This column provides examples of cases in which students have gained knowledge, insight, and experience in the practice of chemical engineering while in an industrial setting. Summer internships and co-op assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of the analytical tools used and the skills developed during the project should be emphasized. These examples should stimulate innovative approaches to bring real world tools and experiences back to campus for integration into the curriculum. Please submit manuscripts to Professor W. J. Koros, Chemical Engineering Department, University of Texas, Austin, Texas 78712.

FROM THE CLASSROOM TO THE WORKPLACE

Motivating Students to Learn in Industry

A. CHRISTIAN FRICKE
Rensselaer Polytechnic Institute • Troy, NY 12180

What makes a successful engineer? No one would deny that technical expertise is critical to mastering real-world engineering problems. Yet technical mastery is only half the battle; there are also many complex social skills that must be learned in order to make successful use of technical knowledge in a workplace setting.

The purpose of this article is twofold. First, it will note a few examples of specific nontechnical skills that can be useful in managing the day-to-day workplace realities of a BS-level engineer. These skills and strategies are taken from the author's personal experience in working as a process engineer for three years at a mid-sized manufacturing consulting firm, as well as from conversations with and observations of dozens of colleagues working in varied chemical and mechanical product design and manufacturing settings. The majority of these engineers were within six years of graduation and were in the process of learning the social skills necessary for moving up the corporate ladder from technically oriented process positions to more business-oriented managerial functions. It is hoped that these observations will prove useful to engineering professors who have not worked for an appreciable amount of time at the BS level and who therefore have experienced the industrial setting in a much different context.

Second, this article will outline several ways in which the need for acquiring these informal skills can be communicated to the vast majority of students who will end their education at the BS level. The conveyance of technical concepts, skills, and information is undoubtedly what the undergraduate experience is all about, but by suggesting some of the social contexts within which these skills will be mobilized, engineering educators can increase students' effectiveness in putting this technical material to use in the workplace.

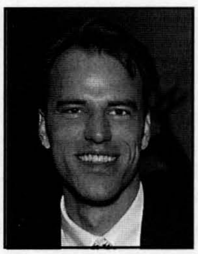
There exists a real need to alert undergraduates to the fact that excelling in the classroom, although critical, is only half the equation in preparing to be an effective professional. Otherwise naive students need to be explicitly made aware of the seemingly commonsense notion that one must indeed "learn in industry" in order to be a successful corporate engineer.

STUDENT PERCEPTIONS

This need is illustrated by a recent survey of seventy-six undergraduate engineers at Rensselaer Polytechnic Institute (RPI) in which 95% indicated they had a "very firm" or at least a "somewhat firm" idea of what the daily work experience of an average engineer is like (see Figure 1). A close look at the numbers indicates that students likely do not have the firm grasp of engineering workplace realities that they profess.

For instance, there was no correlation between students'

A. Christian Fricke *graduated from North Carolina State University with BS degrees in chemical engineering and biochemistry. He has worked in a Merck Pharmaceuticals production facility, as a research assistant in a molecular genetics laboratory, and as a process engineer for CTC, a manufacturing consulting firm with headquarters in Johnstown, Pennsylvania. He is currently a doctoral candidate in the Science and Technology Studies program at RPI.*



There exists a real need to alert undergraduates to the fact that excelling in the classroom, although critical, is only half the equation in preparing to be an effective professional. . . Success on the job . . . entails learning many complex social behaviors in addition to those necessary for classroom success. It also entails developing an entirely new perspective on what constitutes "engineering."

reported knowledge of "what it is that engineers do on a daily basis" and their personal relationships. Students who had no close relatives or acquaintances with engineering backgrounds (more than 60% of those surveyed) were just as likely to indicate a firm knowledge of daily working realities as those with engineers "in the family." In the absence of actual engineers to talk with and observe, student conceptions of "workplace realities" are vague and simplistic at best.

