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AN ALTERNATIVE APPROACH TO THE PROCESS DESIGN COURSE

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A COURSE WHICH many departments find troublesome to teach is the senior level process design course. Problems may arise because there is no available faculty member with either significant design experience or who does research in the area of process design or simulation, and the option of bringing in an industrial practitioner may not be possible because of geographical considerations. Even when an appropriate faculty member is available, a question which must be addressed is: What goals should the course have, given the continual evolution of technology and the shifting of traditional positions of employment for BS chemical engineers? An additional consideration is: How can these goals be realized when the course is taken by second-semester seniors who can be expected to lose intensity after spring break?

In this article, the format of a senior design course structured for the present economic and business conditions and for a group of students with diverse interests, is described. In addition, the content and format are such that an instructor who is not an expert in design can still provide a useful and interesting course for the students.

The primary goals of the course are to

1. **Develop the students' ability to "create" good solutions to engineering problems for which many alternatives exist.**
2. **Expand the above goal to include all types of problems for which a student's knowledge or experience could be useful.**
3. **Improve written and verbal communication skills.**
4. **Encourage students to form a viewpoint about science and technology and to look beyond the current situation to see the bigger picture.**
5. **Expose students to some of the issues which they will face when they leave college for their chosen profession.**

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Goals 1 and 3 are traditionally present in any design course, but the other three, which are also important in the education of students who will pursue a broad range of career paths, are not. To meet these goals, elements other than design projects and lectures on topics related to design must be incorporated into the course.

The process design sequence at Notre Dame consists of two 3-credit courses which meet three times a week for fifty minutes. In the fall course, basic design topics such as economic analysis, short-cut design methods, process synthesis, and flowsheeting are covered. In addition, students are given instruction and practice (in the form of small projects) in the use of the process simulator Process™ [1]. Because many of the fundamentals of process design have been included in the fall semester course, great flexibility is possible in the content of the spring semester course. This allows for the opportunity of extending the curriculum of the design course to address goals 2, 4, and 5.

The components of the second semester course are:

- **A process design project**
- **A project which involves the invention of an original product**
- **Class discussions on pertinent moral/social/economic issues**
- **"Problems of the week" (defined below)**
- **Lectures on various topics**

Each of these features of the class will be described below in terms of the intended goal.

It is worth noting our experience with the use of a process simulator which allows for the simulation of some rather complex equipment configurations. The process for the separation of the light hydrocarbon stream required five distillation columns, ten compressors, numerous heat exchangers, and various other equipment. While this could all be simulated, the time involved in getting many separate pieces of equipment to work correctly was excessive.

PROCESS DESIGN PROJECT

Given the success of our "team teaching" approach in the undergraduate labs where four or five faculty members are involved (each having complete charge of two experiments), we decided to try a similar approach to process design. For this semester, four faculty members (including the course coordinator) were part of the course, with each directing two groups of three students on a single design project. The course coordinator had overall responsibility for the course, including lectures. With only one project to direct, each faculty member could become quite familiar with the details of his design problem and its potential solutions. He was therefore able to provide suggestions to assist the group's progress as well as to evaluate their performance. Two groups were assigned to the same project. This allowed for competition as well as for comparison of final solutions, but did not result in the problem being overworked, with all its subtleties "shared around," which often occurs when an entire class does the same project. The projects used were: separation system for a light hydrocarbon mixture (adapted from a CACHE problem, suggested by D. S. Maisel, which was implemented at Carnegie Mellon University); design of a separation scheme to remove dimethlyformamide from water (adapted from a problem in the Washington University AIChE Series, authored by Frank Rush and implemented at the University of Delaware); design of a process to produce ethanolamines (suggested and directed by J. T. Banchero, Emeritus Professor at Notre Dame); and a process which involved a novel use for waste whey (suggested and directed by F. H. Verhoff, an adjunct professor of our department).

The projects were chosen in consideration of a nine-week time constraint for completion. While this period is shorter than those usually allocated for large projects, I have been a student recently enough to know that the amount of time and effort spent working on a large project is not determined by the total time interval (or the difficulty of the project), but by the number of sub-parts (*i.e.*, progress reports) necessary for its completion.

The design project was introduced through a memo from the instructor which specified that a go/no-go decision on a particular project was to be made by the parent company on a specific and not-too-distant date (early April). The task before each group was to get the best possible solution as to the project's feasibility and its associated economics before that date. Intricate details regarding equipment selection were not to be addressed.

On the first day of class, and after being divided into groups, students were given a short written description of four projects and were asked to list their choices in the order of their preference. Not surprisingly, reflective of the time (and with no knowledge of which of the faculty was going to supervise which project), six of the nine groups listed the whey utilization project as their first choice.

Progress memos, specified as "on time or not at all," were due every two weeks, which made it necessary for the students to work on their projects virtually every day. This rate of progress allowed the major technical and computer-intensive work to be done before spring break. The progress memos were the standard type, with the first one requiring that the students examine the literature for answers to such questions as: Is there any current need for the process? What are the uses, the selling prices, and the world demand for the products? How are these expected to change in the future?

