THE INDUSTRIALIZATION OF A GRADUATE
THE BUSINESS ARENA

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WE HIRE ENGINEERS to effect change, to make things work or work better—but it requires more than technology to be an effective engineer. It requires people skills and a "make-it-happen" mentality. I think that such skills should and can be included in the style of a technical education and that colleges which do so will be recognized by industry as producing faster-starting, more effective graduates.

Throughout my 13-year industrial experience, I found the technical training of engineering graduates to be sufficiently grounded in fundamental principles and concepts to allow the engineer to learn a specific process technology and successfully guide technical decisions. Schools teach technology well. However, humans are involved in the chemical process either as operators or as policy makers and, more often than not, a technical process change simultaneously requires a change in attitudes and perspectives. Technical change, the engineer's job, takes place within a human environment and requires an adeptness with human nature as well as with technology. Unless managers and operators accept it, a technical change will not happen: the engineer will be ineffective. The human awareness required for technical effectiveness is not, but can be, incorporated in the education experience. Because this is a time in which the market demand for new chemical engineers is low, I think that departments which develop industrial savvy in their graduates will have a competitive edge.

For the first twenty years of an individual's life, schools train him/her to be a learner and to work inde-

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pendently. By contrast, an engineer must become a doer and work within a team environment. In growing from student to engineer, an employee must internalize a new understanding of the objective and change his/her approach to the tasks. No business wants an engineer to stop with the statement, "I understand the process now," or "If only they'd accept my idea we could save . . . dollars." Business wants the engineer to "make-it-happen." Performance approaches that make a good student are not necessarily those that make an effective engineer.

By analogy to the socialization process in kindergarten, which prepares children for the teacher/student and peer social structure of school, there is an industrialization process for a new graduate. This industrialization process takes about two years, involves several aspects, and has been widely acknowledged [1-5]. With new names for the players, I will draw upon my industrial experiences to provide some examples of the industrialization process.

Although sometimes mathematical analysis is useful, in this instance I missed taking ownership of business need. I appropriated the problem in pursuit of my own personal need which, I think, was to exhibit technical competence. I would like to make two points from my story. The first is to contrast the make-it-happen motive of business in comparison to the "develop skills" motive of the classroom.

In this article I'll describe some of the characteristics of the corporate industrial arena which are both important to business and which constitute major changes from academia. In a subsequent article I'll offer teaching methods which incorporate industrial experience within formal engineering education. Such experiences can accelerate the industrialization process without displacing topics from an already overcrowded curriculum.

MAKE IT HAPPEN

In a competitive business, the fundamental reason for hiring employees is to do a job or to realize a business opportunity, and the profit motive calls for someone who can "make-it-happen." Wanted are active, goal-oriented people who take ownership (internalize responsibility) of the end result and who do whatever task is necessary to make it happen. For example, in business the end result is not an academic task, such as the calculation of an optimum reactor operating temperature; rather, it may be a reduction in operating cost that results after management agrees to a temperature change, after operators are trained in an associated new process procedure, and after a process is smoothly operating at the new temperature without unforeseen hitches (control stability, heater element life, thermal degradation, *etc*). There is an extra-technical perspective required to be effective in industry. Here is a personal example.

I enjoyed engineering math as a student and have the general view that if I can model a process, I can understand it, and I can intelligently optimize it. My confession is important: I enjoy math. In an early project of mine, we were developing a dry-spinning process to extrude a new fiber. Polymer was dissolved in a solvent, the solution was extruded through tiny holes, and as the resulting liquid streams fell, they dried. The continuous filaments of polymer were wound in a criss-cross fashion on a tube to build a wheel-like bobbin. The polymer structure within the filaments was essentially amorphous, and subsequent hot stretching oriented the polymer and strengthened the fiber. The bobbin-wound filament, however, was not totally dry; some residual solvent remained and evaporated from the bobbin surfaces as the yarn waited for subsequent stretching. The bobbin fiber did not dry uniformly. Fiber at the surface dried before the internal bobbin fiber dried; and, since it was wound in a criss-cross manner, the residual solvent level changed every six inches along the length of the continuous filament. The residual solvent acted as a plasticizer and, consequently, the post-stretching process (and resulting fiber properties) changed periodically along the fiber length. Customers don't want such variability.

