EXPERIENCE WITH TEACHING DESIGN

Do We Blend the Old With the New?

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One of the most challenging tasks facing a chemical engineering instructor today is presenting a capstone design experience that comprises an appropriate balance between the "old" and the "new." The old would be the classical design experience, heavy on the fundamentals, hand-calculation intensive, and rigorous in approach, whereas the new corresponds to a more team-oriented, computer-usage intensive approach incorporating the development of written and oral communication skills. Based on the proliferation of articles in the literature on the subject of teaching design and how design should be integrated into the curriculum,[1-8] it is obvious that this is an issue that continues to be debated and for which there is no simple solution. There also appears to be some disagreement between industry and academia as to what skills a student should possess after completing a four-year engineering program.[9,10]

This article addresses some of the issues associated with teaching design and in particular looks at the capstone design sequence developed at the University of Dayton and the experience gained developing and teaching these courses. The pros and cons of chemical-process flowsheet-simulator use, together with feedback from students who have taken the design courses, will also be discussed.

DESIGN COURSE SEQUENCE

The design course sequence, as it has evolved over the last seven years, is outlined in Tables 1 and 2. As can be seen, the first course (Design I) is offered during the fall semester of each year and the second course (Design II) during the following semester. Design I is a fairly standard introductory design course covering topics such as the basic concepts of design, safety issues, costing and economic analysis, materials of construction, and some mechanical design. Additional details can be found in the table. Evaluation of student performance for this course is based on two midterm examinations as well as a comprehensive final examination. Performance on homework assignments is also weighted into the final course grade.

Design II, the second course in the sequence, has two main components: the design problem and special topics. The design problem is a fairly comprehensive plant design (discussed later), and the special topics include diagrams and layout, optimization, shortcut design procedures, and other topics specifically related to the design project being undertaken, *e.g.,* if the plant design requires a bioreactor, some details of microbial growth kinetics and fermenter design would be discussed. Evaluation of student performance for this course is based on a single examination (toward the end of the semester) that covers the special topics as well as some aspects of the design problem, and grades from the design-project assignments. The assignment grades would typically constitute approximately two-thirds of the final course grade. Some additional details can be found in Table 2.

DESIGN PROJECTS

As mentioned above, the major component of Design II is a fairly detailed plant design. Details of some of the projects undertaken are available in Table 2. Selection of appropriate projects is important. They need to be feasible, yet challeng-

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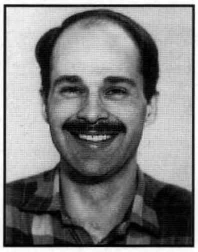

TABLE 1
Design I Course Outline
Fall Semester • 3 Credit Hours

1. *Introduction (0.5 week)*
   - Basic concepts
   - Steps in the design procedure
2. *Safety, Loss Prevention and Health Issues* (2 weeks)
   - MSDS (Material Safety Data Sheet) terminology
   - Health, safety hazards: toxicity, flammability, explosions, etc.
   - Loss prevention, HAZOP studies
3. *Capital Cost Estimation* (2 weeks)
   - Equipment costing, cost charts, cost indices, etc.
   - Overall plant cost, Lang Factor method
4. *Manufacturing Cost Estimation* (1 week)
   - Fixed capital, working capital
   - Direct, indirect, general manufacturing expenses
5. *Economics and Profitability Analysis* (2 weeks)
   - Interest
   - Present value of money
   - Depreciation
   - Profitability analysis, discounted cashflow
   - Break-even analysis
6. *Materials of Construction* (3.5 weeks)
   - Introduction
   - Mechanical properties of materials
   - Phase transformations and heat treatment
   - Corrosion
   - Special properties required of materials
   - Materials selection
   - Commonly used materials of construction
7. *Mechanical Design of Process Equipment* (1 week)
   - Design pressure, temperature, stress
   - Joint efficiency, shells and heads
   - Design equations
   - Vessel supports

TABLE 2
Design II Course Outline
Spring Semester • 3 Credit Hours

1. *Design Problem* (different problem each year) [class size]
   - 1991 Revamp NGL processing unit (based on 1991 AIChE Student Design Contest Problem) [27 students]
   - 1992 Methanol from coal plant [27 students]
   - 1993 MEK from 2-butanol plant [29 students]
   - 1994 Ethanol production from molasses by fermentation [23 students]
   - 1995 Methanol plant (based on 1995 AIChE Student Design Contest Problem) [25 students]
   - 1996 Hydrogen from methane plant [37 students]
   - 1997 Ammonia from natural gas plant [23 students]
2. Special Topics
   - Flowsheeting, P&I diagrams, symbols
   - Short-cut design procedures, "rules-of-thumb"
   - Process optimization
   - Plant layout
   - Computer-aided design programs, ChemCAD III
   - Other topics, as required for the design problem

ing for the students, and preferably should incorporate a variety of basic unit operations and some form of material conversion. Exotic separation techniques or reaction systems are generally avoided due to their complexity, but may be included to illustrate the power and capability of computer simulation packages.

