula from scratch.

Weed-out

Jen Lopez is a Hispanic woman; Glenn Phillips and Rick Williams are African-American men. Although these labels identifying race and sex[5] were non-negotiable for students, the significance they played in students' lives is more problematic. Despite the expectations associated with her status as both minority and woman, Jen appeared in many respects to be the prototypical engineering student who sought the appropriate goals and adjusted herself properly to fit the curricular demands. Although Glenn and Rick had difficulty finding ways of fitting themselves to engineering, in neither case was race the problem or issue.

The core knowledge content of engineering curricula is what engineers call "engineering problem solving." Learning how to draw a boundary around a problem, abstract out the mathematical contents and solve it in mathematical terms, and then plug the solution back into the original problem is central to the fashioning of engineers and a major challenge to the bodies and minds of students. Students regularly asserted that the goal of certain courses was to "weed out" students from engineering curricula.[6] For students who stayed, these and other courses also appeared to weed out a part of themselves as persons.

Establishing disciplined habits and attention to detail are typically a student's first adjustments to the practice of engineering problem solving.[7] Rick found the content of this discipline different from his experience in the Navy:

> Oh, it's a different type of discipline. When I was in the Navy, they would say you have to stand this guard pose, and you gotta do this, and you gotta do that. They would lay it out for you. Here, it takes more self-discipline because you gotta figure it out for yourself.

An associate dean of engineering articulated a key feature of this self-discipline when he told incoming would-be engineers and their parents at freshman orientation that "engineers have to learn how to have fun . . . efficiently." We later repeated this to a friend who was completing his Ph.D. in mechanical engineering. After laughing heartily for a minute or so, the student stopped suddenly and said, "You know, he's right." The discipline in engineering problem solving is a total body experience that extends across all engineering "disciplines," a term that seems particularly appropriate in engineering (see Foucault 1979). As a dean told graduating seniors in engineering:

> What you've all learned in engineering is how to attack and solve problems. It doesn't matter what discipline you go into. You all learn the same thing. Solving problems is what engineering is all about.

The first two engineering courses that students take at Virginia Tech, appropriately called Engineering Fundamentals, explicitly describe disciplining the body and the mind as essential prerequisites to later success. One instructor in the first course described his course as "probably as much training as it is education." On the first day of class, for example, this professor announced, "The wooden pencil is dead for you." Holding one up, he said, "This is gone. You don't use it anymore. You are an engineer in training. You are on your way to the

126

top. This looks crummy." Then, holding up a mechanical pencil: "This looks great. . . . Zero point five millimeter HD lead." In the second class he frightened students with a pop quiz, had them grade it themselves on the honor system, and then informed them that it would not count, to their great relief: "I just wanted to get across to you [that] you are always responsible for knowledge contained in a previous class." In the third class he outlined the connections between good habits, including a regular bedtime, and success in engineering:

> One of the biggest mistakes students make is they have an irregular bedtime because tomorrow their classes don't start 'til eleven, the next day they start at eight . . . and your body, instead of developing a habit, you just change that every day. Folks . . . it won't work. I haven't met any student that's been successful that way. . . . The ones that oscillate back and forth, in the long run do not succeed.

New engineering students find out quickly that engineering problem solving revolves around homework exercises and that engineering courses have more daily homework than any other curriculum. To get a good grade, every correct homework assignment must include the student's name, course number, and date lettered properly at the top of a sheet of engineering paper, which is a cross between unlined paper and graph paper. One writes on the unlined side, guided by faint lines that show through from the other side.

It is significant that every problem undergraduates encounter begins with the word "Given." The boundary has already been drawn. Engineering problem solving confines itself to the ideal world of mathematics. All the nonmathematical features of a problem, such as its politics, its connections to other sorts of problems, its power implications for those who solve it, and so forth, are taken as given. This contrasts sharply with physics problem solving, in which the main challenge is to learn to "think like a physicist" (White 1996) so that one can bring that unique genius to bear in a process of discovery. In engineering, students learn they must keep reactions, intuitions, or any feelings they might have about the problem out of the process of drawing a boundary around it and solving it. These are irrelevant and can only get in the way.

Good problem solving follows a strict five-step sequence: Given, Find, Equations, Diagram, Solution. Students start by abstracting from a narrative description of the problem mathematical forms for both given data and what they must find in order to solve the problem. Then, invoking established equations and drawing an idealized visual diagram of the various forces or other mechanisms theoretically at work in the problem, they systematically calculate the solution in mathematical terms. They must write down each mathematical translation or risk losing credit. Also, if they write a numerical solution without including units of measurement, for example, as feet, meters per second, or pounds per square inch, the answer has no meaning and frequently receives no credit. The students we followed still learned the computer language FORTRAN, which translates engineering problem solving into computer code, even though far simpler programming strategies were available. It seemed to us that instructors continued to insist on FORTRAN because it penalizes small mistakes, thereby forcing attention to detail. During the undergraduate years, students are expected to solve thousands of problems either on paper or in programs.

