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 interns and coop assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of 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.

THE CHEMICAL ENGINEERING PRACTICE SCHOOL PROGRAM AT TULANE UNIVERSITY

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The Chemical Engineering Practice School Program at Tulane University was established in 1951 to serve as a means of introducing undergraduate students to the types of problems encountered by practicing engineers.[1] The program, which consists of one six-credit course, is required for all students during the spring semester of their senior year. The students are divided into groups of three or four, and each group is assigned a unique project provided by a local industrial firm. Each group has both a faculty advisor and an industrial contact engineer. The program thus gives the students experience in solving an industrial problem while still under the guidance of the chemical engineering faculty. The program differs from a traditional co-op program in that it is taken as part of the regular sequence of courses. Unlike other programs, such as the one at M.I.T.,[2] the Tulane program is restricted to undergraduates.

INDUSTRIAL PARTICIPATION

Probably the most important factor in the continuing success of the program is the extensive degree of industrial participation (being located in the heart of this country's oil and chemical industry is, of course, helpful). The Chemical Engineering Department maintains a pool of approximately fifteen companies that have either previously participated in the program or expressed a desire to do so. The current pool is comprised of large oil and chemical companies as well as smaller manufacturing firms. Although not a strict requirement, most of the companies in the pool have a facility located within a one-hour drive of the New Orleans area. (The students must make a minimum of two visits to the company's facilities—at the beginning of the project for an initial kickoff meeting and again at the end of the semester for a final presentation of results.)

Each October, one faculty member (designated as the Practice School Coordinator) begins contacting companies in the pool about possible participation for the spring semester. Typically, several new companies are also contacted in order to maintain a diverse and dynamic pool. The number of projects solicited depends on the number of students who will be participating in the program. The typical class size is approximately thirty students (average over the past five years) and our experience has indicated that three students per group is about optimal. (Some of the projects involve too

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much work for two students, while having four or more students leads to uneven work loads.) Usually, several potential projects are requested from each company, and the one best suited to the program is chosen, although more than one project per company has been used on occasion. We stress that the most desirable projects are those that would be of some real benefit to the company as opposed to simple exercises. Students typically respond much better to projects that have some actual value.

The types of projects provided are quite varied. With the larger firms the projects are frequently those that are "good ideas" but not of high enough priority to justify extensive use of company personnel. With the increasing trend toward downsizing, the Practice School thus provides additional resources for a company to supplement a reduced engineering staff. On the other hand, some of the smaller companies (especially those in manufacturing) may not even employ a full-time chemical engineer. In these cases, the Practice School provides a cost-effective means of studying a problem that is outside the areas of expertise of the company employees.

Because the Practice School is considered a design course, all projects must be design oriented. Projects that involve an extensive amount of laboratory work or projects that are merely literature searches are thus not acceptable. (Note that the Practice School is not a part of the "capstone" design course, which is taken in the fall semester.)

Once the projects have been chosen, each is assigned a faculty advisor. A typical faculty teaching load during the spring semester would be one lecture course plus one Practice School project. When possible, the projects are matched to the faculty members' interests or experiences. In addition, each company is asked to identify one person at the plant who will serve as the industrial contact for the students. This is typically a young engineer (five to ten years of experience) who is familiar with the group's project.

REQUIREMENTS OF STUDENTS

As mentioned earlier, the Practice School consists of a six-credit course—twice as much as a regular lecture course. Each student is therefore expected to devote 15 to 18 hours per week to his or her project. Every group is required to have an initial kickoff meeting with company personnel at the start of the semester and to give a final oral presentation of its results at both the plant site and Tulane. The students must also submit a final written report to both the faculty advisor and the industrial contact. All other requirements are generally determined by the faculty advisor and the specific nature of the project. Most faculty require weekly reports and meetings to discuss progress; more detailed midterm reports may also be required. Each student's grade is determined by the group's faculty advisor, with possible input from the industrial contact. Normally, each student's individual contribution and the overall performance of the group are considered.