Students are guided through the plant design via a number of assignments that are distributed throughout the semester and are typically 10-14 days duration. Details of a typical assignment sequence can be found in Table 3.

Each assignment is comprehensive and in some cases requires the students to write computer programs to perform the design, *e.g.,* incremental design of a packed-bed catalytic reactor. Some aspects of the mechanical design of vessels are included where appropriate.

A report is submitted upon completion of each assignment, and currently each student is expected to submit a report, *i.e.,* report writing is performed individually. Although some level of collaboration between students does occur while working on these assignments, excessive collaboration is discouraged because overall course grades are individual and to a large extent are based on the assignment reports. Performing these assignments and writing the reports in teams is something that has been considered because of the "teamwork" experience that would be gained by the students and also for the reduced work load in evaluating the assignment reports. To date, however, we have continued to require individual assignment reports, mainly because we view student performance in this course as somewhat of an overall indicator of the student's ability, and as such we have preferred an individual assessment of performance.

USING FLOWSHEET SIMULATORS

Using chemical process flowsheet simulators, such as ChemCAD,[11] has been gradually introduced during Design II over the last five years. Initially, use was limited to certain assignments, and in some cases hand calculations were required prior to using the simulation package. More recently, use of simulation packages has not been limited and students

TABLE 3
Typical Sequence of Design Project Assignments

1. Process background and literature, overall material balance
2. Material and energy balances
3. Reactor design
4. Heat exchanger design
5. Distillation or absorption design
6. Miscellaneous equipment design and preliminary costing
7. Economic analysis, final report

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have been free to use them as much as they like. This approach, however, has had mixed results. Some students revel in the situation, can use the packages well, and get good results quickly. Others appear to become obsessed with getting a computer simulation to work for a situation where a few hand calculations would be perfectly satisfactory. As a result, a tremendous amount of time and effort is wasted on getting the packages to work rather than learning anything of engineering significance. This is the situation that we had tried to avoid by limiting package use previously.

One cannot question the ability of simulation packages to efficiently and conveniently perform many chemical engineering calculations, but one should never forget that using these packages is sometimes more difficult than doing calculations by hand, and that sometimes the results obtained may just not be realistic or appropriate for the situation being considered. Many students tend to present results obtained from a simulation without really considering their applicability. Sometimes a "back-of-the-envelope" hand calculation or "common sense" can reveal where problems lie. One should thus try to avoid situations where simulation packages are overused and thus become a substitute for a basic understanding of the chemical and physical phenomena occurring.

STUDENT FEEDBACK

Student feedback concerning these two courses has been generally positive. On the university-administered course evaluation, when asked to give the courses overall ratings, Design I received an average of 2.8 and Design II an average of 3.0 for the last six years (4=excellent, 3=above average, 2=average). When asked if they had learned a great deal from the courses, Design I received an average of 3.1 and Design II an average of 3.3 (4=strongly agree, 3=agree, 2=neutral).

On a departmentally administered comment sheet used for Design II, students were asked about the course's strengths, its weaknesses, and suggestions for improving it. As is typical for such a survey, there was a wide variety of responses. The general nature of the student comments was

> Course strengths: *Good capstone course, incorporating many of the skills and techniques learned throughout the curriculum; linked many of the topics studied separately prior to this course.*
>
> Course weaknesses: *Excessive work load and time-consuming; lack of guidance on some assignments.*
>
> Suggestions for improvement: *More guidance and details of what is expected on assignments; reduce workload (possibly by working in teams).*

The workload during Design II is high, and we are addressing the issue by making some curriculum changes that will allow us to distribute more of the workload between Design I and Design II. Workload during Design I is typically a lot lower than that required during Design II, and we believe that the changes that we will introduce in the near future will alleviate this problem and result in a more even distribution of effort. The teamwork issue is one that continues to be debated.

CONCLUDING REMARKS

The senior-year chemical engineering design sequence at the University of Dayton has evolved over the last decade. Some of the "new" innovations (use of process flowsheet simulation packages) have been introduced with some success, but for the most part we have retained a more traditional approach to teaching these courses. This was intentional.

We are living in a time when industry expects students to graduate not only with a good fundamental understanding of chemical engineering principles, but also with the skills traditionally acquired after graduation via industrial or work experience. The latter are skills best acquired in an actual work environment, and as such can be acquired by a student through internship or co-op programs. If a student chooses not to participate in these programs, then prospective employers need to appreciate that the graduate will be lacking that practical experience and associated skills. If the graduate possesses a good understanding of the fundamentals, however, then these experience-based skills can be acquired fairly rapidly in the work environment.

Universities, and engineering programs in particular, are under tremendous pressure to recruit students and then to retain them at all costs. As engineering educators, we must resist the impulse to accomplish these goals by "watering down" the programs. The design sequence described in this paper demonstrates our resistance to the trend and indicates that we are trying to provide our students with a good grasp of the fundamentals. Feedback that we have received from industry-employed graduates indicates that they have benefited from this approach and that they have been more than capable of competing and succeeding in today's work environment.

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