127

All engineers learn something about "engineering ethics," but not to enable them to critique the ethical dimensions of the problems they solve. Rather, in order to be good problem solvers, engineers need to behave ethically. Being ethical is about controlling one's passions and impulses, making it more akin to a habit than a commitment. An administrative memo distributed to new students, for example, introduced the subject of ethics in the context of good problem solving. "Engineers in professional practice," it stated, "are required to perform their work in a neat, orderly, timely, and efficient manner. . . . Since they design and construct facilities upon which the safety and health of the public depends, professional engineers must conform to a strict code of ethics in their work." An introductory reader collated by faculty abstracted different types of ethical principles from the writings of philosophers. Students learned that "utilitarian ethics" alone could be dangerous because self-interest can lead to self-destruction, "duty ethics" alone could lead one to neglect the needs of individuals, and "rights ethics" alone could lead one to overlook the general welfare. "Value ethics," attributed to Aristotle, were perfect for engineers because these encouraged "tendencies, acquired through habit formation, to reach a proper balance between extremes in conduct, emotion, desire, and attitude."

As students become transformed into engineering problem solvers, what gets weeded out is everything else. That is, engineering students experience a compelling demand to separate the work part of their lives from the nonwork parts. Work is about rigorously applying the engineering method to gain control over technology and is simply not about any other stuff. Budding engineers can have the other stuff in their lives, but not in their practices as engineers.

We found that the constraints of engineering problem solving fit well in bodies where "other stuff" meant forces of identity or challenges to personhood whose meanings did not make competing demands of personhood. Jen, for example, was convinced of a deep connection with engineering because she had been interested as a kid in fixing cars and other things and had attended a science and technology high school. For her, the habits and attention to detail in engineering problem solving were simply an advanced form of tinkering, and high school had added the appropriate mathematics. Moving from tinkering to engineering problem solving was simply a shift from a private activity to a collective one. Jen thus found the demands she encountered entirely reasonable and appropriate. "It's just to make everything easier to read," she said, "like for instance if you need to present something to your boss, you're not going to just slap the answer on a piece of paper. You have to say, 'This is what I was given, this is what you asked me to do, and this is what I found out.'" Jen had made engineering a personal goal at a fairly early age. "I always knew I wanted to do engineering," she told us.

Accepting the rigors of engineering problem solving also fit very well Jen's desires for upward class mobility. Raised in a working-class family, she clearly felt class identity as a challenge and source of force: "I think eventually I will leave engineering because I want to work with management. I think I'm ambitious." She even arrived with some understanding of how being an engineer could be positioned as a job in a corporate environment. In high school she had worked ten hours a week as an intern at an engineering firm: "I got to see what

it was like, and I liked it. I liked the atmosphere, the job atmosphere." Granting authority outside the self was no problem because Jen expected to work in a job with a boss. It was also important that, in Jen's image of class mobility, success in life was the outcome of sacrifice and individual determination. At freshman orientation, she recalled, "They were saying that, if you look around the room, half the people won't be graduating." Asked if that intimidated her, she replied, "A little bit, but I think if you really want something you can get it, if you try hard enough."

Finally, the expectation in engineering problem solving that one will con-trol one's emotions fits the stereotypic definition of a mature man, one who is strong and in control and who exercises considered judgment. For Glenn, who had trouble keeping his emotions out of his problem solving, this part of the challenge in engineering courses posed a significant problem. He told us, for example, that he had a tendency to say "I feel" in expressing his views. "I don't think it was accepted too much," he said. "Maybe 'I think' was accepted more." As Rick explained in another interview: "I've never seen someone say, 'Well, sir, the answer is because I feel that.' The professor will just cut him to pieces." Re-ferring to his feelings got Glenn in trouble in job interviews, where he appeared to be wishy-washy and lacking in self-confidence. His strategy for getting through engineering courses was to link himself to people whom he believed were in a similar situation, namely women. That is, rather than contest the challenge from engineering or the stereotypic man, Glenn made use of the stereotypic woman by seeking out emotional support from a network of female engineering students and avoiding men, who he believed would not talk about such things.

