ChE *learning in industry*

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, Georgia Institute of Technology, Atlanta, GA 30332-0100.

RETURNING AS A PROFESSOR

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Chemical engineering departments should stay in contact with industry so their students can be taught material that is useful after graduation and so research will be relevant to the needs of industry. Unfortunately, very few of the professors being hired from graduate schools or after post-doctoral experiences have significant industrial experience. In this article we will discuss one way to maintain this contact—by bringing back experienced engineers from industry as post-early retirement Industrial Professors or Engineers in Residence. These individuals should be integrated into all aspects of teaching and research within the department. This article is based on the experiences of one of the authors (GB) who joined the School of Chemical Engineering at Purdue University during the spring semester of 1998 and who has served in the Industrial Professor role since that time. The results are generalized for other "wannabe professors" from industry who are contemplating a career shift, as well as other chemical engineering departments considering initiating such an infusion of industrial talent.

MOTIVATION, OR THE ADVANTAGES FOR THE INDUSTRIAL GUY

Dr. Gary Blau had a successful industrial career with the Dow Chemical Company, primarily on the technical ladder. A Canadian, Gary graduated in 1964 from the University of Waterloo with a BASc in chemical engineering and went on to get his PhD at Stanford University in 1968. He then went to work with Dow Chemical. In 1991, he accepted an offer to work with DowElanco (now DowAgrociences), a joint venture between the agrochemical business interests of Dow Chemical and Eli Lilly.

At DowElanco, his final assignment was leading a group of six engineers in the development and application of mathematical modeling tools to optimize work processes within the company. He remained professionally active by writing over fifty journal articles, coauthoring a book on mathematical modeling, editing another on *Environmental Exposure to Chemicals*, organizing meetings, and serving in various leadership roles in the Computing and Systems Technology (CAST) division of AIChE. In 1998 he won the Computing Practice Award from AIChE.

Why, then, did a highly successful, mid-career engineer decide to take early retirement for a lower-paying, temporary position? The answer embraces timing, location, opportunity to develop a business, fulfillment of a dream, and idealism. Gary's sponsor had just retired, and the resultant lack of management support made fighting for proper recognition for his group increasingly stressful. In other words, the job was not much fun any more. After thirty years of experience, he was eligible for early retirement—so he began to look for new challenges.

Gary, like many PhD engineers in industry, was a "closet academic." Going to academe would fulfill the academic dream that all Stanford graduate students harbor. A model for this ambition was Dr. Park M. Reilly, who had worked in

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His primary motivation, however, was his desire to be the faculty "industrial guy" and to share his real-world experiences with future engineers. He felt he could prepare the chemical engineering students for what industry is really like.

industry for 25 years before pursuing a successful academic career at Waterloo. Gary also had a desire to do independent consulting in the modeling area, but his networks and paper trail were too thin to support this activity.

His primary motivation, however, was his desire to be the faculty "industrial guy" and to share his real-world experiences with future engineers. He felt he could prepare the chemical engineering students for what industry is really like. He planned to develop "ill-defined, open-ended" problems and to teach the students how to use their engineering skills to solve them. He would train them in the proper use of statistical modeling, quality control, and risk management techniques so they could have an immediate impact in industry. He would show by examples and "war stories" that "soft skills" are really important in industry. Since Gary had developed and taught process optimization short courses to literally hundreds of Dow engineers and chemists around the globe, he felt his teaching skills were sufficiently honed to motivate students.

BECOMING AN INDUSTRIAL PROFESSOR

While at Dow Agrociences, Gary became involved in supply-chain optimization issues, resulting in joint research collaboration with Professor Joe Pekny at Purdue. Gary helped support some of Joe's research, worked with him on organizing the Foundations in Computer-Aided Process Operations conference, and presented some lectures. He also knew Professors Rex Reklaitis and Nick Delgass (Head and Associate Head of Chemical Engineering, respectively) from their days as graduate students at Stanford. Since Purdue was a short 50-minute commute on the interstate, Gary decided to accept Rex's offer to be a Visiting Industrial Professor.