TABLE 1
Overall Survey Results
(76 respondents)

Response to the question:

"Do you have a firm idea of what it is that engineers do on a daily basis?"

Very Firm Idea:	30%
Somewhat Firm Idea:	65%
No Firm Idea:	5%
No Idea Whatsoever:	0%

This simplistic view can undermine an engineer's effectiveness in accomplishing personal, professional, and societal goals in the workplace. In addition, the apparently prevalent student attitude of believing they already know what professional working realities are all about can seriously limit the benefits to be gained from intern and co-op experiences. These experiences provide the ideal setting for observing the practical day-to-day social skills and strategies necessary for BS-level success. In order to realize this benefit, however, students must be *actively looking* for these potential lessons in the first place.

UNDERGRADUATE SOCIALIZATION

The majority of undergraduate students form their first concrete conception of "engineering" through survey courses and introductory seminars that are structured to help freshman and first-semester sophomore students choose a particular discipline. At RPI, for example, second-semester freshman students take a course, titled "Engineering Seminar," that is designed to "provide the student with information relative to the various engineering fields and curricular areas."[1] These types of survey courses generally focus on the end products of engineering work. In other words, they emphasize what it is that the various disciplines accomplish. They leave undergraduates with a feeling that they understand what it is that engineers do, but without an appreciation for the social realities of *how* these tasks are accomplished.

This distinction is significant. Undergraduate coursework fosters the perception that the engineering working experience is one of solving highly conceptual, well-defined, science-based problems in a largely individualized setting, with emphasis on arriving at a single, objectively "correct" solution. But the reality that working engineers encounter is one of solving highly practical, undefined, procedural-based problems in an extremely tight-knit social setting, resulting in multiple potentially "correct" solutions. In his book *Designing Engineers,*[2] Louis Bucciarelli characterizes these fundamentally social aspects of engineering design and practice in the following manner:

> *[P]articipants in design work within a rich, multidimensional environment that reaches well beyond the narrow confines of their own object worlds. A customer's needs are not given or discovered, but must be created; an operator's capabilities must be defined; building codes need interpretation; costs must be tried out; budget limits must be agreed upon. The task must be organized into subtasks; suppliers must be coaxed to commit to a price and delivery date; the dropout problem at Photoquik must be constructed. All of this is designing. In all of this, choices are being made, decisions foreshadowed, and possibilities discounted.*

In other words, working engineers must create and manage formal and informal social structures in order to generate built products.

Success on the job therefore entails learning many complex social behaviors in addition to those necessary for classroom success. It also entails developing an entirely new perspective on what constitutes "engineering." Without restructuring the entire undergraduate experience to incorporate these workplace lessons, engineering educators can nevertheless prepare students for this impending paradigm shift by at least bringing it to their attention. In addition, there are many specific exercises that can be easily incorporated into the existing undergraduate curriculum to reinforce some of the nontechnical social skills necessary for success in the corporate workplace.

WORKPLACE REALITIES

According to one early '80s study, "technical professionals typically spend over a third of their work week writing, editing, or preparing reports."[3] If you also include composing letters, proposals, drafting schedules and procedures, taking field notes, and generating other more informal modes of written communication, then "writing" easily occupies more than half of the typical engineer's work experience. Oral communication also occupies a major portion of the engineer's time. This can include time spent in meetings or on the phone with vendors or customers, time spent on the shop floor interacting with technicians and workers, etc.

Taken together, these two activities comprise by far the bulk of an engineer's work week. In the workplace setting that the vast majority of graduates will enter, typical engineers will likely use only 10% of their technical background 10% or so of the time. Of course, the specific 10% will vary widely for each individual, making technical breadth within the curriculum essential. But the fact remains that most of a working BS-level engineer's time will be spent not actively solving technical problems, but instead communicating potential technical solutions to others. Engineers' effectiveness, reputation, and career success will be based on technical expertise, yet determined by how well they manage to translate this expertise into action through mastering such nontechnical workplace skills as effective communication, organization, and persuasion.