Because the stereotypic woman is emotional by nature, she is not the ideal engineering problem solver. For Jen, the continued currency of the stereotypic woman gave her a chance to stand out as an individual: "[Being a woman in engineering] feels kinda neat, because not many women are engineers. I kinda like that I stand out in a way because I don't want to be one of the nameless en-gineers. Girls aren't supposed to be [engineers], so I'm glad that I am one." Jen had indeed encountered overt discrimination from at least one male professor who drew on the stereotype in treating women, but she discounted this experi-ence as exceptional. "You've always got those chauvinistic types," she said somewhat casually, such as the one who put on a worksheet a question "some-thing like 'an engineer goes home to the housewife da da da.'" When she went in to ask for help, this professor "treated me like I was, you know, like a baby or something." But she insisted he was unlike the others: "Most professors are really nice."

Standing out as a woman did call for special strategies if Jen was to make sure that faculty were blind to the stereotype in judging her merit. One strategy she used to demonstrate her capabilities and commitment to male professors was to go and talk with each one, making sure they would have to treat her as a full person. "Most of the time professors like me a lot," Jen said. "I'll go talk to a professor just so they know who I am, not necessarily so they'll know my name or anything, but just so they know my face and they recognize me." She also had to compensate for a lack of study partners. Because she did not identify

herself as a "woman engineer," she did not seek out other female students: "Not like real good friends or something." Also, there were few engineering students in her dorm:

> *Jen:* It's especially hard. I live in an all-girls dorm. How many girls are engineers? Most of the guys, you know, had at least two or three on their hall. So you just walk down the hall and there's a guy doing his engineering homework too. But there weren't any other girls on my hall that were engineers. So it's kind of like, "Well, what do I do?"
>
> *So, what do you do?*
>
> *Jen:* Well, I kinda figure it out by myself.

The dominant image of the graduate engineer is one who controls technology, who creates by translating internal knowledge into object form; in short, one who designs. One department brochure summarized its curriculum simply with the words: "Engineering teaches students to design." The College of Engineering routinely advertised itself with photographs of solar cars designed and built each year by students. First-year students meeting in small group interviews regularly described how they long "to design something." Said one, "I want to be the person that draws it . . . that kind of designs it in a way, and then hands it to somebody else and they go do it."

However, the images of design that incoming students carry with them often differ greatly from those that discipline their work. Most students we encountered started out viewing engineering design along the lines of the stereotypic architect, whose designs are a deep, personal expression of some distinctive perspective, subjective orientation, or emotional reaction. Indeed, the romantic fantasies that drew students toward engineering in the first place, such as helping society through new designs, helping one's people improve economically, or advancing civilization through space, generally included a heavy measure of agency or even autonomy for the individual engineer. But it was not easy to hang on to these visions.

In engineering problem solving, design is the timely, disciplined application of the engineering method to real-life problems. In this image, the genius of design shifts from the person to the method itself, and authority shifts to the curriculum. Because seniors were most likely to have mastered the method, they were usually the ones who got to practice design. The solar-powered car, for example, was designed and built each year by a group of senior students. But for newer students, becoming successful engineers meant giving up on the fantasies that made them the geniuses behind great designs. Instead, they had to accept the constraints imposed by the curriculum and learn to solve problems properly. As we followed students through these challenges, images of creative invention tended to dissolve away, and engineering design lost its romance.

Rick's main fantasy was to solve problems "relevant to ordinary life," but the commitment to mathematical problem solving in engineering course work soon left him with a strong sense of personal loss:

> Drawing a cylinder with a hole in the middle and at two different angles had to be perfect. You had to have it just right. That's what I hated the

most. I really did. Took me at least fifteen hours a week sitting at the computer to get it right. I hated it.

In Rick's view, the heart had to be connected somehow with the job:

> My opinion is that anyone can do engineering but not everyone can love engineering. I didn't love it, so I couldn't do it. My ex-girlfriend loves it. Every other word out of her mouth is in touch with systems engineering. She loved it.

Rick united his work with his heart by switching to biochemistry, whose activities felt more relevant to ordinary life:

> I had gone from an engineering major that morning to a biochemistry major by dinner, and I already felt the difference. I could really feel the difference. Now, my biochemistry class, I love it. I mean, I sit down to do my biochemistry problems, and I can't believe the Navy is paying me to do these things. Just yesterday we were analyzing protein structures and how they interact with each other due to spatial orientation and how they function. I was sitting there, you know, "Wow, I can't believe I'm getting paid for this."

Class identity played a significant role in Rick's career path, as it did with Jen. A naturalized US citizen born in Ethiopia, Rick was graduated twenty-second from his high school class in upstate New York. He had enlisted in the Navy because his mother could not afford to send him to college. Moving to biochemistry rather than say, anthropology, preserved his goal of upward mobility, because the Navy would pay for his education and he could anticipate a well-paying job later.