The courses Gary would teach and his time commitment to Purdue were finalized during initial discussion with Rex. Gary felt that 2/3 time during the academic year, with summers off, would provide time for him to pursue both consulting and leisure activities. He identified a required core course he was well-qualified to teach and a new elective course he would like to develop. He would also become involved in the systems research program and help jointly direct the research program of some of Joe Pekny's graduate students.

Once a mutually agreeable salary was determined, Gary became a Purdue professor. Since tenure was not an important consideration, the position was not on the tenure track—making it easier for the university to develop the position.

The process by which the new industrial professor and the institution found each other is probably transferable, so a list of the steps that took place is appropriate. First, the potential professor should generate a record of accomplishment in industry that is respected by the academic community. If research is to be part of the academic position, this industrial record must include an adequate publication record. There should be personal contact (networking) with some of the professors in the department. The applicant should become involved with the research program—sponsoring research is particularly helpful. He/she needs to give some lectures to undergraduate classes and, if appropriate, to the graduate research seminar.

After determining core undergraduate courses and one or more electives that he/she is qualified for and wants to teach, the applicant can make a proposal to the department head concerning time commitment, course assignments, research involvement, salary, etc. Since the question of tenure can be a major stumbling block, formal ties are easier to forge if a yearly contract is acceptable.

Of course, "making it happen" is not the sole responsibility of the industrial practitioner. The academic institution can also be proactive by identifying individuals who might be good candidates for the industrial professor program. A departmental representative can talk with the prospect about the program and determine if there is any interest.

EXPECTATIONS VERSUS REALITY

Like many other senior engineers, Gary frequently taught short courses, and since there had never been complaints, he believed he was prepared for teaching in a university. Although he hadn't graded in these short courses, he expected that the grading scheme would be unchanged from what he had observed as a student or that he would be given clear instructions on how to grade. He expected the students would be courteous and neatly groomed. After all, he reasoned, they were in school because they wanted to learn and thus should be highly motivated to learn from someone who could show them the value of their education.

Gary assumed that the students would have the same strong technical background in mathematics and science as he and his classmates had thirty-five years ago. He expected to share his knowledge and thus prepare the students for careers in industry. He looked forward to building personal relationships with some of the students, and he viewed teaching as the most important role he would fill, with research being a secondary consideration. Since he was experienced, teaching just one class (even if it was a large class) three times a week would be a "piece of cake," allowing him plenty of

time for other pursuits. Finally, it never occurred to him that the students might challenge him.

Those were the expectations. The reality had a different face. A book by Peter Sacks[1] gives an accurate portrayal of the trials of returning from the working world to become a professor, and although he had read Sacks' book, Gary thought that engineering students would be different. That did not turn out to be true. Unfortunately, many students believe that if they do poorly, it's the professor's fault, not theirs. As a new professor, Gary unwittingly played into this rationalization for poor performance by giving tests that were difficult and too long. With test averages in the 30s and 40s, the students blamed Gary for their lack of preparation.

Gary also learned that many students seemed to be more interested in the final course grade than they were in learning the material. Since grading procedures were never well defined for him, he tried to enforce what he thought were reasonable grading standards, but some students argued constantly with him in an effort to raise their grades.

Teaching evaluations were a new concept for Gary since they had not been in use when he was a student, and he found that some students used them to "dump" on a professor. He worried that firm grading would be penalized when students filled out the mandatory teaching evaluations. Also, being connected on-line to the class allowed students to provide immediate, often unflattering, feedback on Gary's classroom performance. Because of his position in industry, Gary had always been insulated from direct criticism from subordinates, and he found the harsh criticism from 19- and 20-year-olds hard to accept.

Gary found that today's students are different from those of thirty-five years ago in other ways. For one thing, they wanted to be entertained. Fortunately, he found that his experience was useful in this regard since the students enjoyed listening to his industrial stories. He also found that the students' work ethic was low and that they were less comfortable with ambiguity. When he introduced his industrially inspired "open-ended, ill-defined" problems, many students were frustrated with them, wanting instead problems that were crystal clear and did not require assumptions.

