THE PRACTICAL SIDE OF CHEMICAL ENGINEERING

At The University of New Brunswick

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In an attempt to better prepare our students for their life after graduation, the Department of Chemical Engineering continuously seeks ways to expose the students to the practical aspects of chemical engineering. Factory tours and laboratory exercises present students with early opportunities to experience the world of chemical engineering during their first and second years.[1] After studying several of the chemical engineering core courses (material and energy balances, heat and mass transfer, fluid mechanics, and thermodynamics), the students are given the opportunity to apply what they have learned to real industrial problems through an industrial project course known as "Practice School," and during their senior year, their practical experience is extended during a Plant Design course. This paper describes the industrially oriented approach taken in both the Practice School and Plant Design courses.

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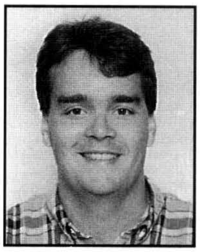

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PRACTICE SCHOOL

Practice School projects can be considered as an introduction to the concepts of industrial design. They generally accent the application of material and energy balances and thus tend to be relatively basic from a design point of view. But within the scope of their project, the students are expected to develop a detailed design solution. This industry-sponsored endeavor allows the students to become familiar with many aspects of an engineer's working life. Almost all students participate in this course (a limited number, however, exercise the option of preparing a report on a departmentally approved research topic).

Course Logistic

A two-week project in selected industrial process plants is scheduled after the spring examination period (the last week in April to the first week in May). Groups of third-year students (jointly supervised by a faculty member and a professional engineer employed by the company) are assigned to engineering projects to be carried out on industrial process units. While working in the plant, the students are introduced not only to the problem at hand, but (perhaps of equal importance) also to the various aspects of real-life engineering, including time management and teamwork. The students are also encouraged to take very detailed notes while working in the plant.

At the end of the two-week period, the group presents their results orally and submits a preliminary typewritten report to the company representatives. The students are then expected to work during the summer months on the final solution to the design problem. Although the group members tend to disperse to summer employment during this time, they are able to stay in effective contact through electronic mail, fax, and telephone. The combination of detailed plant notes and continued communication throughout the summer months is critical when the students return for the fall semester since, at that time, the results of their work are documented in the form of a final comprehensive report that must be submitted by the end of September. The following outline shows the typical content of the comprehensive report.

- Introduction to the Design Problem *This section presents a brief introduction to the industry and the assigned task.*
- Theory *A detailed discussion of the governing equations and principles is given in this section. The knowledge gained in the core courses is essential to providing a concise description of the relevant theory.*
- Results *The data taken at the plant are presented in this section.*
- Data Analysis *An in-depth data analysis leads to the final design. Simulation software packages may be of assistance to the students in the final design. Working with industry on a viable solution to one of its problems also entails an economic evaluation of the final design.*
- Conclusions and Recommendations *Suggestions for the implementation of the final design and the possible continuation of future studies are put forward to the company.*

To complete the requirements of the course, each Practice School group is required to present its work in a 15-minute oral presentation scheduled during the month of October. Invitations to visit the department and attend the presentation are extended to the companies that participated, to the other engineering departments, and to the public.

Suitable Practice-School Projects

When the Practice School course was initiated in 1970, all of the projects were supplied by a lead-smelting company in the northern region of the Province. At that time, enrollment in the department was less than it is now; today, we have as many as thirty-five students for whom we must find suitable projects each spring. With groups of three or four at each industrial location, this translates into a need for ten or more projects every year. As a result, students now work in industries from across the Province, and we rely heavily on the industrial contacts of the individual faculty members to obtain the necessary projects.

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The industries that participate in the Practice School welcome the opportunity and, in many cases, have come to depend on the work that is done by the students every year. Many of the problems that our students work on are problems for which the typical process engineer in these plants does not have the time. Examples are projects involving process water balances or balances on components of waste streams around sections of the plant.