In contrast with both Rick and Jen, Glenn's main fantasy had to do with race. Raised in urban Washington, D.C., he wanted to stand out as a black man in a white world, thereby challenging the racial stereotype of black people as mentally slow, physically lazy or undisciplined, and, hence, inappropriate:

> My high school was all black. I chose to come here over North Carolina A&T [a predominantly African-American school] 'cause I thought I needed to experience the world. It's not just going to school with white people; it's living with them.

Glenn elaborated on how he wanted to become a role model for other African-American students: "I want to inspire others to get into engineering. I guess me becoming [an engineer] encourages others to do that also. That's a contributing factor to why I stuck with it." A sense of loss would come later.

As we have already seen, Jen's fantasy embraced the identity of an engineer as a pathway to a job and income, but all this was alongside another passion: ballet. Jen had studied ballet since childhood and remained deeply committed to it, hoping also to learn choreography. However, doing both engineering and dance brought great stress:

> Every single night we had practices from after dinner 'til at least 12:00. My classes ended at 3:00 so there was no time to do homework. Sophomore year there's like three problems to do in every class and it takes

131

you a long time. The people in charge of the dance were all like, "Go talk to your professor to get an extension on your homework." I was like, "You've got to be kidding me. No engineering professor is gonna do that."

Jen talked to an engineering professor after receiving a poor grade on an exam. "Worst choice," she said. "He's like, 'Why did you come to Virginia Tech? You've gotta decide for yourself, you've got to set your priorities straight. Did you come here to dance or to become an engineer?' He told me that directly to my face." Jen was angry about the image that "if you're an engineer at Virginia Tech, that's all you can do." She wanted to contest the view that mathematical problem solving was everything for a prospective engineer, "because you have to be well-rounded. . . . If you just sit at your desk or work at your computer all day long, you can't survive in society," she insisted, "because work is not just what you can do on your computer, it's how you associate with people." She reacted to the challenge with even greater determination: "It pissed me off and I was like, 'Well, no, I'm gonna do them both.'" Yet ultimately she gave in, adjusted, and reduced her involvement in dance:

> I just did the best I could. I did less dancing. I went to another dance company but I didn't do as much. I didn't choreograph because that takes a lot of time. I knew I wanted to be an engineer and I was gonna do it. I was only in one dance in that group whereas the year before I was in four. It worked out fine. I did well with my grades.

Students have no room or opportunity to challenge the priority given to mathematical problem solving in engineering lives and work. The curriculum is just there, demanding that they make all the adjustments and informing them through grades of the extent to which they were succeeding. Homework after homework, test after test, and course after course rank each student on a linear scale. Glenn struggled for a long time just to achieve the C average he needed as a minimum demonstration of membership; in other words, to graduate. When asked if he ever felt engineering was not for him, he said:

> Probably every other day. Freshman year, I kind of just said, "Well, I have to adjust and do better next semester." The grades were the biggest thing that kind of told me. They made me tell myself to struggle to stay here and stay in engineering. I always believed that I could do better but I didn't know how. I messed up.

Fortunately for him, Glenn was able to locate one essential, that is, natural, connection to engineering: "I am more technically minded than most people." So he persevered. He had come to Tech with three black friends from D.C. Before the end of second year, all three of Glenn's friends had left school.

By the time students reached their junior year, the vast majority appeared to have found strategies for accommodating their bodies and minds to engineering problem solving. As courses became specialized within majors, the mathematical challenges in engineering problem solving became more complex, and strategies accumulated for commanding greater control of the world in mathematical terms. Back in engineering statics, for example, which many

called the "first real engineering course," students had learned how to apply a single mathematical equation to a range of different circumstances. However, in the engineering thermodynamics course we attended, students found that any problem could have several pathways to a solution. They faced a whole menu of equations that may be appropriate in any given case and had to decide which assumptions to make in choosing which particular configuration of pathways to follow. "It's more intense," Jen said. "It's harder stuff, so it's [all about] how much you can handle . . . how much work you can handle."

One cost was a sense that the rain never stops. The experience of isolated struggle in the early years of engineering education had been replaced by a more shared struggle just to get through whatever came next. When we asked upper-division students how they were doing, we often heard the simple mantra, "Eat-sleep-study." By this point Rick had already left. Glenn was clinging to his female groupmates, still struggling to survive. Having failed thermodynamics, he said, "When I got into my major, it was like starting over for me. It really did feel like starting over freshman year."