The groups met with their project supervisors each week for about a half hour. Depending on the skill of the group, the involvement of the instructor would range from making vague suggestions to examining specific details of the students' work. In general, the faculty tried to provide as little guidance as possible in hope that the groups would solve their problems independently.

It is worth noting our experience with the use of a process simulator which allows for the simulation of some rather complex equipment configurations. The process for the separation of the light hydrocarbon stream required five distillation columns, ten compressors, numerous heat exchangers, and various other equipment. While this could all be simulated, the time involved in getting many separate pieces of equipment to work correctly was excessive. Greater educational benefit would have resulted if the problem were simpler (in this case, fewer chemical components). This would have allowed more time for the students to take full advantage of a process simulator, *i.e.*, to propose and check numerous alternative

schemes and to spend more effort on optimization of the best scheme.

The memos provided an opportunity for the students to practice their writing. We have found that this is not an overwhelming necessity, however, since students at Notre Dame must take advanced humanities courses which require papers. In addition, our seniors have by this time completed two semesters of chemical engineering lab. Consequently, our students can write well if they take sufficient care. I was less certain about the ability of students to communicate verbally. To give them practice, groups had to give twenty-minute oral presentations to the entire class, describing the results of their projects. The presentations were surprisingly good. All of the students had given a similar report on at least one prior occasion (in the fall chemical engineering laboratory), and a lecture/discussion on the mechanics and goals of such talks was held in the current semester.

PRODUCT DESIGN PROJECT

Professor James Wei [2], expressing his concern for the future health of the chemical engineering profession, has made the statement, "We have to put a bigger share of our best brains into manufacturing; bring in people who can make the economic pie bigger rather than those whose job it is to divide up a pie that is already baked." This general idea has been expressed by many who worry that chemical engineers may become less valuable in society if they are limited to the design and operation of chemical processes. Encouraging creativity in our graduates is certainly one way to prevent the decay of the profession.

This part of the course, which occurred during the last four weeks of the semester, began with a lecture/discussion inspired by James Christensen [3] and Richard Felder [4,5]. At the beginning of one class period I mentioned to the students that they should not be limited by normal thinking, but should try novel methods for solving problems. They were then left to work on some in-class exercises which I had devised. Exercises which produced the most creative solutions were: develop a homework problem in fluid mechanics which involves a priest, a swimsuit model, and a sea creature; describe as many uses as possible (other than personal viewing) for a complete set of the episodes from the TV show *M.A.S.H.* on VHS tapes; and, devise an advertising strategy for a major Wall Street investment banking firm which wants to enter the consumer investment market.

With this introduction, groups were asked to invent a product which they feel is needed by the world but which does not already exist. The original intention that the product should be related to chemical engineering was loosely enforced. This allowed the students to consider any interesting ideas, and they were not limited by a lack of technical knowledge. The first memo, due within a few days, had to describe the reasons for their product and, more important to the goals of the course, had to include a list of (at least) ten ideas which were rejected. A wide variety of good and bad ideas filled the lists, some of which may have patent possibilities. The second memo, due two weeks later, was to describe the technical aspects of the product, *e.g.*, how it can be made, or what the exact design or chemical formula is. A final memo had to contain a rough economic forecast and describe the perceived market sector and corresponding marketing strategy. Again, oral presentations were given, describing the product to the class.

This time, however, a twist was included. As the project was originally formulated, an advertising campaign was required if the product was intended for use by consumers. When I included this in the original instructions, I did not anticipate that all the groups would pick consumer products. The consequence was that we were subjected to two and one-half hours of presentations, interrupted by commercials. One group made a video tape describing the technical aspects of its product, but most of the commercials were "live." While the strategy and style of the commercials were not really novel, the content was.

Needless to say, the students found this aspect of the course quite enjoyable; but how can we rate the educational benefit? I believe that it provided an opportunity for *all* students to use their creativity, which is not possible when solving difficult design problems. While design problems may lend themselves to creative solutions, only the very best students who understand all of the technical aspects are in a position to develop imaginative solutions. Weaker students are left to struggle along and to get any answer they can.

When I mentioned (to anyone who would listen) my plans to try such an exercise with a class of seniors, the typical responses were that either it would work great or it would be a total disaster. The verdict: It did work well. The students put in the time necessary to ensure the success of the project; if they had not exerted this effort, the idea would have failed.

The product design project allows for obvious extensions if time permits. The ASEE summary of the Quality of Engineering Education Project [6] mentions that, "Employers are generally satisfied with the basic technical preparation of today's graduates, but

find them largely unaware of the steps needed to bring new products from the idea stage to the marketplace and of the vital roles that engineers play throughout." Groups could be required to examine the manufacturing steps necessary to actually make the product, with the goal of identifying operations which could cause problems with reliability. In addition, marketing forecasts could be done in greater detail.

