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32 Leaders for Manufacturing: Educating for the Future

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One of the most heartening developments in the manufacturing arena in recent years has been the resurgence of interest in manufacturing at universities, both in schools of engineering and in schools of business. The Massachusetts Institute of Technology (MIT) has been one of the leading institutions in creating the renaissance in manufacturing education, and five years ago, we began our Leaders for Manufacturing Program. At MIT, we have extensive experience in working with the manufacturing industry, but the Leaders Program has raised the level of interaction to a new level.

Recently our dean of engineering said that the Leaders for Manufacturing Program is the most valuable program that MIT has undertaken in the past decade. I feel even more strongly about it;

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in my opinion, it is our most significant undertaking in the past thirty or forty years, from an educational point of view.

MIT issued a commission report several years ago, a book titled *Made in America*, we think that the origins of the problem of America's diminishing manufacturing competitiveness lie in the institutions that educate Americans for work. We are blaming ourselves at the university for whatever is wrong. At MIT, industry sponsors $60 million of research each year, double that of any other university; we receive more patents than all the federal laboratories combined; and we license over 50 percent of those patents to industry. We may point to those statistics with pride, but while we recognize MIT as one of the best universities in the world, there is nonetheless something wrong with this great American institution of higher education.

Universities need to change. They need career paths for faculty who want to work closely with industry, and we need more prestige for manufacturing. I obtained tenure at MIT working in manufacturing, but I did not dare use the word "manufacturing," and in fact, I had to sneak in the door. (When I told my associate dean that I wanted to write a book called *The Science of Welding*, he told me that was a contradiction in terms.) Perhaps this is why universities have failed to offer new educational research models. Basically we are doing the same things we have been doing for thirty or forty years. If any company was doing things the way it did four decades ago, it would not be doing anything today because it would be out of business. Industry's failure is that it has had problems creating a learning type of organization.

Without major changes in the way schools and firms train workers over the course of a lifetime, no amount of macroeconomic fine-tuning or technological innovation will be able to produce significantly improved economic performance and a rising standard of living. Motivating factors for starting our program included the huge divide we have between engineering and business today. Everybody in universities such as MIT and Harvard is trying to bring the two back together. (We have to get the government involved also.) We recognize that you cannot solve the problems in manufacturing with either a technological fix or a management fix. The solution must be integrated.

The Leaders Program has raised the level of interaction with industry to an entirely new level at MIT, and the companies interact with each other as well as the university. We have had partnerships-internships between Digital Equipment Corporation (DEC) and Motorola and between DEC and Boeing, for example, and we
are talking about setting up such an arrangement between Alcoa and Chrysler. The rest of the university is pointing to us and saying, that's how we should be interacting with industry. This program is becoming a model for how we should think about our interaction between the university and industry.

Our logo is three rings, symbolizing industry, the engineering school, and the Sloan School of Management. Likewise, there are three codirectors. I am the engineering codirector, and Thomas L. Magnanti is the management school codirector. We also have an industry codirector, William C. Hanson, vice president of logistics of DEC. Essentially, he is an executive on loan, but unlike many similar arrangements, he truly is an executive on loan. Mr. Hanson, who was vice president of manufacturing at DEC for many, many years, spends 80 percent of his time in our office, working on this program.

In the Leaders Program the organization we put together had to have people from industry actively working as partners in advising students, teaching, and doing research. We needed a sufficiently large number of firms; we started out with eleven and now have thirteen, representing different markets and cultures. We also wanted to use industry sites, because one cannot really teach manufacturing and what happens on a factory floor at a university. One has to go out into the real laboratory—the workplace. A program of this type also needs open-minded faculty members, and we were able to find some. We are engaged in patient experimentation and lots of feedback, and after five years we are still trying to work some things out.

The program is run by a governing board that is composed of representatives of the thirteen companies (who are quite senior) and several representatives of MIT, including the deans of the management school and the engineering school. The governing board meets several times a year to set policy, just like the board of directors of a company. The operating committee, which meets three or four times a year for six or seven days, essentially helps the codirectors implement the policy set by the governing board. This operating committee includes a representative from each company, typically a vice president or general manager, and a number of MIT faculty members.

One of my faculty colleagues in engineering feels that the university has given control of this program to industry, and the way he says it makes one suspect he finds that terrible. On the other hand, indicative of the ambivalent feelings we all have, he tells me that, through the program's internships for his students over the
last four years at the company sites, he feels he has learned more than his students have.

There are twenty or thirty companies in this country that are actively investing millions of dollars in trying to change the culture of the universities, which is what the Leaders Program is all about. Because of the price of entering the program, the partner companies have to be big companies. The companies' investment in MIT over the first five years has been about $50 million; MIT's investment has been about $10 million or $15 million. A number of times we have discussed how to involve smaller companies, and we hope to make this change over the next few years, but sometimes, big companies are the only ones that can provide funding on a large enough scale.

