Retaining and Retraining:

An Innovative Approach to Educating Engineers in a Changing Economy

Leslie P. Martinich, SM IEEE
Lead Faculty, Engineering Leadership Institute
Center for Lifelong Engineering Education
University of Texas at Austin, Austin, TX 78712 USA
lmartinich@ieee.org

Catherine M. Polito, M.S.
Executive Director,
Center for Lifelong Engineering Education
University of Texas at Austin, Austin, TX 78712 USA
cpolito@mail.utexas.edu

***Abstract*— Changing economic and technological conditions require that talented and experienced engineers adapt and update their engineering skills. Communities support education and retraining in order to retain the human talent. This paper describes an innovative approach to helping engineers overcome barriers to career transitions, which incorporates career and personal development, an engineering skills refresher, a semester-long course at a top-tier engineering school, and an internship at a company in a high-growth sector.**

We describe the motivation for embarking on a career re-engineering program. A large percentage of the engineering population in the Austin community is engaged in semiconductor design and manufacturing, an industry in decline. In order to harness the collective skills and talents of engineers in the semiconductor industry and to redirect those skills, the Center for Lifelong Engineering Education provides training to help engineers to re-tool their skills for growth industries.

We describe success factors for a career re-engineering program, including (1) the engagement with multiple stakeholders: a university engineering faculty, community development organizations such as workforce commissions, companies in high-growth sectors, the university career counseling center, and governmental agencies; (2) the acquisition of funding to help support engineers as they embark on a retraining curriculum; and (3) the application process and selection criteria.

We describe the curriculum, including an initial orientation and assessment program; the selection of appropriate and available fall-semester engineering classes in fields such as biotechnology, nanotechnology, and environmental sciences; monthly workshops designed to improve communication, presentation, adaptability, and networking skills; weekly small-team meetings designed to keep participants accountable; regular meetings with individual mentors; and a spring-semester internship with a firm in a high-growth sector.

Programs to help retrain engineers and to retain engineering talent within a society are critical to community sustainability and growth.

Keywords- engineering professional development; continuing education; retraining; community development.

I. Introduction

Economic sustainability requires communities to adapt to changing environmental conditions. At both the macro-level and the micro-level, communities that fail to adapt to environmental changes decline. Programs to help retrain engineers and to retain engineering talent within a society are critical to community sustainability and growth.

II. Historical Perspective

History provides us with examples of communities, both broadly and narrowly defined, in which engineering expertise provided the basis for economic growth, and in which the failure of the community to adapt to changing conditions and build new technological expertise led to economic decline.

A. Portugal

Navigational technology enabled Portugal to become a world power. In the early fourteenth century shipbuilders moved from a heavy shipbuilding technology, using overlapped wooden planks to keep water out of the vessel, to a lighter construction with a simple skeleton and caulking, the caravel construction. The caravels were larger, lighter, cheaper to sail and more seaworthy than their predecessors [1]. Mathematicians developed techniques for estimating distances from port to port, dead reckoning. Navigators developed port books or "*portolanos*" which allowed them to plot their voyages. By the fourteenth century, the compass was in use in Mediterranean allowing sailors to navigate even in cloudy weather [2].

In the fifteenth century, Prince Henry of Portugal (Henry the Navigator) launched several expeditions, apparently for both religious crusades and commercial reasons [3][4]. Henry the Navigator's nautical school helped prepare Vasco de Gama, who, at the close of the fifteenth century and early sixteenth century, rounded Africa and sailed to India, establishing Portuguese colonies around the coast of Africa, and creating important trade routes.

Portuguese navigational skills made the Portuguese rise to world power possible. When navigational skills became commonplace and less of a competitive advantage, Portugal did not sustain its dominant position. By the seventeenth century, the skill giving competitive advantage was the ability to manage far-flung empires, new forms of legal and financial risk-sharing (early insurance companies) and commercial trading companies.

