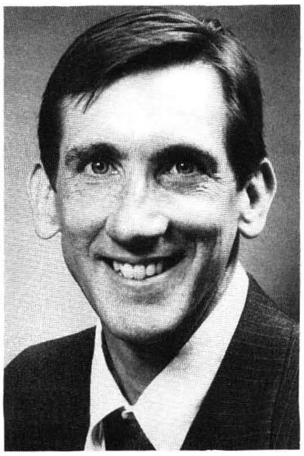
ChE lecture

THE INDUSTRIALIZATION OF A GRADUATE

METHODS FOR ENGINEERING EDUCATION

R. RUSSELL RHINEHART
Texas Tech University
Lubbock, TX 79409

THIS IS THE SECOND of two articles* on the industrialization process. In the first article the industrialization process was defined as a required change in perspective as a person moves from student to producer. This change occurs during the first two years of an employee's career and has been called "learning the ropes." In recruiting interviews, industry looks for "fast starters" who will "hit the ground running"; by these terms they mean people who have the extra-technical awareness that will make them effective within the human environment and business priorities. In the traditional academic environment a student is not exposed to industrial experiences. Instead, he is programmed narrowly and technically to work in isolation and graduates with neither a make-it-happen attitude nor an appreciation for the complexity of life. In this article, I will discuss some teaching methods which I believe can broaden student awareness of the importance of, and skills required in, effective human interactions. The methods can also bring the typical open-ended, incompletely defined industrial problem scope into the classroom and, therefore, can accelerate the industrialization process and create faster starting, more marketable graduates.



R. Russell Rhinehart is an assistant professor of chemical engineering at Texas Tech University. He received his PhD from North Carolina State University after a 13-year industrial career as an engineer and group leader which included development of reaction systems, process control, solvent recovery, and process safety and reliability. His interest in the special aspects of industrial process modeling, optimization, and control techniques led to his pursuit of an academic career.

*See *Chemical Engineering Education*, Vol. 21, No. 1, (Winter 1987), page 18.

EXTRACURRICULAR ACTIVITIES

Each year, student professional organizations and senior seminars generally invite a few engineers from industry to present an industrial technical project. A speaker's reinforcement that academic skills are used in industry can inspire students to view classes with a more serious attitude. I would suggest that such speakers have at least five years of industrial experience and that they be asked to address the non-technical aspects of industrial projects as well as the technical aspects. Further, I would suggest that technical managers be invited to discuss requirements from their perspective of personal effectiveness. Such testimony could enhance the awareness of the business world, develop a student's perceptiveness for the extra-technical demands of employment, and perhaps accelerate the industrialization process.

Student organization activities also provide an opportunity for students to make-things-happen. Student leaders plan, work through details, interface with the university, relate to people, and take ownership of the project in order to move a conceptual idea to a happening. These experiences are important to their professional preparation, and a department's efforts to support such activities should be viewed as important to their service responsibility.

Co-op and summer technical employment can be an excellent awakening for previously book-bound people, and departments should work with industry to encourage these real-life experiences. Whether the job is that of a technician, or an operator, or at an engineering assistant level, the student's experiences with real equipment, business priorities, and people can be important [1].

CLASSROOM EXPERIENCES

Classroom assignments can be modified to simulate practical experience. I make some assignments which are incompletely specified, some which require open-ended design and self-critique, some which require a discussion of aspects (such as environmental impact, safety, labor, and controllability), and some which require students to use last semester's course notes. I am honest with the students and preview these aspects in an attempt to prevent frustration. Pedagogically, I recommend an openly "tricky" approach and even give erroneous or conflicting data and require the student to be critical of his own work and of the "givens." I occasionally give the students data which incorporate nonideal conditions and ask them to postulate causes for the unexpected result and to describe experiments to discriminate the cause. (For example, contrived shell-and-tube condenser performance data could indicate that the "U_oA_o" is 40% lower than expected. Causes might include condensate puddling, fouling, or plugged tubes, and each has telltale consequences.) Analysis of industrial operations are full of assumptions, and the answer is neither unique nor known. Students should be prepared for such situations throughout their education. Open-ended problems and critical thinking should not be reserved for a brief senior design experience. Assignments with such complications, however, can only be given after the student has practiced on idealized problems and understands the technology basics.