This is, of course, not a one-way flow of information. For every memo that is written or presentation that is given, someone (presumably) reads and listens. The successful engineer also has to take in and interpret an enormous amount of written and verbal information. Organizing and making effective use of this information requires good critical reading and listening skills. Given the enormous amount of information generated in the typical corporate workplace, quickly and effectively separating the wheat from the chaff is an important skill in itself.

The vast majority of a BS engineer's time is taken up with both taking in and communicating information. Success requires possessing the "nontechnical" skills necessary to first recognize and then convince and organize others to act on information that is important.

CONVEYING WORKPLACE REALITIES

So, how can you alert engineering undergraduates to this reality? One strategy is to suggest that effective communication is an essential engineering skill—one that can be just as important as any technical ability. In the words of historian Henry Petroski,[4] "some of the most accomplished engineers of all time have paid as much attention to their words as to their numbers, to their sentences as to their equations, and to their reports as to their designs." Pointing out to students the vital importance of mastering effective writing, reading, speaking, and listening reinforces the notion of engineering practice as a social activity.

Yet there are many other "nontechnical" skills that are also important to success at the BS level. If presented to students at all, these skills are most often communicated in the most general of terms, with successful engineers described as possessing "curiosity," "perseverance," "self-confidence," "common sense," and so forth. What undergraduates need is a resource that highlights the importance of specific skills, motivated by a concrete social context and picture of the day-to-day realities of corporate engineering practice. The key is to motivate students to appreciate the complex social realities of engineering practice by giving them a tangible feel for the workplace setting that most will find themselves in.

Using Popular Culture • One resource for accomplishing this is the comic strip "Dilbert." In many respects, "Dilbert" is an entirely accurate ethnographic account of the typical BS-level engineering experience. According to one leading management consultant,[5] "It's not a comic strip, it's a documentary—it provides the best window into the reality of corporate life that I've ever seen." It therefore provides an excellent resource for undergraduates' (or anyone else, for that matter) interested in the daily interactions of practicing corporate engineers. "Dilbert" can be read as providing very specific, contextualized examples of the many workplace issues and challenges that BS-level engineers must confront and overcome in the process of applying their technical knowledge to real-world problems.

Of course, illustration does not imply prescription. "Dilbert" should certainly *not* be taken as illustrating a social ideal or model for how engineering professionals ought to navigate these issues. It can, however, offer a view of what some of these issues are and motivate students to contemplate how they would manage similar circumstances in a more constructive manner. "Dilbert" provides an alternative insider's perspective that, if presented as serious social satire and critique, can be a valuable learning tool for preparing for the reality of the engineering workplace.

Taking "Dilbert" as serious social commentary can prepare students for making the leap from viewing corporate engineering as a purely technical activity to seeing it as a technically mediated, yet essentially social, endeavor. It can also prevent the disillusionment commonly generated by the experience of realizing that daily workplace realities are quite different from naive undergraduate preconceptions.

Discussing Specific Strategies • A truly comprehensive list of specific social skills useful for managing "Dilbert"-like situations in a constructive manner would be almost infinite in length. This section merely presents five strategies that can be particularly critical to workplace success. "Newly minted" BS-level corporate engineers usually learn these strategies only after a sometimes painful and potentially damaging period of trial and error. Discussing these important nontechnical skills within the context of appropriate undergraduate coursework can benefit graduates by accelerating their on-the-job learning curve enormously.

1. *Save everything that crosses your desk.* Undergraduate education reinforces the notion that when something is "done," it's over with. With the end of each semester, textbooks are returned to the bookstore and class notes are relegated to recycled paper bins. But in the real world, projects never really come to an end. You never know when, say, a cost analysis done for a long-forgotten proposal might come in handy.

Saving old work (even draft work) can prevent future duplication of effort.