Talking during class was also rampant and required special control techniques that had been unnecessary in his small classes in industry. To his surprise, some students were actually rude and disrespectful. Some staff members also let Gary know that as a visiting professor, he was at the bottom of the heap.

Gary found that teaching was much more difficult in academe than in industry and that it was difficult to learn everyone's name, let alone build a personal relationship with them. Students in industry were more polite, more motivated, and better prepared—they *wanted* to be in the educational session, and any errors in presentation were quietly corrected. But at the university the students were vocal about errors and were unwilling to think their way through a derivation and develop all the details by themselves.

While students in industry never complained about too much material (apparently they sorted out for themselves what was useful and what wasn't), university students were overwhelmed by the amount of material, and trying to introduce new methods such as new software only made matters worse. The resistance to change was much greater at the university than it was in industry.

Testing was a challenge that had never arisen in industry. Some students would become angry if they were unable to finish a test, so creating one that was not too long became an enormous challenge. Gary found that students often seemed incapable of doing very simple problems, particularly if there were multiple steps. Grading the exams took much more time than he had anticipated, and Gary soon came to see the beauty of short-answer problems. Student cheating led to Gary's general distrust of students, and he learned to place students in alternate seats and to roam the classroom during exams.

Gary also found that teaching was more time consuming than he expected. For the initial course offering, each 50-minute lecture took over four hours to prepare, and the second offering took almost as long because of the many revisions that had to be made. An unexpected responsibility was supervising two graduate TAs and eight undergraduate TAs—Gary felt that he had traded six highly motivated self-starters in industry for ten students who were just "doing a job" for the money.

Since it was essential to be present for every class, teaching meant a much less flexible schedule than Gary had had in industry. It came as a surprise that in some ways, time pressures were greater in academe than they had been in industry.

Finally, Gary found that at a research university, teaching was not the top priority. It had to be adequate, but research (specifically, research funding) was most important. Most professors wanted to talk about research, not teaching.

LEARNING TO SURVIVE

The most important step to surviving is adaptation: reflecting on what happens, sorting through the criticism, talking to students and professors alike, revising, and doing it again. Talking to students revealed that their pressures are much different than they used to be—they are busier and many of them work part-time. Fewer have strong backgrounds in mathematics, chemistry, physics, or other areas of engineering, and fewer still are dedicated to becoming chemical engineers. In talking to the students and professors, Gary also found that he had not been singled out as a new professor for criticism—it was more of an equal-opportunity endeavor, and more important, there were methods to prevent it. There were also approaches that would improve the course while at the same time reduce the time required to conduct it.

Initially, Gary's self-confidence was so badly shaken that he asked the associate head to team him with one of the more successful teachers in the department. Although this presented a scheduling nightmare, Gary was allowed to share his teaching responsibilities with Joe Pekny, a younger but more experienced professor. Gary was a good student and absorbed the lessons rapidly.

Discussions with students and experienced professors convinced Gary that a course outline with firm dates for exams and major assignments was absolutely necessary since students could not adjust their complicated schedules to accommodate last-minute changes. He was also advised to reduce the amount of material covered, which was easy initially but proved to be more difficult as additional cuts were needed. The process is ongoing.

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Gary tried several presentation styles. Students complained that his handwriting was unreadable, so he tried class notes—but in addition to the construction being time consuming, they were boring and students either did not attend or went to sleep. He then tried notes with spaces for one-word answers, but the students viewed those as childish. He found that notes with large spaces for examples or derivations worked best, and they were easy to construct. He already had complete notes for lectures and created student notes by simply removing parts from them. This procedure allowed for more time for questions and stories, kept the students interested, and reduced the number of board errors.

As he became more experienced, Gary was able to write exams and projects that would challenge, but not overwhelm, the students. He scheduled exams at times that gave the students extra time, and he learned to recognize those problems that would be difficult to grade and used them only when it was educationally necessary. With more time available to him, Gary was able to get to know the TAs and the students better and found they were more like the students he remembered than he initially thought.