Student feedback to such realistic "trickery" in class assignments is mixed. On the one hand, they appreciate the additional perspectives gained from such an approach; but on the other hand, they would rather have the more directed and explicit traditional homework problem—it requires less time. A student's false starts associated with incomplete or conflicting specifications, the uncertainty in completing problem specifications, the formulation and testing of postulated causes, and the consideration of auxilliary aspects do take more time. It also requires more of the teacher's time. Although modification of the textbook problems to incorporate trickery is easy, grading requires close attention to the student's often inventive approach as well as a generous amount of subjectivity. As I interpret the feedback, students especially appreciate comments on their open-ended work, such as, "Yes, with its low thermal conductivity sulfur would make a great pipe insulator. However, wouldn't a fiberglass composite be safer and easier to install?"

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Logically organized, explicitly stated technical analysis, with assumptions acknowledged and defended, and answers whose reported digits and wording reflect the limits of the analysis, are important features toward establishing technical credibility. I require such features in all assignments. With requirements on assignment structure and presentation, the student practices submitting credible work; additionally, I believe that the student's technical grasp is heightened.

R. M. Felder reports on a teaching device which he calls "The Generic Quiz." [2] We professors realize that constructing a final exam is an intensive learning process. Even in outlining the problem one reviews the technology, selects a portion, and incorporates all the necessary assumptions and restrictions into the problem statement. The problem creator must find the givens, not just accept and use them. Occasionally we express humor or relate interest stories in the problem statement. Why should the fun and learning process be reserved for the professor?

The problem statement in Felder's take-home "Generic Quiz" is essentially, "Prepare a final exam and its solution for this course." He previews for the student implicit/explicit, qualitative/quantative and derivation/application formulations. He reports his own pleasure with the results and an almost unanimous student response that the test was challenging, instructive, and enjoyable. I have used the generic homework approach: "Create and solve an original homework problem which incorporates three out of five [listed] skills." I, too, am pleased with student response and believe that the open-ended, often multidisciplinary, creative experience is good for their professional development.

LABORATORY APPROACHES

Opportunities for "trickery" naturally arise in the unit operations lab where data are already real. Fuzz and conflicts do not have to be contrived. A teacher can utilize that fact and not try to make lab data a perfect expression of the idealized classroom theory. Instead, students can be required to find sense among the statistical noise, external systematic effects, and nonidealities.

The unit operations lab also creates a special opportunity to practice the important task of communicating credibility through technical reporting. There are several classes of reports, including academic papers, oral presentations, internal business memos, and project technology summaries. Each report has its own purpose and style. The students would benefit if they were required to practice each style and understand where each would be most effective. A well written report is more credible than a poorly written one which offers the same conclusions.

Finally, the unit operations lab can be a key training ground in several other areas including the statistical treatment of real data, the student's design of the experiment, and his accountability for safety and hygiene. Robert M. Bethea and Elizabeth Orem [3] describe those various lab functions and the integration of technical and non-technical aspects at Texas Tech University. Such an integrated approach accustoms students to professional expectations.

I recommend assigning term papers in technical courses. The breadth of technology is such that only the tip of the iceberg is presented in the lecture and text. From one of twenty or thirty associated topics, small student groups can select and write a paper that could be used to teach their chosen subject.

REPORTS

I recommend assigning term papers in technical courses. The breadth of technology is such that only the tip of the iceberg is presented in the lecture and text. From one of twenty or thirty associated topics, small student groups can select and write a paper that could be used to teach their chosen subject. In such an exercise, the students would see the expanse of information and realize the limits of their own knowledge. They would practice what they will have to do to learn job-specific technology, and they would be required to communicate technology in a logical manner. I have been pleased with the results of this approach, both in my graduate education (Optimization of Engineering Processes, under R. M. Felder at North Carolina State) and in my teaching (Fluid Dynamics, at Texas Tech). Further, rising beyond a learning experience, the presentation of a polished, finished group work is a make-it-happen experience.

My industrial experience has taught me to view my final report as tentative. After being satisfied with organization, impact, and completeness, I'd give the draft to a few people in related departments along with the note, "Please review. Have I overlooked a concern that you might have?" With the frequency of project changes in a business career one is always a novice and can easily miss at least political sensitivities, if not technical aspects. Rather than training students that a report is finished when they are satisfied, I recommend grading it and then saying, "For your second grade, please explain how this impacts on . . .," and fill in some concern about safety, or equipment maintenance, or maybe plant flexibility. Or perhaps, with less structure, requiring students to seek and respond to two reviews of the draft prior to its completion. Where word processors are available to the student, report modification would be easy.