Like many students we encountered, Jen coped not only by disciplining herself for engineering work but also by making sure her life had other things in it as well. The key lay both in maintaining a sharp boundary between the work part and the other parts and in making sure that their meanings for one's identity as a person did not conflict. Consider Jen's images of bounded, efficient play in a group interview of advanced students who had just outlined the pitfalls of dating nonengineers:

> *Deepak*: I think it's engineers. They don't want you to have a social life.
> The ME [mechanical engineering] department, or any department.
> *Jen*: You *can* have a social life.
> *You can? Do you guys all say that?*
> *Thuy*: We get as much as we have a chance to get.
> *Dan*: Budgeted.
> *Deepak*: Budgeted, yeah.
> *Did you hear what they said in freshman orientation, that engineering students are not like the other people? You have to learn how to have fun efficiently.*
> *Jen*: That's true.
> *Dan*: That makes sense, I think.
> *Thuy*: Very true, yes.
> *Dan*: Some people's idea of having fun is just sitting around and just yakking. Just really nonproductive.
> *Jen*: I think that's why I don't watch TV. I'd rather be out with my friends having a good time instead of sitting in front of the TV.
> *Dan*: Do a good quality two hours of fun time.
> *Jen*: Yeah.

Establishing an identity as an engineer can mean allowing engineering values to diffuse into other areas of one's life, even while holding these separate.

As the classroom encounter with Ann Landers illustrated, students by this point had come to treat instructors narrowly as functionaries who simply transmitted the knowledge students needed to pass tests rather than as indepen-

133

dent sources of reflection and interpretation. Although professors might bring human characteristics to their work (one "is a lot of fun" while another "will slam you"), such factors were relevant only around the margins of standard pedagogy—presenting and testing mathematical knowledge. Students knew that the curriculum had been established by some past authorities and that the truth or validity of its contents was not subject to question:

> *Jen*: I took a class in family and child development. It was like the biggest trip. The teacher's up there talking, people aren't paying attention. People are fighting over a multiple-choice test, saying the teacher didn't have the right answer. If they walked into an engineering class, everyone would be like, "Who the hell is she saying that professor is wrong in their answer?"

The value of engineering knowledge in the world persists over time. We were amused but not surprised when the thermodynamics class used the same textbook Gary Downey's own class had used in 1971.

Having survived the solitary struggles of the first two years, students had adopted a range of strategies for getting through their courses efficiently. Said one: "I now know that the homeworks and tests are what's important, so I'm a lot more efficient. I hate textbooks and never read them. I just listen to the lectures and work the problems." Also, a student no longer stood alone as an engineer but had become part of a larger group, an engineering major. "I see a lot more familiar faces in my classes now," said one student in a group interview. We heard all sorts of strategies for doing group work, including what qualities make good study partners and when group work helps the most or gets in the way. We followed one organized trio of students who divided up their three toughest courses in order to conquer them together. Each did the homework for one class and prepared the others for the tests.

In sharp contrast with the entering student, the engineering graduate who emerges from the curriculum is understood to be a disciplined, knowledgeable, and powerful person, at least in terms of engineering problem solving. Knowledgeable students have gained control over technology in a way that is unavailable to other persons, whether human or corporate. Through the logical, precise actions of identifying and solving problems in mathematical terms, each student has, by definition, succeeded in extending the realm of human control to include technology, transforming technology into a tool for human use. The stereotypic engineer is this and nothing else.

However, unilinear ranking also insures that students do not all attain the same level of control or receive the same credit. As students reached their last year of school and began looking for work, they focused on their grade-point averages to an extent they could only have imagined earlier. In a profession that does not make graduate school a prerequisite of employment, one's value as a potential employee depends in the first instance on the grade-point average. GPA is the key line in every résumé because it is read as the main indicator of accomplishment. We once listened to an African-American recruiter for a corporation advise African-American students to keep their résumés from looking "too black," or employers might become suspicious that a student was putting

racial identity before engineering identity. Glenn was one of several students we encountered who tried to resist this system of evaluation by leaving his GPA of 1.95 (C-) off his résumé at the annual job fair:

> At the first booth I went to, he pretty much told me, "Keep on walking."
> I remember one lady gave me a lecture. She was like, "Isn't your GPA any better?" She went on telling me all this stuff and she said, "Well, you need to work on your problem." I was like, "I don't have a problem."
> I felt my potential is much greater than what my grades say about me.

Glenn had been very active in student organizations and had accumulated considerable work experience, but he was unsuccessful in championing these as indicators of talent and motivation apart from his grades. Six months after graduation, Glenn had not yet found a job.

Interviewing for jobs also brings a new set of challenges to personhood as students emerge from the cocoon of mathematical problem solving and begin to face the vagaries of economic and social life. Jen's B average surpassed the minimum standard of acceptance, which students consider to be a B- average, yet she received far more interviews than students with much higher grade-point averages. She attributed this primarily to her status as a minority woman. In contrast with her experiences as a student, this time she felt the challenge deeply:

> I've never had any type of conflict [within engineering from being] Hispanic at all. I mean, me personally, I don't like the word "minority." That bugs me because the definition of minority means "less." So I really don't associate myself as being a minority. I'm Hispanic, not a minority.