As might be expected, certain projects lend themselves better to the Practice School structure than others. Because of the student's relatively short stay at the industrial site, the projects must be well defined by the company, with clear objectives that can be met in two weeks. Also, it is important that any equipment provided by the company for a sampling campaign or for laboratory analysis be in working order and ready to use on the students' first day at the plant. Furthermore, we have observed that projects that allow the students to work independently (*i.e.,* limited dependence on plant personnel for assistance in sample collection or laboratory analysis) are most desirable. Table 1 lists the most recent Practice-School topics in which we

TABLE 1
Recent Practice-School Projects

Industry	*Project Title*	*Objective*
Integrated wood pulp and chemical production facility	**Design of an HCl vacuum scrubber for the electrochemical plant**	**Eliminate the environmental and operational hazards associated with the filling process of concentrated HCl into tank trucks**
Integrated wood pulp and chemical production facility	**Sodium chlorate filter replacement and an alternative method for sodium hypochlorite removal**	**1) Design of an economically feasible separation process for the removal of sodium chlorate.** **2) Develop a system for the complete removal of sodium hypochlorite from one of the plant's product streams.**
Crude-oil refinery	**Desalter waste minimization**	**Determine the desalter impact on the effluent unit.**
Lead-concentrate mining operation	**Residence time distribution and grade recovery of the lead-upgrading circuit**	**Evaluate the performance of the lead upgrading cells using a $CaCl_2$ tracer.**

have been involved as faculty supervisors.

Conclusion

Practice School is one of the first steps our students take in becoming acquainted with the industrial environment. Although the actual time spent in the plant environment is only two weeks long, the program ensures that essentially all of our undergraduate students have some industrial exposure by the end of their third year. During this two-week period and the subsequent report-writing stage, students have an opportunity to put the theoretical knowledge they have gained and the skills they have developed to practical use. They build confidence in themselves and in their ability to apply what they have learned to solve industrial problems. These Practice School projects ease the students into the senior year of the chemical engineering program.

PLANT DESIGN

One approach to the senior Plant Design course is to make use of prepackaged (and sometimes outdated) case studies. The instructor might have twenty such cases to choose from, and the course is essentially run as any other lecture. But is this approach in the best interest of our customers, the students? Engineers who have gone through a "traditional" (chemical) engineering education tend to agree that additional practical components should be added to the curriculum and especially to the senior design project. The expression "plant design" should immediately imply industrial applications;[2] consequently, industry should be involved in the design course. Working with practicing engineers on relevant industrial problems and not just trying to fulfill their degree requirements gives students a great sense of achievement and satisfaction.

The Plant Design course, as our department defines it, is a capstone course in which our senior undergraduates use their knowledge to work on an industrially relevant problem. Over the years, close ties between New Brunswick companies and our department have been established. Through personal contacts, the department seeks to obtain industrially relevant design problems for our students, while the industries are interested in obtaining solutions for their design problems. If successful, the students *and* the industrial partner will benefit from this cooperation. The various steps involving the successful completion of an industrially sponsored design project are described below.

Course Logistics

During initial meetings between the industrial sponsor and the course instructor, the design project's topic and scope are established. The company designates an engineer to supply relevant project information such as process and instrumentation diagrams, flow sheets, and plant operating data. Recent design topics supplied by industry have ranged from "Design of a Sodium Chlorate Plant" to "From PET to the Soft Drink Bottle."

At the beginning of the term, the class is divided into design teams (comprised of three to four members each) that are required to solve different design problems. As the individual groups begin working on the design problem, they are concurrently being introduced to the concepts of group dynamics,[3] hierarchical plant design,[4] design of experiments, and scale-up procedures. The steps taken to arrive at an optimized solution of a design problem are:

- Formulation of the Project Parameters *Pertinent materials, such as P&ID, flow sheets, and any other information relating to the design problem, are given to the students during the first lecture. One reason for identifying the process specifications is to make sure that there are no surprises for either the students or the company upon completion of the project. Where possible, a plant tour during the second week helps the students learn more about the plant operation and assists them in establishing contact with the company engineer.*

