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.

# THE ROLE OF INDUSTRIAL TRAINING IN CHEMICAL ENGINEERING EDUCATION

MAMDOUH T. GHANNAM
*United Arab Emirates University • Al-Ain, United Arab Emirates*

Industrial training plays an important role in preparing engineering students to be future professional chemical engineers. The training offers a golden opportunity to acquire numerous technical and nontechnical skills that can not be obtained in a classroom environment. Some of the benefits of industrial training are[1-4]: observing daily work activities firsthand in a real setting, gaining the ability to apply technical and theoretical knowledge to industrial problems, direct exposure to nontechnical skills such as oral and written communications, understanding the diversity of the chemical engineering industries, applying computer software programs to real industrial situations, teamwork experiences, time management and deadline objectives, getting familiar with the industrial environment to set and achieve future career goals, working effectively in a multidisciplinary environment, and boosting the student's self-esteem and confidence by gaining today's industrial skills.

## UNDERGRADUATE INDUSTRIAL PROGRAMS

There is no classroom course that could simulate or replace the industrial experience gained from working with several operators in a real industrial environment. Numerous universities allow their students to gain industrial experience through a variety of programs.

### Cooperative Education Program

One such program is the cooperative education program.[1, 3] Co-op education is based on rotation between schooling and full-time work periods. It connects undergraduate students directly with industry to gain strong fundamentals and invaluable insight into the chemical engineering profession, acquire technical knowledge, earn academic credits, and receive wages. Some universities offer co-op programs on an optional basis while others are mandatory. Among the colleges of engineering offering an optional program are the University of South Alabama,[5] the University of Minnesota,[6] and the University of Pittsburgh.[7] Mandatory programs can be

***Mamdouh Ghannam*** *received his Ph.D. from the University of Saskatchewan, Canada, in 1991. He was an assistant professor at Cairo University, Egypt, from 1992-1995, after which he joined the University of Saskatchewan as a research engineer. Since 1998, he has been with the Department of Chemical and Petroleum Engineering at the United Arab Emirates University as an associate professor. His research interests are coating of Newtonian and non-Newtonian solutions, and interfacial and rheological properties of crude oil emulsions.*

found in universities such as Drexel,[8] Ryerson,[9] Toledo,[10] and Cincinnati.[11] Cooperative education programs have been well established in these universities for a long time. For example, cooperative education was founded at the University of Cincinnati[11] in 1906 and at Drexel University[8] in 1919. Most cooperative education programs offer financial benefits to students. The financial reward for students is usually based on location and type of task. Students' wages from their co-op jobs can even help finance their educations. At the University of Cincinnati,[11] average salaries for co-op jobs are almost twice the tuition fees. Therefore, students do not have the burden of having a part-time job, giving them more time to devote to academics and other activities. At the University of Pittsburgh's[7] Department of Chemical and Petroleum Engineering, approximately 40-50% of the students take advantage of the available co-op program. According to a study completed by the co-op office in Cincinnati,[11] 96% of graduating students acknowledged that the college program including co-op experience provided a better education than the traditional program without co-op.

Most engineering schools that offer cooperative education have certain requirements for a student to participate in the program. For example, at the University of Minnesota,[6] the undergraduate student needs to be in good standing, have completed all program course requirements including fall semester of the third year, have completed at least five out of seven elective courses, and maintain a minimum GPA of 2.8. The co-op student will work full time for one year continuously in the industry. After successfully completing their co-op programs, students earn two credit hours per semester, which count toward technical elective courses.

### Industrial Training Program

Around 10 years ago, the College of Engineering at the United Arab Emirates University (UAEU) recognized the importance of industrial training and its crucial role in preparing students for professional engineering. In 1995, a very committed program was established by the Unit of Industrial Training and Graduation Projects at the college. This program is mandatory—*i.e.*, part of the engineering education curriculum—for all engineering students in the disciplines of chemical, civil, electrical, mechanical, and petroleum engineering. Students can be granted 15 credit hours after successful completion of their industrial training. The following discussion focuses only on the chemical engineering industrial training program (ITP). The industrial training program at UAEU is selected in this article as an example to address its benefits and highlight areas that can be improved.

## PROGRAM LOGISTIC OF ITP

To ensure that students have enough theoretical background to comprehend industrial training tasks, the program requires students have a minimum GPA of 2.5 and to have completed 114 credit hours. Any student with a lower GPA will be required to complete 126 credit hours (the total credit-hour requirement to earn a B.S. degree in engineering is 168). Each eligible student should prepare and submit a file to the industrial training unit that contains academic records, a one-page resume, and a completed application form.