Of course it was easier for Jen to avoid the label minority or woman as a student taking tests than as a potential employee trying to sell her labor in the marketplace. How could she maintain a sense of accomplishment for what she had achieved?:

> *So does it bother you, for example, policies like affirmative action?*
> Jen: Well, it helps me, so I don't mind, but I wouldn't like people saying "She only got the job because she's a girl," or "She only got the job because she's Hispanic." Because I don't think just because of that they should pick me. They should pick me on my merit, not from where my parents are from or what sex I am. It is an advantage because I get a lot more opportunities because I'm a woman and a minority.

This was a problem that mathematics could not solve. Jen's work life suddenly threatened to become Hispanic and/or female in content, undercutting her long-standing efforts to separate her work from her race and sex. She wanted a job, the best possible job with the most money and highest potential for advancement into management. Affirmative action had explicitly mixed race and sex with merit in a way that made these inseparable, yet without affirmative action would the currency of stereotypes by race or sex in corporations have prevented Jen's many opportunities from appearing in the first place? For her, this

135

sort of problem could only be resolved through long-term job performance, demonstrating her worth as a person rather than as a Hispanic woman. She accepted a position and got started.

In sum, while the challenges to personhood that engineering students experienced overlapped challenges from the stereotypic man and a desire for upward class mobility, these conflicted with challenges from the stereotypic woman, the stereotypic black person, the stereotypic Hispanic, and a desire to link work with nonwork in some sort of organic whole or total self. In none of the three cases discussed here did stereotypic expectations drive students away. Wanting to challenge the stereotypic black person had actually motivated Glenn both to enter an engineering program and to stay, despite poor grades. The curricular insistence on keeping emotions out of problem solving added to his sense of being marginalized, however, for in seeking out female friends in engineering Glenn kept the distinction between work and nonwork permanently blurred. For Jen, being Hispanic was largely irrelevant, while being a woman provided great motivation. Her bodily adjustments involved trying to keep instructors or prospective colleagues from using stereotypes to classify or judge her. Finally, Rick left not because of a racial stereotype but because he could not live with a work self that not only had to be kept separate from everything else but that lived entirely in an ideal, esoteric world of mathematical problem solving.

Pathways

But what about other students? How might this account hire in to theorizing and accounting for the problems of underrepresentation in engineering education and the flexibility of engineers? Because it will take far more than three cases to map students' experiences sufficiently to make the investigation plausible, we expect a book manuscript to be a necessary vehicle. Still, as we elaborate below, an argument or hypothesis that emerges from this account of students' experiences is that statistical underrepresentation is a special type of citadel effect, an effect of conflicting challenges to personhood. That is, the challenge from engineering problem solving to bifurcate the person between work and self, where work is dedicated wholly to solving bounded mathematical problems, might be driving away people who experience this as a denial of self rather than simply a novel encounter with discipline. Also, helping students understand and grapple with this bifurcation may have the effect of shifting the meaning of flexibility in engineering education from malleability to sophistication in critical reflection.

Stereotypes do count. For people who already feel challenged by stereotypes that somehow make them or the people they care about invisible or subordinate, might separating a raceless, sexless work self from a nonwork self feel like a double whammy, yet another demand for invisibility? Might one feel a need to leave or avoid engineering to demonstrate one's wholeness as a person? We have collected a great many stories that appear to fit such an account.

Wholeness in personhood is a Western problematic, built on a stereotypic image of society as a collectivity of autonomous individuals. This powerful im-

age values coherence in personhood and challenges people to pursue coherent selves as a means to fulfilling lives. Indeed, any self in an adult body that is less than a coherent whole is considered downright pathological. Rick clearly sought such coherence in his person and life, as have the two of us. For Rick, the challenge from engineering education to live half his life in mathematical problem solving separated sharply from everything else he did or wanted was plainly intolerable. We propose there are many more who, like Rick, felt they had to weed out their persons in order to become engineers. One does not, for example, become an engineer-woman, engineer-African American, or engineer-world-helper, but only an engineer who happens to be a woman, an African American, or a person interested in helping the world. Unlike professional training in law and medicine, which understand themselves as adding expertise to an already educated, mature, and complete person, engineering education seeks out the high school graduate or, as one professor described it, the "blank slate." The disciplining in engineering education must be all or nothing.

Although our proposed generalizations are still tentative, Jen and Glenn may illustrate the strategies of many women and minorities who remain in engineering, resisting stereotypes by standing out as individuals. Knowing that "girls aren't supposed to be engineers" motivated Jen to prove that the stereotype did not apply to her. Similarly, Glenn wanted not only to prove to himself that he could "live with" whites but also to encourage other African Americans to follow him. Yet for the student who wants to "be around people like me," as several told us, standing out as an individual among white male engineers could feel like a lonely sacrifice of selfhood.