The nature and extent of the interaction with the company personnel varies from project to project. In some cases, the majority of the work can be performed on Tulane's campus and the group may need to make only one or two additional trips to the company—an example would be a project involving a large amount of computer simulation. In other projects, the students have had to visit the plant site as often as twice a week.

While on location, the students are required to follow all rules and regulations imposed by the company. This includes using all required safety apparel (*e.g.,* hard hats, safety glasses, hearing protection, flame-retardant clothing, etc.), obeying smoking and vehicle restrictions, and following any specific requirements set by the local operations manager. (All specialized safety equipment is supplied by the company.) Some companies also require the students to undergo several days of safety training at the start of the project. The students are clearly told that while on site, they are to conduct themselves in a manner consistent with that expected of the company's full-time engineers.

EXAMPLE PROJECTS

Ten projects that have been recently used in the Practice School are listed in Table 1 (next page), and more detailed descriptions of three of these projects are given below. These projects, which are quite diverse, illustrate the range of training that the students receive in the program.

Flow Meter Comparison Study • The engineering staff at a local refinery was interested in improving the flow-metering capabilities of the plant. The staff felt that advances in metering technology could be used to improve performance monitoring throughout the refinery. The company contact engineer wanted the group to first develop an overview of the existing level of technology in this area and summarize the advantages and disadvantages of various meters in tabular form for easy access by plant personnel. The students

were then to make recommendations on the type of meters that should be installed at specific places within the plant, given the desired accuracy level at each location.

In collecting information, the students used both technical journals and information supplied by instrumentation vendors and also attended a local trade exposition. Using this material, the group provided detailed descriptions of seven different flow meters, ranging from the traditional differential pressure meter to more elaborate devices such as vortex shedding meters. The group then reviewed the use of each of the meters at the various locations specified by the company. Where applicable, a total cost value for each meter was calculated, consisting of the installation, replacement, calibration, and inspection costs, as well as the energy costs associated with pressure losses through the meter.

Fuel Pipeline Capacity Study • This project involved evaluating the capacity of a fuel transport pipeline extending from a refinery to a distribution terminal. The company wanted the students to develop at least two alternatives for increasing the capacity of the line to a target flow rate and to provide a detailed cost analysis of each option.

The group approached the problem by first developing a rigorous hydraulic model of the pipeline. A detailed description of the pipeline and all associated equipment, such as valves, fittings, and pumps, was produced. This information was then input to a generic fluid-flow program supplied by the company. Given a flow rate and inlet pressure, the model could predict the pressure at any point along the pipeline. Two field verifications were then performed to validate the model. (These verifications also allowed the group to determine if any significant obstructions, such as a plugged filter or damaged valve, were present.)

Once an accurate model was available the group simulated the effect of various modifications to the system. It was found that a substantial increase in capacity could be obtained by simply rearranging two pumps to operate in series. This change, involving only a minor capital expense, still did not produce the target flow rate, however. To reach the desired capacity, the group recommended installing a new booster pump near the refinery. A third alternative was the injection of a drag-reducing polymer into the fuel. The group worked with an outside vendor to determine the cost for this proposal and the resulting increase in throughput (see Figure 1). All three ideas were presented to company management.

Waste-Water Treatment Facility Evaluation • In this project, the students were to evaluate the performance of the waste-water treatment facility of a local plant. The facility had an ongoing problem with sludge accumulating at various holding tanks in the system. The group's objectives were 1) to evaluate the performance of the various components of the system, and 2) to develop a list of recommendations for

TABLE 1
Recent Projects Used in the Practice School

- ▶ Develop an overview of the existing level of technology in flow metering and make recommendations for specific applications.
- ▶ Develop a hydraulic model of a fuel pipeline and make recommendations for improving capacity.
- ▶ Evaluate the performance of a waste-water treatment facility and recommend changes for improvement.
- ▶ Develop a finite element model to predict the flow of ground water around a large plant.
- ▶ Develop a list of recommendations for optimizing the cycle time in a batch filtration process.
- ▶ Investigate the potential use of an idle distillation column for additional product recovery.
- ▶ Analyze the performance of an on-line computer control system and develop a set of maintenance priorities.
- ▶ Develop a set of spreadsheets for use by plant engineers in material balancing and performance monitoring.
- ▶ Investigate alternatives for reducing corrosion in a water purification system.
- ▶ Determine an effective and environmentally friendly solvent for a degreasing application.