And finally the competitive advantage afforded by the Industrial Revolution in the nineteenth century was slow to take hold in Portugal [5], giving a competitive advantage to England and France. Portugal fell from its position of world domination and suffered economic decline.

B. The Steel Industry

The United States turned to steel manufacturing during the depression of the 1890s. The industry flourished, and steel was the archetype and innovator of American commerce, dominating all competitors, nationally and internationally. Used for soup cans, automobiles, the cabling for the Golden Gate Bridge, steel production provided jobs for thousands of Americans. Early engineering advances fell aside to the later short-sightedness of upper management. Even as late as the 1990s leaders at Bethlehem Steel refused to adapt their traditional methods despite advances from "mini-mill" steel companies as well as the resurgence and development of alternative materials (aluminum and plastics) [6].

This failure by upper management to respond proactively to the influx of cheaper, foreign steel and remain entrenched in historical methodologies led to the loss of thousands of jobs and dramatically impacted a way of life for many Americans.

C. Digital Equipment Corporation

At the micro-level, the level of an individual company, the story of the rise and fall of Digital Equipment Corporation, is telling. DEC's engineering strength, culture of innovation and its dominance in the mini-computer market allowed it to rise to be second only to IBM in the computer industry, with annual revenues of $14 billion. DEC's decline, however, was precipitous, falling from market dominance to its demise in less than ten years.

The reasons for DEC's failure involve a complex array of issues. The obvious one is that DEC failed to adapt to the shift in the market, away from minicomputers to personal computers. Less apparent but equally powerful reasons involve the DEC culture and its focus on innovation and consensus. When the market shifted to one with far lower profit margins, the engineering skill that bestowed competitive advantage changed from expertise in innovation to capability in efficiency, cost controls and managing to very tight budgets.

Microsoft, Dell and Intel have de-bunked the myth that the best technology "wins." At different intervals, DEC had the best computer, best processor, and best search engine. DEC missed the market window by being too late (processor) or too early (search engine). Management's inability to seriously consider the threat of competition and develop an agile response led to the company's ultimate downfall. [7]

According to [8], "dealing with the business problems requires switching from the 'fun' of innovation and growth to the 'hard work' of creating a business strategy process, of becoming cost conscious, of changing organizational routines toward efficiency…, of modifying the basic processes in engineering and manufacturing to respond to changing technology."

The story of DEC is a chronicle of a failure to adapt to a changed environment.

III. CHANGES IN THE SEMICONDUCTOR INDUSTRY

The global electronics industry suffered a significant decline in 2009, and the Austin technology community has suffered a 24% decline in employment [9]. Industry observers do not expect that the region will regain these jobs. Dell, Spansion, AMD, Freescale Semiconductor, Samsung and Applied Materials have reduced their manufacturing employment from approximately 40,000 to approximately 20,000. Table 1 illustrates the decline in the manufacturing industry in Austin.

The decline in technology jobs in the Austin region disrupts the careers of engineers, reduces the value of manufacturing plants, reduces the property tax revenue, and disrupts the ecosystem of suppliers and service companies that provided parts and services to the semiconductor companies.