I saw an application for my training. If I could model the bobbin residual solvent evaporation phenomena, I could determine the length of time one had to wait for the inside-to-surface residual solvent difference to be so low as to not create drawing differences. After several days refreshing my math, diffusion, and evaporation principles and making simplifying assumptions, I was left with one unknown parameter: an effective diffusivity of the solvent through the yarn/air matrix. I then asked the lab to do some effective diffusivity measurements, and about a week later I began to question the validity of the lab-proposed test procedure to simulate the on-bobbin mechanisms. Meanwhile, the fiber draw nonuniformity still existed. Within the business priority list, nothing has happened.

Also meanwhile, two of my co-workers, Ted and "Mr. Clean," saw that we just needed to dry the fiber completely in the first place. So they tried this and that and finally found a way to wind-up with dry yarn. Within about six days all extrusion lines had been modified, the draw uniformity was as desired, and Ted and "Mr. Clean" went out for a beer.

The business goal was to fix the draw uniformity, not to determine the required inventory time through fancy modeling. Although sometimes mathematical analysis is useful, in this instance I missed taking ownership of business need. I appropriated the problem in pursuit of my own personal need which, I think, was to exhibit technical competence.

I would like to make two points from my story. The first is to contrast the make-it-happen motive of business in comparison to the "develop skills" motive of the classroom. The second is to indicate that individual human needs can interfere with a rational view of the objective. Extremely rare is the person who is not driven by personal needs, who does not attempt to exploit situations to get promoted, to exhibit competence, to gain approval, to gain power. . . . To be maximally effective as an engineer (and as a person) one needs to recognize his/her own personal needs and

to allow their expression only when they complement the true goal.

> *Does engineering education train students to make-things-happen? Do students graduate understanding the hidden motives behind human behavior?*

CHANGE AND CREDIBILITY

On an average, during my engineering career I had a new supervisor every fifteen months and switched projects every two years. Those changes were in part due to promotions and in part due to transfers in response to business needs. I believe that such change is the rule rather than the exception, and such change has several implications for the employee—one being the engineer's credibility.

The engineer must convince management of his/her proper overall perspective, and because of the constant personnel flux, the engineer must constantly reestablish his credibility.

In order to be effective in convincing management to take a particular action, an engineer's recommendations must be considered credible within a broad interdisciplinary scope. Further, these recommendations must be consistent with the business's traditions, with national values, and with the business's long-term goal and contingency plans. The scope of topics which enters into a business decision is immense, and the required perspective is much greater than the usually myopic, one-technology experience indicated in technical courses.

The engineer must convince management of his/her proper overall perspective, and because of the constant personnel flux, the engineer must constantly reestablish his credibility. Credibility is an image. It is a belief within others that one's work can be accepted. An engineer projects credibility by presenting information from a technical and non-technical perspective which coincides with the listener's priorities and concerns.

Managers are busy people. To make an engineer's work easily accessible to them, the initial sentences of oral and written communication should incorporate the topics which are important to the manager in terms that he understands. The initial statements should also summarize non-technical issues and critique the work. I'll use Neil as an incredible example. He was as technically able and eager to produce as anyone I have seen. His reports were technically complete with assumptions acknowledged and defended and with conclusions analyzed. However, his work came from his own point of view. It did not incorporate the views of production and was not compatible with long-term business goals. It was therefore devoid of some important non-technical business issues, obviously incomplete, and required more analysis before it could add business direction. Technical correctness was his pursuit, and only after pages and pages of development were business consequences addressed (as though they were secondary issues). Neil's exclusively technical approach and the inevitable management frustration are characterized by this anecdote.

Neil and a manager were on a trip and the manager, who was driving, noticed a sign "Highway ends 2 miles." He asked Neil to look at the map and decide whether to turn left or right at the exit.

