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.

COOPERATIVE EDUCATION

A Key Link Between Industry and Engineers in the Making

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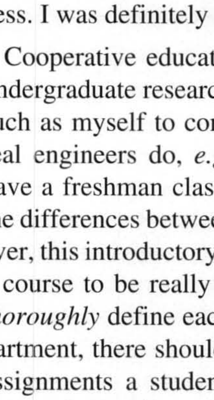
A complex metamorphosis must take place before an engineering student understands what it really means to be an engineer. Like most processes, there are many paths to achieving the desired final result. This article considers not only my actual experiences in that respect, but also reflects on my discussions with many peers over the years—so it is more than just a memoir of my passage along this path to understanding.

In high school, the process toward understanding often begins upon learning that mathematics and science are tools of a mysterious profession called "engineering." It is not unusual to find that when some of the "smart" people in the graduating class announce their plans to pursue that profession, other students will often find themselves pulled in the same direction. In my case, by the beginning of my senior year in high school I had decided that engineering was the path I wanted to follow. Despite this early decision, when I entered college I still had only the slightest idea of what an engineer's real role in society was or what the typical day-to-day duties of an engineer really were.

The second stage of metamorphosis occurs in the first engineering class when one is challenged to "think like an engineer." At this juncture, the class divides into two types of students. Type I students are extremely intuitive and seem to be able to see processes in their minds without ever having been in a plant, while Type II students can do the math and have intuitive skills, but can't visualize the process. I was definitely a Type II student.

Cooperative education, summer internships, or part-time undergraduate research can eventually help Type II students such as myself to connect what we study to what it is that real engineers do, *e.g.*, solve problems. Most universities have a freshman class that considers and explains some of the differences between engineering fields. In my case, however, this introductory course was extremely vague. For such a course to be really useful to the student, I feel it should *thoroughly* define each engineering discipline. For each department, there should be specific examples of the types of assignments a student might expect. Tours of companies employing various types of engineers could be included to allow students to see where they might expect to work after



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graduation, and a chance to hear an engineer from each environment explain what he or she does would be extremely useful students by helping them make informed decisions about the course of study to follow. The co-op experience naturally incorporates such opportunities for those students, like myself, who participate. Practically speaking, however, I believe co-op opportunities come too late to be useful to many of the Type II students who have become disenchanted in the first three semesters on campus.

Stopgap measures incorporating some of the most desirable components noted above are needed in order to reduce the loss of students experienced as a result of the nonspecific introductory courses offered at the beginning of their educational experience. A good beginning would be to simply show the students pictures of equipment that engineers use in each of the disciplines. For example, chemical engineering students could be shown pictures of separation equipment, computer control equipment, and microelectronic and bio-processing equipment. This would help provide students with a visual idea of the huge range of opportunities available in the field. Also, at least one field trip, complemented by on-campus presentations by articulate practicing engineers, could and should be included in such a course.

Despite this early decision [to go into engineering], when I entered college I still had only the slightest idea of what an engineer's real role in society was or what the typical day-to-day duties of an engineer really were.

A key common element in all these options is the opportunity for a student to see, firsthand, the exciting impact an engineer can have in the workplace. The co-op option appears to be the most practical approach for most students. This conclusion is based on the reality of operation in the time-constrained environments present in companies and universities. The companies that have committed to a bona fide co-op program understand its value as a screening and recruiting tool and are willing to invest in it. Such companies actually have a framework in place to support the program.

For any off-campus opportunity, knowing the answers to the following questions will help students know what to expect and how to prepare for their work assignments:

- *Is the potential assignment part of an on-going established program in the company, or will you be the guinea pig?*
- *Has there ever been a co-op before in the area of the company where you will be working—can you contact prior participants?*
- *Does the company have a year round co-op program, so you aren't disadvantaged in access to class sequences needed for your graduation?*
- *Will you be paired with an actual mentor?*
- *Are there housing accommodations? If the company reserves apartments for co-ops/interns, are they furnished?*
- *How will your salary typically change as you complete rotations?*
- *Do you get vacation days?*

Some of the questions may sound inconsequential, but they aren't. Shuffling back and forth from campus to plant to campus without breaks gives students very little time to digest their experiences. Fitting into an existing optimized structure designed to accommodate students is a huge advantage in terms of the ultimate benefits to participants.

Maintaining such a framework is a significant contribution made by companies that are truly committed to co-op programs. Frameworks for moving and housing, as well as for other placement issues, is less common in so-called internships, since they are typically discontinuous and are centered around the summer months. Moreover, comments by internship participants suggest that such assignments often involve more ad hoc "mentor" relationships, as compared to co-op assignments.