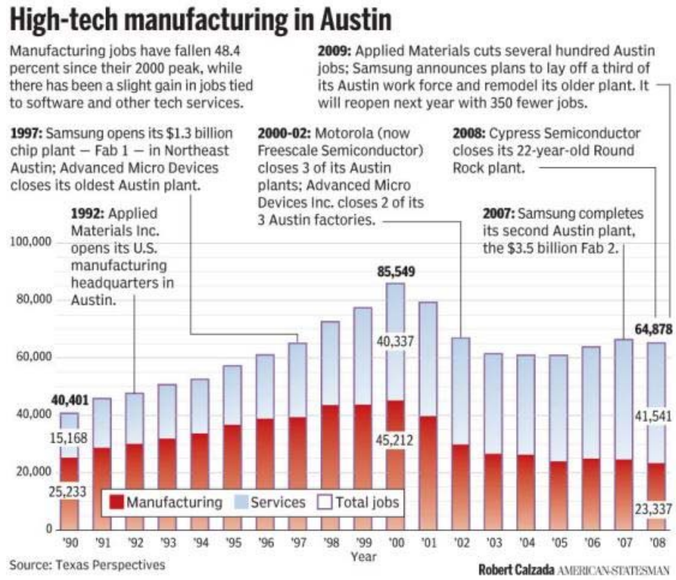
IV. POSSIBLE SCENARIOS

Given the loss of employment in the semiconductor manufacturing industry, what are some of the possible scenarios for the community?

A. Brain drain

In one scenario, engineers leave to work in other communities where their skills are still valued. However, given that the semiconductor manufacturing industry jobs are now primarily in Asia, the opportunity for relocating is small.

Table 1: High Tech Manufacturing in Austin [9]



B. Community decline

In a second scenario, engineers take positions which do not utilize their problem-solving and engineering skills or they remain unemployed. This is the primary current situation. Engineers are currently receiving unemployment benefits while looking for new employment.

C. Revitalization

In a third scenario, engineers receive training in a growth area and help to build new industries, applying their problem-solving skills to new problem domains. With training in entrepreneurial skills, they are able to build new firms and revitalize the economy.

This scenario happens at the individual level with great regularity. Engineers acquire certain skills in their college training, but within a few years, those skills are stale; technology has advanced. Many engineers recognize the need for regular skill enhancement and seek out training opportunities, either through their firms or on their own. Typically, these are technical skills. Engineers who want sustainable careers see the need for frequent skill enhancement.

But faced with a massive industry decline, technical skill acquisition alone is inadequate. In order to help rebuild an economy, the engineers' problem-solving and engineering skills need to be supplemented with leadership, communication, and negotiation skills.

V. Responding to a Changed Environment

How can a community, whether it is a nation, a region, a city or a firm, respond to a change in its technical and economic environment?

First, that community must recognize that if it fails to support the re-tooling of its talent, it will go into certain decline.

Second, it must recognize that it needs to support retraining its engineers to acquire skills in areas of potential growth and skills in leadership in order to help build new industries. Such retraining is necessary in order to retain the engineering talent within the community.

Applied Materials, a leading capital equipment producer serving the semiconductor industry and based in the Silicon Valley, recognizes the risks to its business and is attempting to move into the growth industry of manufacturing solar equipment. This is the sort of adaptability that can revitalize a community, in this case the community of one firm. So far, however, Applied Materials has not found adequate demand for solar equipment in the United States [10].

The Center for Lifelong Engineering Education at the University of Texas at Austin's Cockrell School of Engineering currently offers training to engineers in Aerospace Engineering, Biomedical Engineering, Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Energy and Environmental Engineering, Engineering Ethics, Engineering Finance, Engineering Leadership, Mechanical Engineering, Petroleum Engineering and Software Engineering. These programs fulfill the need for the incremental training that helps individual engineers enhance their skills in order to sustain their careers. This incremental training, while critical for engineers to sustain their careers, is still not adequate to meet the needs of revitalizing an entire community.

VI. A Program for Retraining and Retaining

In order for the Austin community to sustain its economic viability, we propose a program to provide a significant retooling of the current engineers. The program, still in the planning stages, includes several elements.

A. A well-defined application, selection and matching process

In order for this program to be successful, it must have a well-defined application, selection and matching process. Engineers admitted to the program must have talent and intelligence as well as motivation to learn the concepts of a new domain. In short, they must be adaptable.

Participants accepted into the program attend a week-long orientation program. Initial assessments help match individuals with appropriate fields of study and point them in the direction of appropriate course work. Participants assess their professional strengths and create plans to build their skills and networks. Participants attend workshops on communication and presentation skills.

Video snippets of professors and their courses provide the engineers with a sample of what might be of interest to them.