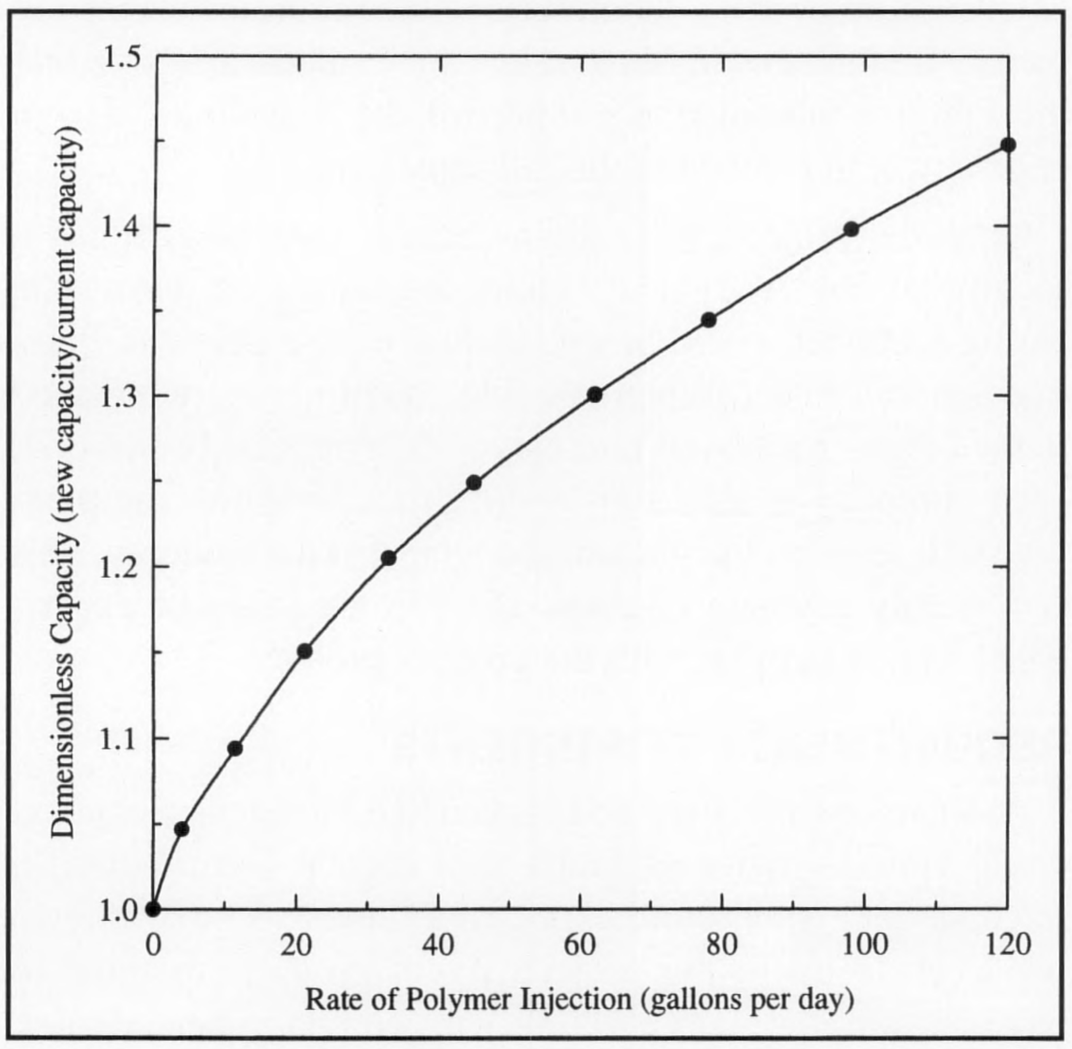

Figure 1. *The dimensionless pipeline capacity (relative to current capacity) as a function of the injection rate of drag-reducing polymer.*

reducing sludge buildup.