The industrial training unit works with each candidate to find a training position with the available participating industrial partners. Students will be required to interview with

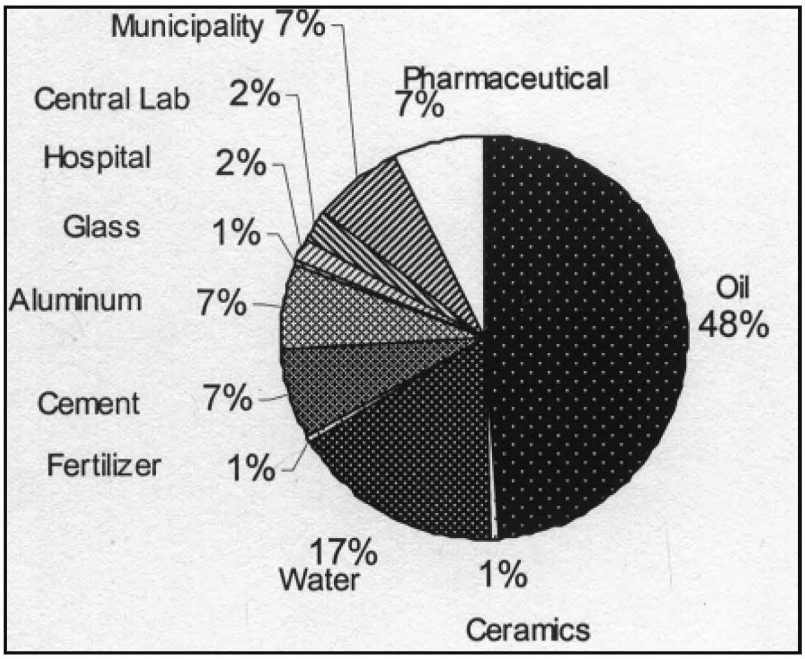


***Figure 1.*** *Participating industries.*

potential companies to be placed. If a student is not accepted by one company, he/she will have an opportunity with another company since the number of industrial partners exceeds the number of training candidates. The industrial training unit ensures that each candidate will receive placement in a relevant industry within the country or abroad.

At the beginning of the training period, each student will receive a training-program schedule outlining the whole 16-week period. This schedule includes a weekly job description with tasks, academic advisor visits, and deadlines for reports and presentations. The schedule is established by the industrial supervisor in agreement with the student's academic advisor. The student is also advised of the evaluation process used to determine his or her grade. Student evaluation during this program is based on weekly progress reports submitted to the academic advisor (15% of total score), academic advisor visits to the industrial site (15%), industrial supervisor's evaluation report (20%), and final report and oral presentation (50%). The presentation and final report are assessed by an examination committee consisting of a college representative, a departmental faculty member, and two or three professional engineers.

Upon successful completion of the ITP, student participants are eligible to register into the final academic year in chemical engineering. Failed participants must repeat the ITP program at another industrial site. With this in mind, most students are committed very seriously to the ITP.

From the above ITP description, it is notable that the objectives are similar to cooperative education in allowing students to gain industrial experience and learn the basics and fundamentals of the industry. The ITP, however, strictly considers students as trainees without financial compensation, not as employees with wages as in co-op programs.

## COMPANIES INVOLVED IN THE INDUSTRIAL TRAINING PROGRAM

The number of participating companies in the ITP for the whole college increased tremendously from around 10 companies during the initial year of 1995-1996 to approximately 140 companies in the academic year of 2004-2005. This increase in participating companies, both locally and internationally, reflects industrial appreciation of the important role of the ITP. The total number of chemical engineering students who participated in the program from 1999-2005 is 198. The number of academic advisors involved in these activities changed from one semester to another based on the number of students. For example, the number of faculty members involved in the first semester of 2004-2005 was four, and in the second semester of 2005-2006 it was seven. For the chemical engineering discipline, the specialties of the involved industries vary widely, as can be seen in Figure 1. The reported percentage represents the number of students completing the program for each industry during the period of 1999-2005. In addition, Figure 2 displays the various regions within the United Arab Emirates, with exception of France and Qatar, in which students of the UAEU carried out their training. These percentages also cover the period of 1999-2005.