2. *Document everything in writing.* There is no such thing as an unambiguous verbal order.
3. *Learn to use a daily planner.* Some corporations provide a standard dayplanner system free of charge to technical employees, but even if their use is not officially encouraged, dayplanners are an essential tool for maintaining order in personal and project schedules (planning meetings, scheduling travel, keeping notes, maintaining contacts, etc.). Undergraduates are used to having order imposed for them—tests, project deadlines, class times, course materials, etc., are all organized in advance. This leaves novice engineers completely unprepared for the job of creating their own order from the chaos of daily events. A good dayplanner system is an indispensable tool for managing this process.
4. *Use the "plus a fifth" rule.* One of the most difficult things to learn in managing complex technical efforts is how to account for the unexpected. Even the most detailed, well-researched proposal or project plan can be subject to unanticipated delays, setbacks, cost overruns, and instances of Murphy's Law in action. Planning for the unforeseeable is a management skill that can only be learned through experience. In the meantime, beginning engineers can instead simply assume that all but the most straightforward tasks will take 20% longer and cost at least 20% more than expected. Even if nothing goes wrong, coming in significantly under budget and ahead of schedule can be much preferable to the alternative for all involved.
5. *Learn where and when to compromise.* A critical skill for managing working relationships is knowing when an issue is important enough to battle over. One engineer who is employed by a large tool and home-appliance manufacturer characterizes this as realizing that "the sun doesn't rise and set on a toaster oven." Maintaining an uncompromising stance on, say, the color of a new product can make collaboration impossible. But no compromise should ever be made on any aspect of engineering design, production, or management that infringes on the health or social welfare of others. Students should recognize that they will have to make such distinctions for themselves and that the answers will rarely be clear-cut and obvious.

Practicing Workplace Strategies in the Classroom • In addition to simply discussing the aforementioned strategies, there are also many relatively simple, straightforward teaching techniques that can be employed to help students develop positive social working skills like good communication, organization, planning, patience, etc. Once again, presenting a truly comprehensive list would be impossible—this is merely a collection of seven specific activities to illustrate the breadth of possibilities.

1. *Performing peer evaluations for student oral presentations.* Having undergraduates evaluate one another's presentations in a structured manner would focus listening skills and give students practice in recognizing key points, initiating critical discussion, etc.
2. *Practicing giving oral and written equipment operation and sampling procedure directions.* Unit-op labs provide a plethora of opportunities for sharpening interpersonal communication skills. For example, students could actively direct and observe each other rather than passively following TA instructions. Also, students could be required to generate written operation and sampling procedures for subsequent lab groups to follow. These experiences would highlight the importance of precision and clarity in giving both written and verbal direction.
3. *Swapping notes for lab reports.* Another potential unit-ops exercise would be to require groups to exchange notes and generate reports based on each other's data. This would highlight the importance of preserving data and other information for unexpected future uses while also stressing the necessity of precision and clarity in all forms of engineering communication.
4. *Writing and presenting standard business communications.* Practice in writing and speaking can be combined with aiding students in their job search. First, students could be asked to research and produce a short report and presentation on a particular industry or market. Then students could generate a resume and letter of application to an appropriate company based on their research. This would give students practice in evaluating what is important to individuals working within other organizations, while at the same time reinforcing proper business communications etiquette, sharpening business research skills, etc. Students could also gain valuable experience from attending departmental seminars and producing short memos or similar communications detailing key information presented, summarizing discussions, etc.
5. *Producing detailed project plans.* Senior design courses also provide a wealth of opportunities for practicing nontechnical, "real-world," social and organizational skills. For example, students could be required to generate detailed project proposals outlining specifically what is to be done and how it will be accomplished, complete with a breakdown of activities, timelines for completion, etc. This would give students experience in organizing work and delegating responsibility in a formal and considered fashion. Coupling this activity with a proposal

presentation would also give students practice in clearly articulating and advocating a proposed course of action. Also, requiring periodic project updates would prompt students to manage delays and setbacks in an organized fashion.

