

Knowledge transfer from academia

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For more than twenty years we have been "high tech" without knowing it.

There is an aspect to the theme of knowledge transfer which I wish only to mention but not to discuss. This is the opposition which sometimes new knowledge or ideas generate. Indeed, it has been said that the newness or originality of an idea, or knowledge, can be measured by the strength, the vehemence of the opposition it generates.

Now, I am not only thinking of the untutored not understanding and hence opposing an idea. Nor am I referring only to the highly educated opposing a new piece of knowledge because of the clash of religious, philosophical, or social dogma with the newly discovered reality. An example is the prosecution of Galileo either because of his espousing Copernican cosmology and astronomy or, as has been proposed recently, because of his atomistic concepts clashing with the dogma of transubstantiation. These situations are relatively easy to understand.

I am thinking of a far more puzzling and fascinating phenomenon: the opposition—apparently irrational—by an expert in the field to new propositions in that discipline. Some of the most famous of these examples illustrate, but do not explain, this phenomenon. Einstein was one of the founders of quantum mechanics, but his opposition to its most startling findings was such that he abjured its study for the rest of his life. Edison was the prime mover in establishing large-scale, commercial, central generating stations and the modern system of electrical transmission. Yet he fought alternating current concepts and practice in the most bigotted way.

It is well beyond my abilities to analyze such opposition, and I am fairly certain it requires more than an after-dinner talk even to begin an explanation. But I felt I had to mention this fact because where it exists, the rate of knowledge transfer is what mathematicians would designate as "identically zero." The other reason to bring up this matter is to reflect on the fact that if Einstein, Edison, and many luminaries of stellar magnitude could suffer such aberrations, it behooves us to question our own oppositions to a new finding of science lest we unnecessarily impede the flow of knowledge into our organization.

This conclusion puts us directly under the most exacting dilemma of science. The philosophy and practice of science demand that we follow two paths: one is to trust the

integrity of other scientists and to rejoice and honor them when they find a new truth and the other is to subject every finding to the most searching tests with the declared and strict intention of falsifying it. Only in following these two paradoxical dictates can we save ourselves and our knowledge from the twin hazards of naive and too ready acceptance of what might prove to be error and of suppressing truth by irrational oppositions.

This demand to follow two opposite paths is extremely difficult to fulfill, and it borders on the unfair. But as President Kennedy is reported to have asked, "Who said life was fair?" And he might have added "or easy?"

Thus, I shall assume that we are in situations where we have no more than the essential and required scientific skepticism to the knowledge generated in academia and furthermore that the knowledge so generated affects our areas of interest. Hence I shall assume we are anxious to have fast, accurate, and complete transfer of such knowledge from academia to our corporate treasury of ideas and productive facilities. The question is how best to effect such transfer.

But, before I embark on my main theme, I think I should address the question of why we should be concerned with the subject of knowledge transfer from academia at this particular time. After all, we have all been engaged at one time or another in acquiring academic knowledge. All of us still attend lectures at universities and read research papers emanating from academia. So what's special about this theme now? What's new?

I believe there are two important new features. The first is that over the last twenty-five to thirty years there has been a radical change in our industry, and in latter years new strategic thinking has gained wide acceptance in our corporations. The second is that over the same period there has been a corresponding change in academic approaches to knowledge in the sciences. These two major changes in industry and academia render the need for adequate and efficient transfer of knowledge from academia to us more urgent than it may have been in the past.

In dealing with the changes in our industry, I am reminded of a character in Moliere—Monsieur Jourdain—who discovers a secret which greatly surprises him. He exclaims: "Good heavens! For more than forty years I have been speaking prose without knowing it." In a similar way, we in our industry have been unaware of a secret which I wish to expose here by exclaiming "Good heavens! For more than twenty years we have been 'high tech' without knowing it." We have kept this secret so well that nobody

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outside our industry, and only a few within it, are aware of it. There are three reasons why the myth that we are a "low tech" industry persists—all are appearances which camouflage reality.

The first camouflage is the appearance that in essence papermaking does not seem to change. Ts'ai Lun tenderized vegetable fibers in alkaline media, washed and cleaned them, beat them, dispersed and filtered them, and then consolidated and dried the sheet to produce paper. So do we—separate vegetable fibers in alkaline media, wash and clean them, refine, disperse, and filter them out, and finally consolidate and dry them. But this is sophistry, for by emphasizing the crude similarities and ignoring the critical differences, we throw the baby out with the bath water. The logical French "put paid to" such short-sighted arguments once and for all when they ignored similarities between men and women and exulted with "Vive la difference."