The following is a brief description of the ITP for a chemical engineering student who completed his training program at the oil service company Dowell Schlumberger, in Abu Dhabi,

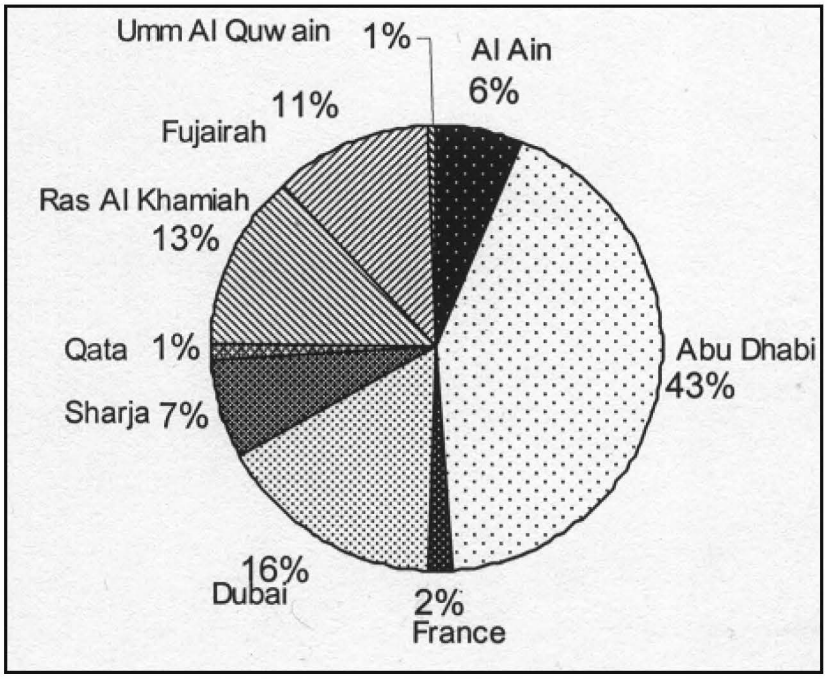


***Figure 2.*** *Industrial locations by region.*

UAE. His training period was February to May 2005. The first eight weeks of his training included attending orientation, learning company safety standards and injury protection, performing laboratory tests, utilizing software, and learning equipment maintenance.

During the second half of his training program, the student attended a company course on equipment and machine safety. He also had the opportunity to learn different aspects of the business such as the transfer of product. In the laboratory, the student was able to analyze materials and perform standard API tests including rheology and stability tests. The student was also able to use a Fann35 instrument to study the slurry-flow behavior and measure the slurry viscosity at various RPM. One sample used consisted of water, antifoam, dispersant, retarder, and cement, with composition of 18.65, 1.0, 0.15, 0.2, and 80 wt%, respectively. The student measured shear stress data versus shear rate and concluded the yield stress and viscosity for this sample was 9.83 $lb_f$ /100 $ft^2$ and 40.03 cp, respectively.

I visited the student at the end of the third and 13th week to check on his training performance and diary, and discuss the feedback and recommendations of his industrial supervisor. The student's graduation project proposal was also discussed.

## IMPACTS AND POTENTIAL IMPROVEMENT OF ITP

### Impact

By becoming a part of the ITP, students gain practical experience, technical knowledge, confidence, time management skills, teamwork capability, and a better understanding of what they've learned in class. Based on a study performed by the Industrial Training Unit at UAEU in the first semester of the 2003-2004 school year, 86% of students who completed the ITP gained strong technical skills. A total of 69 students having completed their industrial training in 42 industrial sites participated in this study. This training mechanism enables students to define their career goals *and* provides an opportunity to find a permanent employment position.

***Based on a study performed by the Industrial Training Unit . . . 86% of the students who completed the ITP gained strong technical skills.***

Additionally, this program is an excellent recruiting tool for participating companies. Employers will have the chance to train, evaluate, and select candidates for future job opportunities. A study was done by the industrial training unit at UAEU to survey participating industrial employers from the first semester of 2003-2004 to the first semester of 2005-2006. This study investigated the responses of the industrial employers on the trainees' performance with regard to the ABET2000 criteria (a to k criteria).[13] A total of 75 industrial employers were involved in this study. The study showed that most of the employers' evaluations exceeded the 70% limit (the acceptable limit established by the UAEU training office) for all the criteria of a to k with a few exceptions. These exceptions occurred during the second semester of 2003-2004 and first semester of 2005-2006. The employers' evaluation was slightly less than the 70% limit for criteria c and j (the ability to design a system, component, or process, and knowledge of current engineering trends).

### Improvement of ITP

If the faculty members are not significantly involved in industrial-site supervision, project choice, follow-up, and academic evaluation of student performance during the training period, the chances of an undergraduate student achieving industrial experience are not very good.[1] As an academic advisor participating for the last seven years in the ITP, I feel improvements can be made to the current program. Implementing these ideas will enhance the overall performance and outcomes of the ITP. Suggested improvements are:

#### *(a) Site Selection*

To ensure the success of the training program for students, an academic advisor should be involved from the very beginning. The advisor needs to work closely with each student in selecting the appropriate training site since there can be several choices. Doing so guarantees matching the student with an industrial site that meets the program objectives, and avoids having students select an industry based on convenience rather than relevancy.