By taking a section of the computer laboratory in the statistics class, Gary learned what was giving the students trouble and was able to improve descriptions for the laboratory exercises. He also got to know the students in this small section very well and was able to recruit competent undergraduate TAs for the next offering of the course.

Today, Gary is teaching a large sophomore-junior class by himself, along with his cadre of selected graduate and undergraduate TAs. Although his grade distribution has not changed, his teaching evaluations have risen significantly and he has been able to put to rest his worry that firm grading would by punished by low evaluations. Both he and the students now agree that it is fun to go to class.

Gary has learned to be an "edutainer," and the students are fascinated by the "war stories" he has built into his projects and exams. Since he better understands the pressures facing students, he is now better able to counsel them and give advice. Many of them realize that a letter of recommendation from someone with thirty years of industrial experience is an advantage and they make the effort to establish the one-on-one relationship Gary was looking for in the beginning. Although the large undergraduate course was Gary's major challenge, he built such enthusiasm for his Risk Management elective course that enrollment had to be capped.

THE RESEARCH COMPONENT

Gary's transition to the research environment was smoother than it was to the teaching component of his new career, although expectations and reality were, again, frequently in conflict. Professors were always willing to talk about their research interests provided Gary could track them down, but they were not actively looking for an "industrial perspective." Gary soon learned that researchers were driven by the primeval need for survival—they needed funding for everything: graduate students, laboratory facilities, computers, release time, telephones, and even copying services. They needed to write proposals, give presentations, serve on committees, teach courses, supervise graduate students, etc. If they were successful, upper-level management in the university often rewarded them with administrative responsibilities.

Gary had no desire to compete in this environment. He simply wanted to work with some of the graduate students to pursue some ideas he felt compelled to develop. Professor Joe Pekny helped by involving Gary with his research group. In addition, he managed to bring in sufficient annual funding for a graduate student or two. This was ideal. He could conduct research, which resulted in publications and presentations while providing the necessary new material for his upper-level course in risk management. He also accepted a position as director for an industrial consortium that would channel funding into the department's systems research efforts.

Gary developed an increasing appreciation for the stimulating nature of the academic environment. Working with professors from other universities and engineers from industry was stimulating, and he was able to develop lasting relationships with some of the students (easier with graduate students, however, than with undergraduates).

Gary had success in bringing an industrial perspective to the department and found it extremely rewarding to see former students who said they used his "stuff" in their jobs and found it valuable. Also, having the summer off for consulting and/or "down time" at the lake has been a bonus no industry is willing or able to match.

The challenges of academe are such that Gary, who was slightly bored in industry, now looks forward to every day. He has found that doing research and working with graduate students is exciting and has led to even more ideas for research. Since there is no textbook for the graduate-level course on risk analysis, Gary would like to write one...and there is always the challenge of getting everything right in teaching an undergraduate class!

IMPROVING THE PROCESS

There are a number of advantages for both the department and the students in having industrial professors on staff. For one thing, it is useful to maintain contact with industry to ensure that curriculum content is relevant. Other professional schools, such as medical and law schools, regularly have practitioners teach, and engineering colleges could benefit by following that lead and developing positions for professors with industrial experience. Industrial professors can help with the teaching load, particularly in design classes (although this was not the case with Gary). They tend to be more committed to teaching[2] and are more likely to assign open-ended problems and projects that include teamwork and writing. Their presence can also help the department prepare students for industrial careers and thus satisfy ABET criterion 4. Professors who had active industrial research programs and contacts can help the department bring in more research contracts and ensure that the research is relevant.

The process can be improved, however. First, a critical mass of professors with extensive industrial experience is needed. One on staff is not enough—it is more appropriate if 20-30% of the faculty has extensive industrial experience.

Although tenure is probably not an issue for most returnees, planning for the next year is. A rolling contract that would allow the visiting professor to know at least a semester in advance whether or not he/she would still have a job would be helpful. (Although Gary's position was originally viewed as a visiting position, the "visit" is now in its fifth year.) A title that implies a longer-term commitment (but without tenure) would be appropriate. In addition, a formal program would ease the red tape involved when the next engineer-in-residence is hired.