Second, our machines appear to be so long-lived; some are 30 or more years old. Again, what is ignored is that the only parts in such a machine which are thirty or more years old are the frame and possibly some of the drying cylinders. In a competitive machine we find all other components are modern products.

Third, many of our large-tonnage products are commodities—newsprint, linerboard, corrugating medium, and even some lightweight wood-free sheets. People who dwell on this feature in our industry either ignore willfully, or are unaware of, the tremendous efforts being exerted to diversify and specialize our products or of the "high tech" efforts going into producing even our commodities.

But where are these "high tech" features? As Elizabeth Barrett Browning put it, "Let me count the ways." Consider tree farming. Our industry's roots, physically and metaphorically, are in the forests. There, we find our scientists laboring to unfold the mysteries of genetics and to revolutionize the way forests will grow, with studies in molecular biology and engineering, tissue culture, single-cell manipulation, and DNA modifications. These studies are at the edge of our biological sciences. When—and I advisedly say "when" and not "if"—these researches and studies succeed, the effects will outrival previous technical revolutions in agriculture and industry.

Or look at our chemical activities. Our scientists are using the most sophisticated combinations of state-of-science spectrometric, chromatographic, and other analytical tools to unravel the complicated tapestry of carbohydrates and lignin—the two primary components in our products—so that a better knowledge and control of our pulping, bleaching, and other chemical processes may be in hand. Subtle structural features are slowly revealed—slowly because digging at the edge of the known and into the hard rock of the unknown is a slow business.

Similarly in the physics of pulp and paper, the old way was to measure *ad hoc* properties and to plot them against each other to obtain cross correlations without understanding causes for the observed effects. Today this is giving pride of place to fundamentally relating basic properties to molecular, thermodynamic, and kinetic parameters using the most advanced mathematical tools. In other words, *ad hoc* explanations of properties are giving way to more basic theories. Increasingly, properties are measured at high speeds on line—and are logically and

mathematically related to end use in subtle and complicated ways, using state-of-the-art electronics.

And to close the list, our processes are demanding materials at the edge of metallurgical science and technology to produce them. We routinely discuss components in our streams not in parts per million but in parts per billion and occasionally in parts per trillion. Flows in our refiners have been demonstrated to be among the most complicated in industrial equipment and, I believe, are well beyond the state of knowledge in fluid mechanics. Certainly, flows in blade and roll coating equipment are taxing available analytical techniques to the limits of available knowledge. Our high-speed processes are demanding and receiving the most precise and sophisticated control strategies.

It was not always so. These so-called "high-tech" features of our industry have come about in the last twenty to thirty years. They are making compelling demands on our engineers, scientists, and technical managers to understand, utilize, and manage the latest in advances. The most profound and basic advances in science and engineering science do occur at academic and semi-academic institutions. Hence, there is an increasing urgency for rapid and efficient transfer of knowledge from academia, where knowledge is its own justification for existence, to industry, where the value of knowledge is further enhanced by putting it to use in ameliorating the quality of life.

In parallel with this change in the quality of technology of our industry over the last twenty to thirty years, profound changes have been taking place at the universities. Chromatography earned a Nobel Prize for its two discoverers and opened up vast new territories in chemistry, physics, and biology. The epoch-making discovery of the structure of DNA by Watson and Crick in 1953, coupled with the new analytical techniques and the power of computers to analyze thousands of X-ray diffraction data, has created undreamed-of powers to unravel most of the complicated biological structures. In turn, these activities led to totally new and revolutionary sciences and technology in molecular engineering and biotechnology.

The advent of the computer was an essential link in all these developments, but there was also another revolutionary change due to the computer. Before its advent, most fundamental equations of science were impossible to integrate analytically. Finite difference or numerical integration was only possible in the simplest of problems. The computer made it possible to integrate numerically differential equations of second and higher orders for most complicated situations in solid and fluid mechanics, in thermodynamics, and in other sciences. This in turn opened up opportunities to use matrices and tensors in ways totally impractical thirty or so years ago.

In short, science and technology as researched and taught at the universities today are accurate, more complex and more powerful. Therefore, their transfer to industry and their conversion into useful tools for creating new products and their processes is presenting greater challenges than ever before.

With these brief, broad brush sketches of the background to our problem before us, what are the best ways for effecting an enhanced, efficient transfer of knowledge from academia?