The third option, undergraduate research, is another area of opportunity I have had experience with, and I will consider its benefits after focusing on the off-campus co-op benefits. While undergraduate research is highly desirable, the time commitment involved in trying to accommodate all undergraduates on campus via this route seems to be unreasonable in typical educational institutions.

As noted above, co-op assignments are quite effective because they give students an empowering insight into what can ultimately be done with their degrees. Such insight can give students the momentum to overcome hurdles along the way to acquiring their degree and can ultimately increase the number of students who actually graduate.

Co-op work can also have second-order advantages. In my case, it forced me to leave the safe surroundings of familiar people and places. It put me into a new state, into a new home, and into a completely different environment. Without a doubt, pursuing a co-op job at Eastman Chemical Company in Kingsport, Tennessee, was one of the best decisions I had ever made. I had always lived in the Raleigh-Durham area, and moving to another state to work was an unsettling decision, to say the least. I was five hours from home when I drove by Eastman, or the "Big E," on the way to my first apartment, and my mouth hung open the entire time as I drove past the plant. I had never seen such a plant before—the Kingsport Division is one of the largest chemical plants in the US. I remember thinking as I drove past it, "I have just made the biggest mistake of my life!!!" I simply wasn't prepared for the smells of a chemical plant, the sight of the looming distillation columns, the reactors, and what seemed to be smoke (actually steam) swirling in the air.

To be honest, at the time I didn't know what a distillation column or a reactor looked like. The boxes that I had drawn on engineering paper to represent such equipment in no way approximated the sights, sounds, and smells of an actual plant. I often think of how disconcerting it would have been if I had never worked on a co-op job, and if the first time I saw a chemical plant was after graduating as a BS engineer. Even if introductory classes had included pictures of a distillation column, I believe a Type II student such as myself would be unprepared for what it is really like to see one in a plant. In any case, however, it would have been more reassuring to at least *know* what I was looking at.

During my first co-op rotation, I worked with a separations group on a high-priority adsorption project for feed purification. Sometimes, I would work from 7 a.m. to 11 p.m. to meet our project objectives, but in spite of the long hours, it was exciting and challenging to be working on a real problem. For my second term, I worked in Cellulose Esters doing compressibility and percent solids analysis, and for my third rotation, I worked on optimizing the sludge system for the polymer division, working with several crews of operators. The reason for describing my co-op experience here is to show that no college course could possibly simulate what it is like to work with other operators, to actually be in a plant, or to work on a truly stressful project where the results mattered. It is a far different experience from just working for a grade!

Contact is made with students from many different schools during one's work cycles, and based on conversations with these peers over the years, I have reached a number of conclusions about the strengths and weaknesses of educating chemical engineers. The following paragraphs elucidate a few of my thoughts about steps that could be taken that would greatly enhance the educational experience of students.

After students select an engineering specialty, regardless of whether or not they know what they are getting into, more practical applications should be included to complement the theoretical backgrounds they receive in the classroom. While in some cases, such practical teaching may not be economically possible, more can usually be done and it can be done much earlier.

Specifically, simple qualitative experimental illustrations would be useful, even when the students don't completely understand every detail and equation needed to describe the situation. For instance, seeing a distillation column concentrate a dye from a feed stream is impressive and offers motivation to learn why it works; seeing a microelectronic part made or a bio reactor work can inspire the student to learn more about complex reactions and mass transfer phenomena. Connecting these exciting processes to the need to learn about chemical engineering fundamentals can make the student want to learn about these subjects. It seems to me that there is no real reason why some of these practical motivational aspects cannot be integrated more effectively into our formal education.

I know that senior-level engineering courses demonstrate some of these practical applications. In my senior design class, we were assigned to work in groups of 3-4 and were given a chemical to produce. Our assignment was to research the chemical in patents and textbooks and even to contact companies to develop a process for making the chemical. While designing the process, we had to perform energy and mass balances to track our components in producing the desired product at the necessary rate. We also had labs where we had hands-on experience with reactors, distillation columns, heat exchangers, etc. The point is that students would benefit more from some type of practical-application exposure throughout their education, rather than packing it all in at the end of their schooling. Even short demonstrations and group projects, when done earlier in the curriculum, would be more satisfying and valuable.

Can something be learned and transported back to campus from industrial, co-op, and intern experiences to enrich the learning experience of all students—even those who never leave campus? I believe so—especially in the area of computer skills and the need to better integrate their development throughout the curriculum, principally through the use of homework assignments.