In sum, statistically significant differences of race or sex between students who stay and students who leave may depend upon a larger, more pervasive source of difference—the challenge made to diverse students to parcel off a mathematical work self from a nonwork self. In emphasizing such a separation, could engineering problem solving be driving away many passionate, motivated people who might be most likely to challenge the boundaries of engineering and/or want to spend their lives improving or changing the world? Based on following the experiences of students, we think that is the case. But must it be so? Must engineering be structured to fit best those who accept established authority and believe the world is pretty good right now? Might these same student experiences make visible pathways for linking engineering work to other dimensions of selfhood?

Attracting and retaining more members of underrepresented groups through support programs appears to be one such pathway. That is, making visible the experiences of engineering students may help affirm the value of recently developed programs for women and minorities that try to increase retention rates by reducing the extent to which such people might feel isolated or alone. One can argue that even white males need some nurturing and support, for the early disciplining in engineering education forces everyone to survive solitary struggles, and later courses keep the burden on students to prove they belong. However, because women and minorities also have to deal with stereotypes that label them invisible or inappropriate as they grapple with the challenge from engineering problem solving to ignore everything else

about themselves, offering such groups extra opportunities to identify with other students makes good sense. For example, being able to frequent a "safe space" that is populated with other stereotypically "inappropriate" people may be one way to reduce the extent to which the stereotypes feel relevant or significant. Choosing to leave engineering should be acceptable as a legitimate decision by informed adults, but not if leaving is solely the product of having to cope with the stress of conflicting challenges to personhood.

A second possible pathway to hiring in is to reimagine the role of mathematical problem solving in engineering education and, accordingly, relocate the sharp separation between work and self. What if, for example, disciplined attention to mathematical detail and the avoidance of extreme emotion and desire were no longer celebrated as more important than anything else in an engineering problem solver? What if engineers located mathematical problem solving as simply one valuable resource among many they might use? Perhaps the stereotypic images of women and minorities would become irrelevant for prospective engineering students rather than congruent with images of incompetence, and the statistical problem of underrepresentation could potentially dissolve away.

This pathway could be elaborated in several ways, of which we have so far tried only one. We designed and teach a course called Engineering Cultures, which tries to demonstrate that placing the highest value on mathematical problem solving in the lives and decision making of engineers is both historically and culturally specific. That is, things could have been otherwise. Although this is only a single course offered as a humanities elective, it does stimulate students to reflect critically on the curricula that shape their lives.

The course begins in the present by illustrating how mathematical problem solving is never the totality, and frequently constitutes only a small part, of the activities of practicing engineers. In other words, the work of practicing engineers extends well beyond the limits of mathematical problem solving. Then, working backward in time to excavate a series of genealogical layers, the course helps students understand how the great emphasis on mathematical problem solving in engineering curricula was molded in response to the perceived threat of Sputnik to American science. Exploring a long-term tension between "design" and "manufacturing" in industry illustrates how competing perspectives with equal value can exist simultaneously and that the very act of drawing a boundary around a problem establishes a claim of authority over it. Tracing several disciplines through mechanical engineering and onto the factory floor establishes a novel connection between the identities of engineering management and labor.

The course then pushes hard on the boundary around engineering knowledge by briefly visiting a number of different systems through readings and guest lecturers trained in different countries and demonstrating that a range of ways of locating engineers is already available. Exploring connections through colonial traditions and the contemporary organization of multinational capitalism offers images of global relations that contrast with the doctrine of competitiveness, which pictures a population of autonomous nations competing with one another on a level playing field. The course concludes by encouraging students to hold on to their romantic images of life as engineers by treating en-

138

gineering problem solving as but one resource among many in careers that could make a difference.

Other steps we might take to reimagine the role of problem solving in engineering education involve using our narrative of students' experiences as a test bed for assessing existing proposals to modify engineering education and for formulating some new ones. These proposals range from the structure of engineering curricula to the daily organization of classroom pedagogy. Proposals to increase the flexibility of engineering curricula, for example, often involve introducing design activities prior to the senior year while still conceiving design entirely as application of the engineering method to real-world problems. Perhaps modifying such activities to examine how engineering problems are connected to other sorts of problems and how the boundary around a given design problem can be drawn differently from different perspectives could help engineering students both to develop greater tolerance for different perspectives and to better assess how and when to apply the engineering method to the problems they encounter. Engineers trained to reflect critically on their own practices are not likely to be malleable but may indeed be more likely to figure out ways of making their disciplines and workplaces adapt to their dreams and fantasies of helping society or otherwise making a difference through engineering work.