#### *(b) Industrial Field Visits*

The department should encourage and enforce a one-day field visit once a semester for all students, especially freshmen, to provide early exposure to different daily industrial activities.[3] Doing so allows students to start forming an opinion as to what type of industry they want to pursue.

#### *(c) Industrial Short Residence*

Due to the short period of the ITP (*i.e.*, four months) in comparison with that usually spent by a trainee at other schools such as Pittsburgh,[7] Drexel,[8] Cincinnati,[11] and Minnesota,[6] participating departments should develop a yearly industrial event in which sophomore and junior students spend two to four weeks during the summer at a local industry in the residence city. Of course, each student should achieve certain limited objectives during this period and be required to provide a written report and oral presentation detailing his/her activities and experiences gained. To make this idea

even more practical, one industrial site can be selected for each student. This requires the student to spend each summer break in different departments of an industrial site.

### *(d) Nontechnical Skills Course*

To improve the nontechnical skills of undergraduate students in general and the ITP in particular, the college of engineering should develop a special course equivalent to two credit hours. The course would focus on enhancement of nontechnical skills such as communication, effective presentation, technical writing, accessing information, judgment, software applications in industry, job interviews, resume building, and explaining technical information to nontechnical customers.[4,12]

This course would be offered to all students during the second academic year, thus allowing enough time before the ITP stage. In this way, students will be well prepared for the ITP. They will be able to maximize the benefits and achieve all the expected objectives of the ITP.

### *(e) Graduation Project Proposal*

One requirement for the successful completion of the ITP is the submission of a graduation project proposal within the final report. This proposal should reflect a valuable idea that attracted the trainee's attention during the training period. The proposal may then be selected as a graduation project by a faculty member within the chemical engineering department. Based on my own experience over the period of 1998-2005, I noticed problems associated with the graduation project proposals such as unclear or incomplete proposals and the lack of technical description and industrial data. It seemed students completed their proposals just to meet the requirement criteria, or did not complete them at all.

The requirement to submit a graduation project proposal itself is a great idea. For greater benefit, however, it needs more involvement and commitment from each side. The following are some suggestions to strengthen the process of the graduation project proposal:

1. *All graduation projects should be based on students' industrial proposals.*
2. *Clear, limited, and well-defined criteria for graduation projects should be established by the department at the beginning of each academic year.*
3. *Each group of three students will be assigned an academic advisor relevant to their industrial training site.*
4. *Forming a solid project proposal should be one of the main duties of trainees in coordination with the industrial supervisor and the academic advisor.*
5. *Both the industrial supervisor and academic advisor should be involved with students to achieve this task by the end of the training period.*
6. *The proposal should cover the details of problem definition, industrial importance, negative impacts, alternative solutions, suggested solution and reasoning, and positive impacts.*
7. *A significant grade should be assigned to the project proposal.*
8. *The academic advisor should involve the industrial supervisor throughout the graduation project stages.*
9. *The industrial supervisor will be entitled to attend the final project exam and to receive a copy of the final report with all results and recommendations.*

### *(f) Academic/Industrial Interaction*

One of the main benefits of the suggested mechanism of the ITP and graduation project proposal is the strong link and interaction made possible between the industrial supervisor and the academic advisor. This relationship can help both parties advance their mutual interests, including:

1. *Faculty member can make a strong connection with different industries leading to research and technical cooperation.*
2. *Industrial supervisor will have better access to the university environment for assistance such as technical recommendations, hiring new graduates, acquiring samples and data analysis, and participating in scientific activities sponsored by the university.*
3. *Research cooperation between the two parties resulting in scientific publication reflects well on the image of the industrial partner.*

Due to the large number of activities requiring faculty involvement, these modifications will be better suited for departments with a small number of students. A larger number of students would require too much faculty time investment, negatively affecting research.

## SUMMARY

It is clear that industrial experience in any program format can be beneficial to students. Some programs may have more benefits than others, but each provides valuable skills and training for our future engineers. It is important that we continue to study and evaluate these programs to make improvements and adopt new ideas. What may work in one university may not work in another. By sharing the fundamentals of the programs, however, engineering colleges may find useful information to improve their current programs. After all, the main objective of any engineering education program is to produce the best possible engineers and to develop, enhance, and advance our society.

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