The passive academic reporting style, which emphasizes technology, considerably conflicts with the action-oriented economic-emphasis report desired by engineering supervisors. A caricaturized mind-set of management is, "What's happened?—What's it mean?—What do I have to do about it?—Move on to the next problem." Imagine, with that mind-set, the manager reading a technical report from a young engineer who was coached in the classic academic style of Title, Abstract, Introduction, Theory, . . . and finally Conclusions. Most engineering graduates have industrial careers. I believe that coaching them to write in a business/technical style as opposed to an academic/technical style will be instantly recognized and applauded by industry. Here are my ten rules, often given to new engineering employees, to aid their technical report writing:

1) Address the factors which are important to your audience (not necessarily to you), and do it in your first sentence.
2) Speak in your audience's language. Do not show off your command of jargon.
3) Still in the first sentence, address important associated issues, such as the effect on labor, the environment, startup control, plant flexibility, *etc.*
4) In that first sentence, either clearly direct an action or report on an activity.
5) In the second sentence elaborate, if necessary.
6) Still in the first paragraph, acknowledge assumptions and critique your work and recommendations.
7) Keep the first paragraph within fifty or so words.
8) In moderate detail, in subsequent paragraphs, set the background for the work, summarize the methods, *etc.*
9) For those who wish the delicious details, offer an appendix. If anyone ever reads your appendix it will be to judge your competence. Be sure that the appendix is structured so that your reader is

clearly guided through the calculational procedures. Be sure that assumptions are explicitly stated and defended. Be sure that the number of reported digits does not over or understate the justifiable precision. Be sure that your answer is labeled and contains units.

10) Before issuing your report, incorporate the comments of several reviewers.

The factors mentioned in the first rule, those which are important to a manager, are economics, or employee safety, or product quality, or system reliability or the like. If a professor invents, or allows each student to invent, a business scenario that requires the execution of some class project (a design or computer program), then the student can submit the project in the ten-rule format with an appendix containing the academic details. I believe such practice is good training for the student and require computer projects to be so reported. I am often surprised at how professional the students' reports are.

THE DIRECTION OF HUMANITIES

Students should be encouraged to take those sociology, psychology, history, and philosophy electives which give a perspective on normal adult behavior and an awareness of one's own needs. I emphasize normal adult behavior. Interpersonal relations with disparate personalities are a necessity in industry. A development engineer interacts with a maintenance foreman. A sales engineer wants the production engineer to run a trial. A young engineer wants an older manager to accept a recommendation. All players are normal adults, and the daily effectiveness of an organization depends on the effectiveness of their one-on-one interactions. Technical graduates learn to manipulate data, but they can be unaware and careless of important individual personal needs. Improved interpersonal effectiveness starts with awareness of oneself and includes recognition of other's needs. One can then temporarily adapt behavior to create an effective interaction, to establish credibility, or to make-it-happen.

PROFESSOR'S EXPERIENCE

Practicing engineers assemble technology and make something work, but they are largely taught by academic engineers who, by contrast, do science and publish elegant papers. We academics often admit our lack of industrial design experience and a weakness in providing relevant direction in the senior design course [4, 5]. But our lack of business experience is more extensive than that. One can imagine practicing engineering in the business environment, but without having lived through industrial experiences, a career academic usually cannot relate general business priorities, methods, and approaches to their students. Instead of being trained in the realities of the business environment, students are normally steered toward academic mind-sets. It is not necessary, however, for every professor to have industrial experience. In fact, I would say that it is very important for students to experience the direction, perspective, and skills of more theoretically oriented professors. However, I recommend a blend of each type on a faculty. Felder [4] mentions the benefits to the undergraduate laboratory, to the students' classroom experiences, and to department management of hiring a faculty member with no research interest but with thirty years of industrial experience. Departments which hire engineers to teach can balance the academic and practical perspectives. Grecco [5] suggests that practiced engineers can be hired as adjunct professors if not tenure-track.

CLOSING

In the first article, I described some key industry/academic differences which need to be internalized before a student becomes a fully effective engineer. This industrialization process, in which a new employee struggles to "get his feet on the ground" or to "learn the ropes," now lasts about two years. I believe, however, that a pedagogic style which incorporates industry-like experiences into the normal student assignments and activities can accelerate that process and produce "faster-starting" professionals.

I have not recommended curriculum subject revisions or additions. I claim we teach technology well. Instead, I have suggested blending make-it-happen and human awareness opportunities with the students' experiences. As a prior employer that would please me, and I would preferentially recruit from such schools.

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