The program can be divided into two areas: education and research. One of the two educational programs is the Fellows program, which enrolls fifty Fellows each year. In this twenty-four-month program, students get a dual master's degree—one in engineering from one of the five engineering departments and one from the Sloan School of Management, which is like a master's degree in business administration. Students also spend seven months at a company site doing a thesis. Because this thesis has to satisfy both the management school and the engineering school, it has to be a holistic thesis, looking at some large part of the whole manufacturing problem. The thesis can be on specific engineering product-process solutions, but the student also has to describe how that fits into the context of the whole manufacturing operation of their company.

In the Fellows program, the students have to take the foundations of economics, management, physical science, mathematical science, and informational science. They then take a set of courses designed to integrate those basics—part-process design, manufacturing policy, total quality management, and leadership, which is really the capstone to the whole thing.

In the program, we look at manufacturing as something other than the manufacturing that has received such a bad name at the universities and is looked upon with such disdain by many of our colleagues in the schools of science, engineering, and management. Certainly, operations lies at the core of the manufacturing enterprise, but, in fact, one also has to have an appreciation for marketing, finance, administration, part-process engineering, and basic research. At the same time, one has to work with a lot of different people—vendors and suppliers, for example—and to interface with the government. Anyone who is educated in the fu-
ture as a manufacturing engineer and who does not have what we call the "big M" view of manufacturing is not going to solve our competitiveness problem in the world. We have to teach that big M view.

We envision that five or ten years after graduation, these students, who average about five years of prior industrial experience, will be managing factories. We have had some graduates who, within six months, were managing factories of several hundred people. In general, however, we are preparing these students so that by their mid-thirties, they will be managing some factory of anywhere from a hundred to a thousand people or so.

We also have anywhere from thirty to fifty PhD students and postdoctoral students doing research on campus in conjunction with the companies.

The research program involves faculty-based, on-campus research with the graduate students, which keeps the faculty intellectually involved in this program (and not just supervising Fellows at companies). There is also field-based research with the doctoral students. Over time, as we learn things at the university that might be worthwhile, we engage in some type of technology transfer to get this knowledge into industry. Moreover, just as much learning travels the other way in this program, that is, from industry to the university. I recall again the faculty member who said he has learned so much while supervising interns over the past four years because he was going to company sites.

What are some of the other accomplishments and benefits of the Leaders Program? One is that the internships act as agencies for change. In fact, I have developed a theory in the last few years that an intern is more effective at implementing change in a company than a new employee. Why? Because although these individuals are usually the same type of people, the company people perceive them differently. We are trying to study this phenomenon because if we can figure it out, we should be able to devise some way to make new employees more effective agents of change.

We recently did a cost-benefit analysis that showed that the program pays for itself in terms of payback to the companies. Savings are easily quantifiable for only about 20 percent of the internships, but those 20 percent generated $20 million of savings—roughly the cost of the internships and the full education of the Fellows. Total savings may be several times that amount.

We have various studies underway. We are looking at whether a country’s indigenous processing equipment capability gives it a competitive edge in the semiconductor industry, the automotive
industry, and the electronic packaging industry, for example. One of the first doctoral theses examined the design of experiments and was able to show that just as much information can be obtained with 30 percent fewer experiments. We kept that student on as a postdoctoral student, and he showed partner companies how they could implement this finding. Some of the companies point to it as representing millions of dollars of savings to them.

A hard-to-quantify benefit is the opportunity for faculty-industry dialogues, such as are presented by the operating committee and the governing board. A number of the companies say that one of the most valuable aspects of the Leaders Program is that they and we can to get together and talk about things on the neutral ground of the university. Industry representatives are now serving on university committees to help us define the directions we should be taking. For our part, we have symposia, workshops, and faculty sabbaticals at partner companies.

We are developing new courses. Getting faculty members to change their ways has been one of the most difficult challenges because teaching is their province, not the companies', but, in fact, we have been able to involve company people in the design and development of courses and in teaching them. Our challenge for the next few years will be to disseminate curriculum materials to the companies, so that they can teach manufacturing science to their employees.

At present, the program is in a transitional phase. It has two new partner companies, Ford and Intel. We think we can add more companies to attain a total of fifteen. We want to increase the number of partner-sponsored Fellows. Thus far, the companies have been sponsoring 20 to 25 percent of the Fellows, but we would like to increase that to 30 or 40 percent. We also want to increase the joint faculty-industry research and the collaboration among partner companies. We have just begun to break down the barriers between the companies, so that Ford, General Motors, and Chrysler, for example, might eventually feel that they could work together on a project more effectively than they could work on it individually.

What is the government's role? Companies have invested $50 million at MIT because they felt that if they could make manufacturing respectable at MIT, they might be able to convince other universities that manufacturing is a respectable profession. Now we are getting the best of the available students, and we are getting them interested in working in manufacturing, not in a research laboratory. Industry wants to clone this, and government
can help. Just like we had a National Defense Education Act, we need a National Manufacturing Competitiveness Act, which would provide a thousand fellowships for manufacturing, similar to National Science Foundation graduate fellowships. Such an impetus could mean that five or ten times that many students would subsequently go into manufacturing with an interest in getting on the factory floor and solving the problems there. Such an act could help forge better links between the national laboratories, industry, and universities.

It is clear that the government comes in during phase three of our plans. Industry wanted to keep the government out of phase one. It was hard enough getting the industry people to work for the university without having a third partner, but, eventually, we do have to get the government involved.