B. Fall semester engineering coursework

Once admitted to the program, participants enroll in one fall semester course. They select the course that will help them establish expertise in a new field.

The coursework will be in growth technology fields, such as power engineering, battery engineering, and biotechnology.

C. Monthly workshops

During the orientation and fall semester, participants attend monthly workshops on communication skills and negotiation skills. They learn how to present a project idea and gain acceptance; how to present themselves at meetings and interviews; about gender and cultural differences and how to communicate effectively will all. They learn presentation skills, including videotaping, critiquing and practicing. They learn to understand their audience and speak in ways that the audience can hear. They learn leadership skills and entrepreneurial skills. They learn practical negotiation skills and how to expand the negotiation space.

D. A five-month and ten-month option

Some engineers find that a five-month program including assessments, workshops and one semester of academic instruction will be adequate to their needs. Others benefit from a second semester (the ten-month option) which includes a five-month internship at a local firm in a high-growth sector.

E. Small teams

Once admitted to the program, participants join small teams of three to five individuals. These teams meet weekly for accountability, encouragement and networking.

F. Mentoring

Once admitted to the program, participants begin working with a mentor, a senior member of the engineering community who can provide career guidance and advice.

G. Broad community support

In order for this program to be successful, it must have the support of the broader community, including the university, the engineering faculty, the Chamber of Commerce, local industry, venture capitalists, workforce commissions and career counselors.

H. Support from the university

Support from the university is critical, because it must be willing to accept non-traditional students into a program that crosses the boundary between academic degree courses and continuing education programs. If a university sees its role as a research institution only, it does not value community revitalization, nor does it see itself as a resource in an effort to revitalize a community.

I. Support from the university faculty

Support from university faculty is critical because the faculty must be willing to accept non-traditional students into their classes. Engineers in need of retraining are often 20 years out of college. They may have exceptional experience, but lack specific courses considered to be pre-requisites for certain classes. The engineering faculty has to work with the program administrators to ensure that the engineers are academically equipped to succeed in the courses while not restricting the admissions onerously.

J. Support from local industry

In order to provide post-training internships, the program requires support from the Chamber of Commerce and local industry. The Chamber benefits by retaining the community's engineering talent. Local industry benefits through the increased and better-trained talent pool. They will find excellent engineers who have taken the initiative to acquire new engineering skills.

K. Venture capitalist support

Venture capitalists support the program by coaching engineers with ideas to become successful entrepreneurs. Building new industries is notoriously risky, and novices need senior guidance.

L. Public workforce commission support

Support from the Workforce Commission provides funding for skills development for engineers.

M. Career counselor support

University career counselors provide assessments and advice to engineers entering the program.

N. Financial support

In order for this program to be successful, it must have the support of funding agencies, such as the National Science Foundation and the Workforce Commission. Unemployed engineers are unlikely to be in a position to fund their training. Moreover, this program is intended to benefit the community, whether it is seen as a local community, a region or a country, by retaining the talents of skilled engineers.

VII. Results from Preliminary Programs

The Center for Lifelong Engineering Education has provided training in leadership for engineering managers and has results of the usefulness of that training for sustaining careers, primarily in software engineering. Results from the Engineering Leadership Institute can be used to determine likely usefulness of various kinds of career and personal development training for engineers seeking to revitalize their careers through a retraining effort. Table 2 summarizes the usage of the skills acquired in this program.

A. Communications skills

Ninety-four percent of students who have taken the Engineering Leadership Institute's Communications Skills workshop report that they are using it extensively to support their careers, and 100% report that they are using the materials they learned in this program.

The workshop includes training in tailoring communications to your audience, presenting ideas with impact, understanding gender and cultural communication differences, listening to understand and delivering bad news.