6. *Dealing with vendors.* Another good senior design experience would be to ask students not just to model a process, but to also locate, spec out, and price the specific equipment necessary to make the process run. This could be done by simply giving students access to a Thomas Register (now available on the Internet) and a telephone. This would expose students to the realities of uncertainty and would likely require management of time and (imaginary) cost overruns.

7. *Rotating group members and responsibilities.* Performing well on corporate-engineering project teams means responding constructively to change. This can be simulated in the classroom by requiring students to periodically reshuffle project, lab, and homework groups. Similarly, specific roles such as coordinator, note taker, etc., can be rotated within groups. Having to constantly fill new roles and interact with different individuals would sharpen both leadership and collaborative, cooperative interpersonal skills.

In general, implementing these activities would require some extra TA work and additional time spent in providing more qualitative feedback on assignments. But all of these suggestions can be incorporated into existing coursework with a minimum of curricular disruption.

Outlining the Positive "Qualities of Success" • Finally, simply presenting a few specific contexts of engineering practice can also motivate students to begin thinking about the contrasts between their undergraduate educational experience and their impending BS-level working reality. For example, successful engineers (whether employed in sales, processing, design, management, or any other capacity) are often called upon to

- **Recognize problems that aren't apparent**
  (For example, being able to walk through a production floor and see opportunities for cost-savings, or recognize subtle ethical questions that others overlook.)
- **Define problems that are nebulous**
  (Problems in the real world rarely come numbered for easy reference.)
- **Choose solutions that are realistic**
  (A skill that doesn't necessarily mean limiting the range of possible solutions—often the most successful engineers are ones who recognize the practical possibilities of seemingly impractical approaches.)
- **Plan how to make solutions work**
  (A process that includes marshalling resources, motivating others, keeping people on task, recognizing potential pitfalls, and a complex combination of many other discrete social skills.)
- **Convince others to follow**
  (This involves recognizing that the importance and urgency of a "problem" and the feasibility of a "solution" are directly proportional to the skill and clarity with which they are presented and defined.)
- **Cooperate in dealing with contingencies**
  (This involves realizing that exercising patience and understanding with one's group members generates the cooperative solidarity necessary for overcoming crises.)

Undergraduates should view themselves as continually striving to meet this positive ideal through the constant acquisition of constructive practical social skills.

CONCLUSION

In summary, undergraduate engineering students likely confuse familiarity with what engineers produce with what professional engineers actually do on a daily basis. This confusion is reinforced through introductory engineering survey courses and an overall curriculum that emphasizes the built products and technical aspects of engineering over the social processes through which these products are generated. Although students are given an opportunity for direct exposure to engineering workplace realities through intern and co-op experiences, the aforementioned preconceptions are counterproductive to using these experiences in the context of developing genuine, conscious insight into the essential social aspects of engineering practice.

Engineering educators would benefit students by simply alerting them to the fact that the creative, challenging process of learning to "do" engineering will not end, but only begins, at graduation. Likewise, undergraduates would benefit from being presented with contextualized examples of the daily workplace realities of corporate engineering life. Taking a few moments to illustrate the social side of engineering practice, along with devoting some curricular effort to reinforcing these aspects of engineering work, would help motivate students to think about their professional futures in concrete terms and provide undergraduates with a constructive context for developing positive professional social skills. In the end, this would result in more reflexive, more effective engineering professionals.

REFERENCES

1. "Engineering Seminar," *Rensselaer Catalog 1996-97,* RPI Publications, Troy, NY, 317 (1996)
2. Bucciarelli, Louis L., *Designing Engineers,* MIT University Press, Cambridge, MA, 149 (1994)
3. Lampe, D.R., "Engineers' Invisible Activity: Writing," *Technology Rev.,* **73,** April (1983)
4. Petroski, H., "Engineers as Writers," *Amer. Scientist,* **423,** September-October (1993)
5. Levy, S., "Dilbert's World," *Newsweek,* **53,** August 12 (1996) ❐