- Literature Review and Generation of Alternative Solutions *A thorough search of the existing literature, as well as application of relevant design and manufacturing codes, helps the design teams minimize design errors and maximize their efforts. Exercises to encourage the lateral thinking process, the background of the students in the field of engineering, and the knowledge gained from the literature search will yield alternative design solutions.*

- Development of Gantt Chart *The management of design projects within the constraints of the university environment,* i.e., *the heavy course load for students, is easier said than done. The plant design course environment is very turbulent and is composed of numerous design team meetings, section report writing, conflict resolution, planning, and communication with the various parties involved. It is extremely important for the students to learn about time management. A bar (Gantt) chart developed by each design group assists everyone in keeping the projects focused.*

- Development of the Conceptual Design *After the preliminary process flow diagrams have been developed, an engineering panel comprised of two practicing engineers reviews the initial conceptual designs. The panel arrives at a "go/no-go" decision.*

Certain recommendations may be put forward by the panel to enhance the proposed design. If the engineers should arrive at a no-go decision (which has not happened yet, perhaps due to the students' intensive practical preparation through practical laboratory exercises,[1] practice school, and PEP), the students would be asked to revise their design and report back to the engineering panel.

- Execution of the Design Calculations and Assessment of Performance *Computer simulations are an invaluable tool for an engineer. Simulation programs such as CMOLD, HYSYS, and FLUENT are used by the design teams to accomplish their design tasks more efficiently. Many design problems, however, still cannot be adequately simulated. Therefore, experimental work or hand-computations are frequently necessary to obtain the required design specifications. The students must also keep safety aspects foremost in their minds throughout the design stage.*

- Optimum Economic Design *In almost every design case there are several technically equivalent design solutions. The optimum size can often be obtained only by cost comparison of different schemes. There is a tendency to evaluate a parameter as being the optimum factor. This sub-optimization may result in an increase in the overall process equipment cost. Care must be taken to study the overall system and its economic implications. The students are required to evaluate their design solution from an economic perspective.*

- Preparation of Specifications *The use of specification sheets is mandatory, but due to time constraints, they need not be fully completed. These sheets are the basis for the company in the continuation of the design projects.*

Ultimately, a final report summarizing the work done on the project must be submitted. The report's content follows a format similar to that described by Seider and Kivnick.[5]

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The individual groups are then required to present their final design at the Annual Industrial Chemical Engineering Conference. The conference, which is organized by the chemical engineering student body, attracts attendees from the university, industry, and government. It is intended to hone the presentation/public speaking skills of the students, to present the design solutions to the participating companies, to allow the graduating students to "rub shoulders" with decision makers and perhaps to discuss employment opportunities, and to develop new university/industry relationships as well as bolster existing ones.

Conclusion

While this plant-design concept has been successful, it should be pointed out that the notion of an industrially oriented plant design course is not new. Articles by Seider and Kivnick[5] and Rockstraw, et al.,[6] have discussed both this concept and their affiliations with local companies. Our effort is different because, while New Brunswick is a highly industrialized province, there is no single industry in close proximity to the University with which we have been able to develop a close, continuous relationship. Rather, projects come from various companies each year.

It is interesting to note that our involvement with industry through the Practice School has led to projects for Plant Design. The most recent example is the sodium chlorate plant-design project mentioned above, which grew out of the sodium chlorate filter and sodium hypochlorite removal Practice School projects. Furthermore, several national and international companies currently support our effort to educate students in a more practice-oriented way. Information technologies have made it possible for the students to work on design problems that are not available in our local area.

GENERAL OBSERVATIONS

Students enjoy working on an industrial design project and feel pride in that a part of their work will be implemented in an industrial operation. When this course concept was first introduced, some students commented:

"I can't design a plant addition for a company; I don't have enough experience to un-

> *dertake this task."*
>
> *"Is this for real?"*

After the students had time to think about the underlying objectives, the comments were more along the line of:

> *"Finally I am not working for the wastebasket anymore."*
>
> *"Thank you for introducing us to the world of practical engineering.*

Although the student comments have been positive, there is always room for improvement. In industry, chemical engineers seldom work on a project by themselves; different disciplines are needed to ensure the successful completion of a project. There will be electrical engineers, mechanical engineers, civil engineers, chemical engineers, architects, and business people working side-by-side.