B. Skills for dealing with different personality types

Eighty-two percent of students who have taken the Engineering Leadership Institute's workshop in Dealing with Different Personality Types and How to Work More Effectively With Them, using the Myers-Briggs Type Indicator, report that they are using it extensively to support their careers, and an additional twelve percent report that they are using the materials they learned in this program. Six percent of the program participants report that they are not making use of this training.

C. Skills for managing up

Seventy-one percent of students who have taken the Engineering Leadership Institute's workshop in Managing Up: What You Boss Needs from You, report that they are using the skills extensively to support their careers, and an additional twenty-nine percent report that they are using the materials they learned in this program.

D. Problem-solving skills

Seventy-one percent of students who have taken the Engineering Leadership Institute's workshop in Problem-Solving Skills report that they are using the skills extensively to support their careers, and an additional twenty-nine percent report that they are using the materials they learned in this program.

E. Skills for dealing with difficult people

Sixty-three percent of students who have taken the Engineering Leadership Institute's workshop in Dealing with Difficult People report that they are using the skills extensively to support their careers, and an additional thirty-eight percent report that they are using the materials they learned in this program. All of the students were making use of these skills in some way.

F. Risk management skills

Fifty-six percent of the Engineering Leadership Institute students reported that they were making extensive use of the risk management skills they learned in the program, and an additional forty-four percent reported that they were using the risk management skills in some way. .