Furthermore, must engineering education require a full body transformation? Might it be possible, for example, to formulate and structure a graduate degree in engineering for students with other undergraduate backgrounds, helping them to understand how engineering problem solving works and enabling them to map differences in engineering problem solving across fields and disciplines without necessarily having to master esoteric fields of engineering science? Couldn't one be just a little bit engineer, and might such people be capable of linking engineering problem solving to other social and personal agendas?

Lastly, what if engineering pedagogy admitted nurturing as necessary to its success? Could engineering instructors help individual students learn how to link engineering problem solving to their long-term fantasies and desires by offering their own personal stories and experiences? What if the thermodynamics professor offered his own reactions to the Ann Landers column or outlined what he was trying to achieve through research and teaching in thermodynamics? Could establishing legitimacy for welcoming and nurturing students improve their abilities to imagine new and different ways for using engineering problem solving as a resource in their later lives and work?

In sum, a theoretical approach that draws on the experiences of engineering students to intervene in engineering education need not demand a total transformation of engineering curricula to do so in potentially significant ways. Fully accepting the responsibility of hiring in to this contested field of education will require us to publish in places engineers respect, visit educators in their own spaces, and use reactions and critiques as opportunities to advance the discussion as a whole. This might involve as little as making presentations to engineering audiences and publishing specific recommendations in engineering publications, or as much as joining key organizations, committees, and ongoing policy debates. In either case, hiring in through ethnographic field

work and applying a cultural perspective on the fashioning of selves might encourage engineers to foreground practices that constantly address and critically rethink the question: What is engineering for?

Notes

1. For lengthy reviews of research on engineers and engineering, see Downey, Donovan, and Elliott (1989) and Downey and Lucena (1994). Some other relevant work in the anthropology of education in science and engineering includes Chaiklin and Lave (1993); Eisenhart (1994); Eisenhart and Marion (1996); Lave (1990); Lave and Wenger (1991); Nespor (1994); Seymour and Hewitt (1994); and Tonso (1996a, 1996b).

2. This mode of critical participation joins with and draws from feminist critiques of science and literary cultural studies, both of which are challenging citadel effects of the academy from positions within it. It is lived most intensely by those people and perspectives that work to make a difference while accepting the risks of life in the so-called private, public, and/or nonprofit sectors, away from the guaranteed paychecks of tenured professorships.

3. Because the image of committed cohabitation is a white, middle-class ideal that can work to hide inequalities and abuses of power, we see the danger of narrowness. But even in everyday language partners can be more than two, be of various sexual orientations, develop a variety of styles of commitment, extend partnering to some areas of life but not to others, etc. Because the key assumption in partnering is that each position presumes the legitimacy (but not necessarily the value) of others in principle, we mean the practice to be multidimensional, constantly involving work, and having varying power dimensions at the capillary level. We worry that the image of commitment may be limited by its individualistic overtones, but it does emphasize the mutual dependence of alternate modes of theorizing.

4. In anthropology, for example, the linear evolutionism that thrived during the nineteenth century could not account for a twentieth-century world of nation-states. Likewise, the structural-functionalism of the 1940s and '50s lost its relevance in a '60s world of rapid change, and a '70s symbolic anthropology could not maintain its holistic image of cultures in a contemporary world where the production of hybrids appears more the rule than the exception. Today, theories of postmodernism vie with theories of late capitalism for control over how to interpret the contemporary scene; eventually both will fall silent in the face of changing circumstances. Arguably, each step has been a historically specific improvement, but to label the whole as progress is to suggest that later forms of theorizing would have been appropriate, indeed desirable, in earlier periods. In fact it seems unlikely that, say, structural-functionalism would have played well in the nineteenth century, or postmodernism in the '40s.

5. We use the word "sex" here rather than "gender" to call attention to the fact that, in popular theorizing, the words "woman" and "man" are uttered and heard as labels rooted in biology. The word "gender" loses this dimension by displacing the label into academic theorizing that treats "woman" and "man" as cultural terms. We must maintain a focus on how our everyday theorizing uses biology to naturalize our categories.

6. Whether or not faculty actually tried or wanted to weed out students does not matter, for weed-out was a student category.

7. In this account we do not address the problem of variation in curricula among the three hundred or so schools that offer engineering degrees in the United States.

140

Sometimes these differences are indeed significant. Often they are not, owing to the fact that almost all schools seek accreditation from ABET, the Accreditation Board for Engineering and Technology, which offers strict guidelines for engineering curricula. One instructor told us, "I tell parents . . . that a student who goes to Clemson, Ohio State, Michigan, Penn State, or Georgia Tech will come out looking pretty much like one who comes through here."