In the 1997-98 academic year, mechanical engineering students will also participate in the Plant Design course, creating a more realistic design environment. A design project involving the local aquaculture industry was carried out in the fall of 1997. It involved interactions with the biology department and was quite successful.

Expanding the design course to involve other disciplines, however, creates some problems that need to be addressed. Of particular concern is the issue of prerequisites. For example, mechanical engineering students do not take courses dealing with separation processes or reactor design, which are both Plant Design prerequisites for our students. During the course of a design project, process economics and safety and environmental concerns have to be considered simultaneously. Having recognized that these subjects are inseparable, starting in 1998-99, we will introduce a new full-year design course to more adequately cover them. The new course will represent the amalgamation of the Plant Design and Process Economics and Safety courses.

Proper planning and preparation will alleviate the "culture shock" experienced by a graduate engineer when accepting a position in industry. The Plant Design course presents an excellent opportunity for students to learn more about the language and customs of professional engineers. Our hope is that our students' transition to industry will be considerably eased.

ON TO THE THIRD PARADIGM OF CHEMICAL ENGINEERING

Wei[7] observed that two paradigms have shaped the field of chemical engineering throughout this century. In the 1920s, the first paradigm of unit operations was developed. Then, with the publication of *Transport Phenomena,* by Bird, Stewart, and Lightfoot[8] in 1960, came the more analytical and fundamental second paradigm. In a recent article, Landau[9] states,

> *"It is my opinion . . . that we need a change in direction toward more relation to practice and to industry, which perhaps might constitute the third paradigm."*

Elsewhere in the article, Landau comments,

> *". . . I believe chemical engineering's third paradigm, if there is one, is to return the discipline closer to the practices in industry, and to strengthen its interdisciplinary ties. . . ."*

While the first two paradigms were indeed revolutionary, the next paradigm should not be. As discussed by Douglas,[10]

> *"As we extend chemical engineering into new application areas, we will need experts in each of these paradigms."*

Whether or not one accepts the notion of an emerging third paradigm, we do feel that our Practice School and Plant Design courses are effective approaches to preparing chemical engineers for their future in the profession. We emphasize practical, industrially oriented projects and are promoting an interdisciplinary structure. The students are also firmly grounded in the fundamentals of chemical engineering and the basic sciences. The positive feedback obtained thus far from the students encourages us to continue thinking of new and innovative approaches for improving the existing courses.

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REFERENCES

1. Chaplin, R.A., "Providing Industrial Experience in a Regular Laboratory Course," *Chem. Eng. Ed.,* **31**(2), 130 (1997)
2. Peters, M.S., and K.D. Timmerhaus, *Plant Design and Economics for Chemical Engineering,* McGraw-Hill, New York, NY (1991)
3. Crosby, P.B., *Problem Solving,* (1991)
4. Douglas, D.M., *Conceptual Design of Chemical Processes,* McGraw-Hill, New York, NY (1988)
5. Seider, W.D., and A. Kivnick, "Process Design Curriculum at PENN," *Chem. Eng. Ed.,* **28**(2), 92 (1994)
6. Rockstraw, D.A., J. Eakman, N. Nabours, and S. Bellner, "An Integrated Course and Design Project," *Chem. Eng. Ed.,* **31**(2), 94 (1997)
7. Wei, J., "Future Directions of Chemical Engineering," in *Advances in Chemical Engineering,* **16**, 51 (1991)
8. Bird, B.R., W.E. Stewart, and E.N. Lightfoot, *Transport Phenomena,* John Wiley and Sons, New York, NY (1960)
9. Landau, R., "Education: Moving from Chemistry to Chemical Engineering and Beyond," *Chem. Eng. Prog.,* 52, Jan. (1997)
10. Douglas, J.M., "The Paradigm After Next," in *Advances in Chemical Engineering,* **16**, 535 (1991) ❐