The department should ease the teaching transition of industrial professors and realize that they need to be taught how to teach—that they *want* to be taught how to teach. If there are no local workshops on teaching, the returnee should be encouraged to go to a national workshop such as the ASEE NETI (National Effective Teaching Workshop) at the annual meeting of ASEE. The department should provide a teaching mentor to discuss teaching with the returnee on a regular basis where both general pedagogical principles and the university's specific rules can be explored. This mentor should invite the returnee to visit his/her classes and volunteer to visit the new professor's classes. The mentor can be particularly helpful with grading and can provide resources such as a guide to teaching at that particular university. The returnee should be made aware of pedagogical journals such as *Chemical Engineering Education,* ASEE *PRISM,* the *Journal of Engineering Education* and appropriate books such as *Teaching Engineering* (available free at https://Engineering.Purdue. edu/ChE/Newsand_Events/publications/teaching _engineering).

These suggestions are also true for new assistant professors, most of whom want or are at least willing to be taught how to teach. Such teaching resources should also be made available to the experienced professors in the department who may want to "tune up" their teaching or learn some new tricks.

If the industrial professor is to be involved in research, the department should ease that transition. The returnee will usually be experienced in research, but the differences between academic and industrial approaches to research are likely to be surprising. Providing a research mentor who is in the same research area, but who is not the same person as the teaching mentor, is advisable. The mentor should carefully explain the need, and the mechanisms, for funding.

The returnee should collaborate with experienced professors on research and on proposals and should be encouraged to write proposals on his/her own—but the research mentor should review the proposal before it is sent out. The mentor should discuss the role of graduate students and undergraduates in research. The returnee should be told of the resources available at the university and of the formal and informal procedures for sharing those resources.

The department should prepare its faculty and staff for the arrival of the new professor, and the faculty should agree beforehand that hiring an industrial professor is a good idea. If the professors treat the individual with respect, the staff will also. The returnee's office should be ready from the start and should be equivalent to the offices of other professors—"ready" means the office is clean, has furniture, the computer is hooked up to the network, the telephone is working, the nametag is on the door, secretarial assignments have been made, etc. Every new professor, whether industrial or not, should be introduced to everyone else in the department and should be invited to faculty meetings and other gatherings.

All new faculty, not just those from industry, can benefit from formal courses or workshops on pedagogy and from informal discussions with experienced teachers. They need mentoring in both research and teaching. Also, some industrial perspectives could be useful for universities—resource planning, for one, is a major push in industry but does not receive the same effort in academe. Risk analysis has proved

valuable in industry and could be useful in academe (*e.g.*, which centers should the university compete for?). Asking questions is valuable—how long do professors need for different tasks, what can be done to improve the process, if students aren't the customers, who is, etc. Industrial faculty members can help ask the questions and help search for answers.

SUMMARY

Many chemical engineering departments have been criticized for a lack of industrial experience in their faculty. One approach to partially solving this problem is to hire early retirees from industry. As shown by the experiences related in this paper, these returning professors will probably experience some degree of cultural shock. Their transition to becoming productive contributors can be eased by providing both formal training in teaching and informal mentoring.

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Process Control Laboratory Experience

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student provided written comments about the text and that no student provided written comments about the laboratory experience over the four-year period. Because there are no formal course evaluations for laboratory courses, student response data from the second-semester junior laboratory course concerning the laboratory course and this experiment is not available. Qualitative assessment of this experience based on comments received from the students during and after the experiment indicate that this experience has been generally well received by the students.

CONCLUSIONS

An introductory laboratory experience in process dynamics and control that is conducted concurrently with the process simulation and control course at Villanova University has been presented here. The experience is intended to reinforce the introductory concepts of dynamic simulation and feedback control presented in the classroom by using a simple liquid-level process. Based on quantitative and qualitative student responses in the laboratory and process simulation and control courses, the students found the experience a valuable addition to their process simulation and control education.

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