The group first performed a material balance around the water treatment facility. Using a flow chart, the students pinpointed exactly where flow measurements and water samples should be taken for the balance and then worked with unit operations personnel to collect the data. The results of the material balance were used to determine the sources of sludge entering the facility. It was also determined that the sludge thickening tanks, long thought to be a possible problem, were actually working as designed. At the conclusion of the project, a series of recommendations, including installing mixers on specific tanks and rerouting several streams, was developed and presented to the plant's management staff.

BENEFITS OF THE PROGRAM

As illustrated by these examples, the Practice School requires students to use a wide array of technical, organizational, and personal skills. Many of these skills (*e.g.,* group interactions, written and oral communication) are of course also required in more traditional group design projects.[3] What makes the Practice School unique, however, is the integration of a classroom design project with the experiences associated with working in an industrial environment. This latter component provides training in a completely different set of skills (see Table 2). For example, students are commonly required to work with a variety of personnel at the plant, including engineers, managers, laboratory technicians, and operators—each with a different set of priorities. Instead of simply requesting that a series of samples be taken for component analysis, for example, the group may have to convince a manager that the samples are truly needed. The students are also faced with evaluating the accuracy of plant data. Students quickly learn that even the simple task of performing a material balance can be difficult in the plant.

Finally, the students are frequently faced with questions or problems for which an answer is not known and cannot be determined. As an example, in performing a mass or energy balance, the flow rate and/or composition of certain streams may not be measurable. The students must then either devise an alternate method for performing the balance or, in the worst case, use their best engineering judgment.

TABLE 2
Training Provided to Practice School Students

Common to traditional group design courses

- ► Assimilating and using a range of chemical engineering topics in a single problem
- ► Focusing on a specific objective
- ► Working together in groups on a large project
- ► Giving oral presentations
- ► Preparing a large and detailed written report

Unique to the Practice School

- ► Working in an operating or manufacturing environment
- ► Working with a variety of industrial personnel (*e.g.* managers, engineers, technicians)
- ► Learning other engineering fields (*e.g.,* corrosion, instrumentation, mechanical equipment) and using the information to solve a problem
- ► Meeting deadlines imposed by different sources
- ► Evaluating the accuracy of plant data
- ► Solving problems with limited data and resources

CONCLUDING REMARKS

Although the program has undergone several minor modifications since its inception (*e.g.,* size of groups, number of credit hours, types of companies involved, etc.), the basic format has remained the same. The response of the participating companies has been overwhelmingly favorable. In fact, very few companies have totally dropped out of the pool. On the occasions when a company has declined to participate, it has generally been the result of a temporary circumstance at the plant, such as an extended maintenance turnaround or a possible work stoppage by union employees.

The students also tend to be pleased with the program. This is especially true when the company shows a great deal of interest in their project, further enforcing the idea that the work is indeed valuable. For many students, the Practice School is their first exposure to an actual operating environment and thus it is their first opportunity to see that the fundamental concepts they have been learning for years will actually be needed on the job.

If there is a disadvantage to the program, it is the large variability in the work required for the specific projects. Projects that at first appear worthwhile may actually require only a limited effort by the group members. Other projects may require either an extensive research effort or significant laboratory work, both of which are inconsistent with the objectives of the program. In such cases, it is the responsibility of the faculty advisor, in conjunction with the industrial contact, to revise the scope and objectives of the project to satisfy the design requirements of the course.

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