Neil observed red, blue, and black lines, towns between here and there, and mileage markers on the map. He began to organize his approach to the problem. Then he asked, "What is the most important criteria: to minimize probable time-to-destination, or probable trip-cost?"

"Neil, there's only a mile and a half left. Which is the best way?" Realizing "best" was a fuzzy word the manager asked, "How would you go?"

Wishing to offer a thorough analysis, Neil computed the mileage each way, estimated the toll cost one way, mentally juggled the time delay through a small town, but also considered the advantage of being able to buy cheaper gas in that town. Then there was the possibility of a ticket, which Neil wouldn't get if he were driving, but his manager usually speeds. . . .

"One mile left, Neil," as he eased off the gas.

Finally, Neil gave his report in the familiar technical style of title, abstract, background. . . .

"You asked me which way I'd go," Neil started; and recognizing no quick answer was coming, the manager slowed down a bit more. "The criteria which would guide my choice have been classified, and weighed against them are the possible events which might happen on either route. Additionally, my analysis indicates a third possibility."

"We've only a half mile left, Neil. Left or right?"

"Before I recommend a direction to you, you need to understand the criteria which I used and the assumptions which I made so that you can accept or reject their validity and decide on the appropriateness of the decision. As Dr. X pointed out, these criteria are subjective. For instance, if. . . ."

"NEIL!!" GIVE ME THE MAP!"

Once again, Neil is ineffective in adding direction to his company.

Let's switch Neil for Al in that trip story, and suppose that Al were working for a middle-of-the-road, striped-suit management. The closest Al will come to conforming to that management style is by pedaling his bicycle down the middle of the road with his striped racing tights.

The manager would prefer to hear something like, "Turn left. You can get there either way but the left road promises easier driving. Want more details?"

Does an engineering education teach effective interpersonal communication skills? Does it address professional credibility? Does it foster multidisciplinary thinking? Do we train people to seek and incorporate the concerns of others, or do we train them to work independently?

THE TEAM UNIFORM

Let's switch Neil for Al in that trip story, and suppose that Al were working for a middle-of-the-road, striped-suit management. The closest Al will come to conforming to that management style is by pedaling his bicycle down the middle of the road with his striped racing tights. Al says to his manager, "Turn left . . . easier driving. . . ." The manager may likely glance at Al and scowl to himself, "What's he mean by 'easier' driving? Can I trust someone whose value system and style are so obviously misplaced to guide my decisions? Can Al consider data rationally? After all, look how he wears his hair. Whatever could be guiding his choices?" Then, out loud, he might say "Yes, I want more information. What are the distances either way? Is there an interstate we can take?" Because of the personal image Al presents, and in spite of his competence and business sense, Al causes others to question the propriety of his analysis. Al's professional credibility is questioned, and he is reduced to the position of a technician. How long would you pay an engineer's salary to a technician?

Perhaps it is unfair that personal eccentricities influence our impression of professional competence. But they do. And it is a factor in having power and being effective within a human environment. To make it happen, it is important to "fit in"—to be in harmony with the organization. To be accepted as a leader, one needs to present oneself as part of the team. Although playing well is important, one must also wear the uniform.

Does an engineering education address the irrationalities of human thinking or foster personal adaptability? Does college teach the importance of community or does it reinforce individualism?

NOVICE PROFESSIONALS

Management mobility requires engineers to consciously present a credible professional image, but by contrast, project mobility keeps them in a relatively novice technical state. With moderate technical expertise in the specific technologies of a job, and with pressure to get results, it is commonplace to prematurely accept an apparently successful result.