PROBLEMS OF THE WEEK

In an effort to improve the general problem solving skills of the students, problems drawn from everyday life, but which required engineering solutions, were posed and then solved using suggestions by the students. This was done at the beginning of class every Friday until time became too short to continue. The premise behind this part of the course is that most students need to think about solving problems when no clear subject (*e.g.*, fluid mechanics or thermodynamics) or method is implied. My favorite problem concerned keeping a Big Mac® hot in a car on a cold day. A simple heat transfer analysis demonstrated that it is better to keep the bag on the seat rather than under the heater. However, one particularly inventive student suggested that the glove compartment might be the ultimate solution.

Initially, I found that very few students would venture even a guess as to how to solve the problem. However, after about the third time they warmed up to the idea, and I subsequently got more than enough suggestions to solve any problem. On the only test, given at about mid-semester, responses to a question regarding the inevitable uneven cooking of a frozen pizza demonstrated that students were enjoying the challenge of solving such problems. The course evaluation questionnaires showed that students felt this was a very beneficial part of the class and that it should be expanded. A good suggestion which will be implemented in the future was to provide students with a summary of the solution after class so that no note-taking would be necessary.

LECTURES

The biggest problem which arises in teaching a process design course when the instructor does research in a field far removed from design, is the selection of topics and the development of lectures. Professor J. C. Kantor had taught this course previously, and during that time he had developed a set of course notes and identified literature sources for important topics, with the intention of enabling other faculty to teach the course. Lectures for the present course were adapted from his notes. Major topics included a survey of the products and economics of the chemical and petroleum process industries (particular emphasis was placed on specialty products), prediction of physical and chemical properties, and optimization. Individual lectures were devoted to batch processing, process reliability and quality control, multiphase contacting, interpersonal relations, and fluid pumping. In addition, an engineer from UOP Corporation gave a lecture on a specialized separation operation. One topic which will be included in the future is the selection and evaluation of separation processes.

CLASS DISCUSSIONS

One of the course goals was to encourage students, who are trained in science and engineering, to develop opinions about technology and its use. To effect this, some of the lectures had a definite point of view which could have been (and sometimes was) disputed. An additional aspect of the course intended to achieve this goal was to have class discussions on controversial topics, such as use/misuse of chemical pesticides and herbicides, or the productivity of the American work force (which was based on a preliminary release of an MIT productivity report [7]). The relatively small class size (twenty-eight) made this possible, and the format used was similar to a debate. Two teams of students prepared arguments for opposing sides of the issue. The rest of the class was free to join the discussion after the opening statements were made. It was not surprising that the students' ability to develop and express opinions was not correlated in any way to their grade averages.

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From the evaluation questionnaires it was possible to get an assessment of this feature of the course. Some students mentioned that it encouraged them to think of technology more broadly, but sometimes the arguments moved on to tangential issues or became totally unfocused. Nevertheless, two or three will probably be held next year, with an effort made to correct the flaws.

DISCUSSION

This course, which differs from traditional design courses in several respects, was structured to meet

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DISCUSSION

The leaching rig described here offers students a worthwhile laboratory experience due to its reliable and predictable performance. As long as a few preliminary calculations are done to set the operating parameters correctly within design limits, the run can be expected to proceed without a hitch. Failure to observe a simple set of logical rules will inevitably lead to disaster, with wasted hours of misery in unblocking underflow tubes awaiting the unprepared.

Experimental tasks using the rig can be made simple or sophisticated to suit the ability of the group. As most experiments attempt to demonstrate performance at steady state, one task set can be to show that steady state has been achieved within experimental error. More advanced questions involve adding economic constraints, *e.g.*, students may be told that the solute stream is the valuable product and that overall profitability of the operation is improved by the total recovery of the solute but is diminished as the stream becomes more dilute. Additional constraints may be that the operating costs of the operation increase as some function of the feedrate. With these considerations in mind, students are asked to perform an optimisation of the operation and then to make the rig work accordingly.

CONCLUSIONS

The apparatus described here represents the result of an integrated approach to design with an emphasis on teaching. The rig is functional, fits well with theory, and needs little maintenance. Its ultimate utility is limited only by the imagination of the user.

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ALTERNATIVE APPROACH

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the needs of a diverse group of students given the present economic and social climate. A survey of the students who took this course reveals that while six have jobs related to product development, only four of the twenty-eight (four are undecided) have accepted jobs which directly involve work on chemical processes. One has accepted a job as a financial analyst with a major New York investment bank. The rest are either going to graduate school (three in chemical engineering, one in law, and one in business), the naval officer program, or will work for firms that specialize in business systems and consulting. Clearly, the present format offered more to this particular group of students than would a course which included only topics traditionally considered as process design.

All indications are that the course was successful in meeting the intended goals. However, it must be noted that this was due in large part to the effort of the students. They worked hard for the first part of the semester to finish the design project. They also exerted significant effort through the end of the semester to make the product design project worthwhile, even though most of them had already accepted jobs.

The structure of the present course may break too far from tradition for the personal taste of many chemical engineering faculties. However, the time could be right to reconsider the content and structure of process design courses which were conceived when the majority of chemical engineers were employed in developing and operating large chemical processes.

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