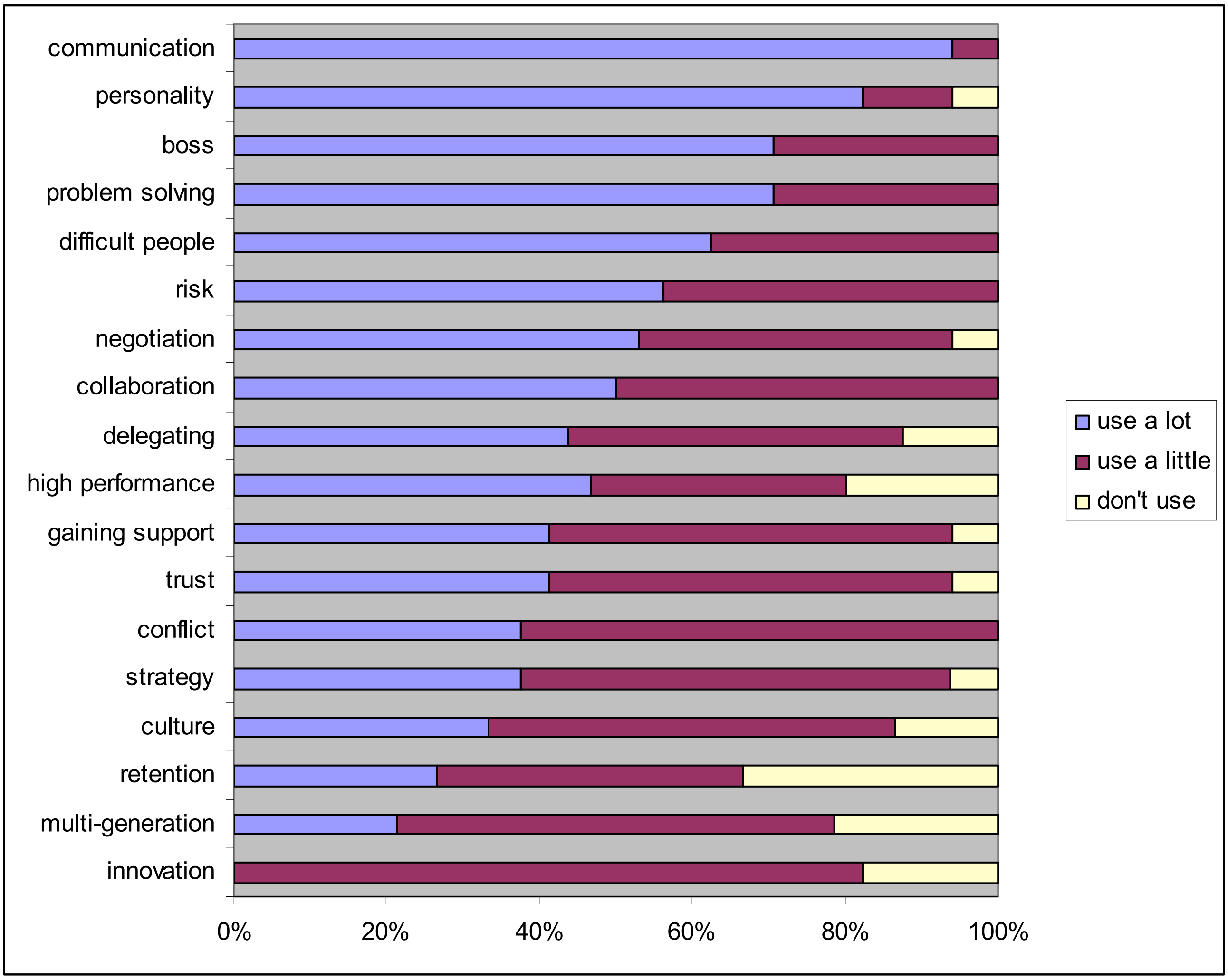
G. Practical negotiation skills

Fifty-three percent of the Engineering Leadership Institute students reported that they were making extensive use of the negotiation skills they learned in the program, and an additional forty-one percent reported that they were using the negotiation skills in some way. Six percent reported that they were not making use of the negotiation skills.

H. Collaboration skills

Forty-seven percent of the Engineering Leadership Institute students reported that they were making extensive use of the collaboration skills they learned in the program, and an additional forty-seven percent reported that they were using the collaboration skills in some way.

Table 2: Percentage Usage of Leadership Skills



I. Delegation skills

Forty-four percent of the Engineering Leadership Institute students reported that they were making extensive use of the delegation skills they learned in the program, and an additional forty-four percent reported that they were using the collaboration skills in some way. Thirteen percent indicated that they were not yet using these skills, primarily because they are not in leadership or management roles yet.

J. Skills for building high performance teams

Forty-four percent of the Engineering Leadership Institute students reported that they were making extensive use of the skills for building high-performance teams they learned in the program, and an additional thirty-one percent reported that they were using the skills in some way. Nineteen percent reported not yet using these skills, primarily because they were not yet leading or building teams.

K. Other skills

Sixty-three percent of the participants were using skills to attract and retain good employees. And more than three-quarters of the participants were using the remainder of the skills taught in the Engineering Leadership Institute, including building trust, conflict management, strategic planning, developing a culture of success, managing a multi-generational and multi-cultural workforce and innovation management.

VIII. REVITALIZING A COMMUNITY

Data from the Engineering Leadership Institute's participants validates the usefulness of the career and personal development skills workshops for enhancing and revitalizing individual careers, and will be useful in building a broader program. Many of the engineers in the program have provided testimonials as to their individual career growth as well as their contributions to their sponsoring company. Most significant: engineers who were technically proficient and had been moved into management based on their technical proficiency felt they were no longer immersed in their area of expertise. This program taught them to balance their technical growth with their leadership skills, thereby expanding their comfort and competency in leading technical projects and/or teams.

The program defined can be used in any community with a top level engineering university. It is customized to the group needs, providing just-in-time training that is immediately applicable. As a result, engineers are able to bridge the gap between their technical training and the demands of managing projects and people. We have defined it in such a way that the community sees the benefit from the program and sees that ongoing efforts to retrain and retain their engineering talent are crucial to economic viability.

Why is this program innovative? Most professional development or continuing education programs for engineers focus on improving on the base of established engineering skills, or on adding people skills to the existing engineering skills. This program is innovative because of its systemic approach; the individual's skills are enhanced within the context of the economic conditions, and they are enhanced in both the hard skills (new technologies) and the soft skills such as communication, negotiation, and proficiency in human interactions.

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