Margaret, for example, was running a pilot-scale liquid-phase batch reactor with an objective to generate a kinetic expression for a plant reactor design. She postulated a homogeneous phase, first order in each reactant, Arrhenius form of the kinetic expression; and, with experiments which held the initial reactant concentration constant, she measured the initial reaction rate for several temperatures. Paying attention to experimental design practices recently learned in an in-house statistics course, she chose the temperatures randomly. The Arrhenius plot of the data [ln(rate) *vs* $(T)^{-1}$] was a straight line, as beautiful as any encountered in a kinetics and reactor design class, and just had to reflect her proper grasp of the technology. From the plot she got the activation energy and the pre-exponential and proudly reported the results. Her boss, a mechanical engineer, viewed the graphs, listened to her story, and was impressed with her experimental facility. Subsequent trials at a different concentration curiously gave a new slope to another beautiful Arrhenius plot. Thinking it due to uncontrolled experimental conditions, she responsibly revised her kinetic expression—by reporting average values. In her novice state, she did not recognize the possibility that surface phenomena could explain the slope differences and that her data neither confirmed nor rejected the first order assumption. Inexperience accepted a superficially "good" analysis. A year later the startup crew would wrestle for months before the reactor would be operable.

Does engineering education train people to critique their own work, or to view the fallibility of their "knowledge"? What are engineers likely to think of their own ability when they receive good grades in school?

LOCAL TECHNICAL FOLKLORE

With a primary business style of make-it-happen and move-on-to-the-next-project (the Edison approach), there is often little effort at confirming why something worked and why it didn't. Often a technical explanation is postulated tentatively, given as a possible cause, accepted as logical, and, as time proceeds, such hearsay becomes generally established in the local information data base. A tentative position is strengthened as the postulate is subsequently referenced. Technical folklore is indistinguishable from valid technology which also resides in the oral tradition of the operators and long-term plant professionals. It can misguide the work of an engineer and can be a formidable institutional mind-set to change.

As an example, years ago a polymer solution concentration limit of 20% was "established" as the maximum that would still permit extrusion stability of a fiber manufacturing plant. However, increases in concentration promised a significant operating cost reduction. Jim was one of several engineers who interpreted R&D trials to mean that the improved spinerette design and solution purity of the day would allow a concentration increase up to 30%. He knew that temperature adjustments would be necessary to maintain viscosity at the higher concentration. The risks of a plant-wide concentration change were high. Realizing that the factors which affect fiber dyeability are not well quantified, the marketing department saw the possibility of monetary claims if a change in fiber performance on some customer's obscure textile process occurred. The production department feared the havoc that an unstable plant could create. After vice-presidential discussions, it was decided to increase the concentration in 0.1% increments each week over a two-year period. To guide the temperature compensation, Jim would monitor extrusion stability and dye properties. As it happened though, after several months Jim was moved, his projects were distributed among others, and an extrusion upset occurred. Now, a ruptured filter or a crosslink event in polymerization is a normal occurrence which temporarily causes such an upset, but the cause was never identified by those left "in charge." The "too high" concentration was blamed, the plant returned to 20%, and that bit of self-proclaiming folklore was reinforced. Many people within the company now accept the 20% maximum as a given.

Does engineering education train students to unquestionably accept that which they are taught? Could it encourage students to evoke critical thinking?

WHAT WENT WRONG

When quality or productivity is upset, the plant and staff personnel mobilize to determine the cause(s) and to take corrective action. Often the cause is not obvious and, in fact, may be the interaction of several effects. Sometimes a crisis is not even real. I'm reminded of the time a flowmeter calibration error made it appear that we were leaking 200,000 lb/month of solvent. Such a mobilization you never saw when that hit the monthly production reports!

Even in research and development, where we want things to change, I was faced with "Why didn't that work?" more often than "How do I design this?" An efficient engineer can systematically rule out inconsistent hypotheses and find and fix the reason for unexpected behavior.

Does engineering education prepare graduates for systematic diagnostic thinking?

CLOSING

Initially, I stated that colleges do a good job in teaching technology. It must be obvious though, that I also think graduates are ill-prepared for some of the non-technical aspects of an engineering profession. We could easily do a better job in training students to be professionals; and, in a subsequent article, I will suggest some approaches in classroom lecture and homework style, roles of the laboratory, directions for humanity electives, and activities for student professional societies. I find the approaches fun as well as effective.

EDITOR'S NOTE: The second part of Professor Rhinehart's lecture, "Methods for Engineering Education," will appear in the next issue of CEE.

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