There are at least four computer programs that are essential for a practicing chemical engineer to be familiar with: Excel, Aspen, PowerPoint, and Word. Most employers, even those found in co-op jobs, expect an employee to be competent with Excel. It seems to me that skills taught on campus in the use of these software programs should lead, rather than lag behind, those that are demanded in an industrial setting. This is often not the case, however.

Throughout their campus careers, students should build steadily on the sophisticated application of tools such as Excel. A good practice to follow is to teach the use of Visual Basic programming—that skill can then be used with Excel in later courses after students master the simple elements of Excel in their freshman course. While co-oping, I often needed to add data to a spreadsheet with over 700 rows, and it goes without saying that editing a spreadsheet that long can be very time-consuming. But (fortunately) an engineer in my group showed me some simple programming in Visual Basic that showed that deleting spaces between data on such a huge spreadsheet need not be done by hand at the expense of hours. From my co-op experiences, I learned that being a good engineer requires being able to optimize time expenditures. Spending hours editing spreadsheets that can otherwise be done more efficiently is not good time management.

Besides learning basic spreadsheet skills, students should learn how to analyze large data sets. During two of my co-op terms, I had to analyze someone else's data, even though I didn't know all the details about the process related to the data. I now understand that one doesn't need to be an expert in all of the process details to gain insight about why something is not going well with the process. A systems engineering perspective should be introduced and emphasized early in the curriculum in my opinion. Assignments should be given where only a brief description of the process is provided with a spreadsheet containing a large amount of data. The assignment should be to analyze the data and then decide which data should be considered. I believe that most practicing engineers would agree that statistics (which is necessary in data analysis) should be required for all engineering students.

In addition to Excel, Aspen (the unit operations simulator) is a key program and should be integrated into more of the chemical engineering curriculum. I had two weeks of Aspen during my second engineering class, and after that class, I never used it again in school. Perhaps it will surface again in the final design course, but Aspen would have fit well in several courses prior to that. Ideally, assignments could be given requiring integration of Aspen and Excel—this does happen in the real world of co-ops.

Two additional easy-to-use tools, PowerPoint and Word, also deserve some consideration. Both of these programs can be used by anyone who can turn on a computer, but to use them effectively takes practice. Given the intense pace in industry, imprecise communication guarantees that problems will occur. At the end of each of my rotations, I had to give a formal presentation in front of my peers, hiring managers, and whoever else wanted to attend. It takes experience to organize and present information in front of a large audience when you are under a spotlight and have to use a microphone, but the thought that a good idea that can't be communicated is wasted must always be at the forefront when planning one of these presentations. I must also add that hearing your own voice echo without quivering in such a situation gives you confidence in your ability to give a presentation anywhere and to anyone after that, so the effort is worthwhile.

Before closing, I would like to mention an additional experience vehicle that already exists on campuses that could be invaluable in assisting the student's metamorphosis to engineer. Increasing student-faculty interactions may sound like a simple idea, but while it may be obvious, it is not simple to do well. Our student chapter of the AIChE had a program in which juniors were paired with seniors in their major, and seniors were paired with a professor to create a mentor-mentee relationship. The problem with this simple but excellent idea is that often nothing happened. For instance, when I participated in it, a meeting was set up for students to meet the professors who had been assigned to them as their mentor—but none of the professors showed up!

We all accept that there are many demands on a professor's time, and such a mentorship program is simply one more demand that the professor didn't volunteer for, which probably places it low on the priority list. Nevertheless, if professors more actively participated and actually showed interest in programs such as this, students would benefit enormously. Ideally, the contact would provide exposure to the professor's research program, and could possibly include some actual research experience for the student. This experience could give the student a more balanced perspective, enhancing the industrial co-op and internship experiences, to draw upon when considering the options available after graduation.

It took a bit of determination on my part to find that such an "on-campus co-op" experience was available. After my industrial co-op, I eventually worked for one of my engineering professors over the summer. The project involved growing bacteria that harbor a specific esterase that we wanted to recover. The professor took an active interest in my career and educational goals, which was an attitude that I had not seen in a teacher since high school. Such a personal relationship goes a long way toward allowing students to discover what they really want to do in life and what they need to do in order to develop the skills for pursuing their goal. I found that simply having an intelligent, experienced, and patient individual to bounce questions off of was enormously helpful in allowing me to frame my long-term plans. In fact, this role is the common element present in both successful industrial or successful campus co-op mentoring. This component catalyzes the organization of all the facts and experiences that are jumbled together in a typical "standard" undergraduate experience. It is one truly essential element that turns a bewildered student into a self-assured graduate engineer. ❐