In every human organization—a corporation, a government department, a church, or a social club—there are two structures: the formal and the informal. The formal line of command and communication is invariably more cumbersome, slower, and less efficient than the informal channel. And so it is with knowledge transfers. The formal channels for communication are letters to *Science*, to *Physical Reviews*, or to *Nature*, reviewed research papers, technical reviews of scientific fields, textbooks, encyclopedias, and patents. The delay involved may be a few months for letters announcing new developments or discoveries, to several years for patents and chapters in books. The information is almost invariably incomplete on some point of detail. Nonetheless, these are channels for transfer of knowledge from academia which are vital for the renewal and upkeep of our obsolescing knowledge.

There are, however, the informal channels. In every discipline there arise, spontaneously, what is known as the "Invisible Academy." This is the group of researchers who are most active and effective in pushing the outer bounds of a particular discipline further out. They communicate with each other not only by exchanging reprints of their papers but also by personal meetings, by telephone, by letters, or by networking via computers. Except for protecting priority of discovery—which they respect—communications are almost instantaneous. Questions of detail arise spontaneously and are usually answered fully. This informal, loose structure for the Invisible Academy is undoubtedly the most efficient and fastest mode for knowledge transfer.

Thus, it appears that the problem is how to get to be a member of such an academy if we are to have an efficient transfer of information. Like any other membership in a group, there are three demands. First, one must pass a qualifying test; second, one must pay an entry fee; and third, one must continue to pay one's dues. What do these demands mean in practice?

To qualify, we must earn the respect of the other members of the Invisible Academy by demonstrated skills and contributions to the field. This means we must have one or more scientists, engineers, or technologists in our corporation who are acknowledged contributors to the field or discipline. There is no way for knowledge to transfer from academia to us if there is no receptacle for it available in our midst—and by that I do not mean someone who can simply understand it. A book on a library shelf does not add much to my knowledge until I read it, understand it, and put it to use intellectually or practically. More than having some who understand the field, we need to have scientists active in the field to earn the respect of the active members of the Invisible Academy, to be invited to their private enclaves, to their casual suppers and the interminable discussions after hours, and to be recipients of their letters.

Second, the entry fee. One must do something to advance the well-being of the Invisible Academy which, in turn, means advance the discipline. This means establishing a worthy reputation by publishing our own findings and offering our knowledge to them by letter or personal contributions to their papers.

Third, one must continue to pay the annual dues. This demands continuing the steady contributions to the field of studies, continuing a constructive participation in the

ever-going debates and discussions—the life blood of Invisible Academies.

In my judgment, this is the ideal mode of knowledge transfer from academia. Of course, it does not always happen that we have such a participant of an Invisible Academy in our midst. Then, I think if we are interested to have a transfer of knowledge from academia to our organization, we should work towards qualifying. There are two ways of doing this. One is to hire a member of such a group and build a unit around him or her. But it is not always possible to do so. And we must not raid our universities indiscriminately and hire their most productive professors without due regard to the needs of society: otherwise, we shall be in the same position as the farmer who has eaten all his seed potatoes. There will be no future harvest to look to. But hiring graduate students or faculty who have decided on their own to move to industry is perfectly legitimate and desirable.

The other means of qualifying is to send one of our scientists to spend a sabbatical year, or two or three, working with an acknowledged member of this Invisible Academy. To pay our dues and earn qualification, such a move should be at our own expense. When he has finished his stint of duty, he would not only bring back knowledge we could not acquire as well, as thoroughly, and as efficiently in any other way, but he would have established a permanent link to the Academy I speak of.

I think this is much too neglected a procedure. I would like to see a regular program by most of our companies to send some of their brilliant scientists for at least a year, preferably two or three years, to universities or sabbatical arrangements. Such actions should be at least financially neutral to the host university; preferably, it would not hurt if some contribution was made to the extra research which would ensue from the Fellow's tenure.

In my judgment, all other methods of knowledge transfer which do not involve a bodily transfer of a knowledgeable mind are only second in value and efficiency to this approach. It is a challenge to our industry to adopt this approach and accelerate our technical advances.

An interesting confirmation of my thesis comes from a totally independent source. In a study of successful technical entrepreneurial business, two major findings come out. First, of established firms, only those with strong technical resources succeeded in bringing in revolutionary process changes; those who were weak almost invariably failed. This fact speaks to the need to have a member or members of the Academy in our own organization if we are to benefit from knowledge transfers. Second, it was found that almost always transfer of technology in entrepreneurial enterprises involved the transfer of people. In the most successful businesses, the transfer involved not one person but a small group. This again speaks to the essential need to accentuate knowledge transfer by direct personal participation in acquiring and nurturing the new knowledge.

In brief, there is a guiding motto for the most effective way for the transfer of knowledge from academia: "To those who give, shall be given."

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