GOALS OF AN UNDERGRADUATE PLANT DESIGN COURSE*

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PLANT DESIGN IS A PROCESS involving many different aspects, all of which are critical if a profitable product is to be produced. The purpose of an undergraduate chemical engineering plant design course is to acquaint the student with all the myriad aspects of the design process and to give them a feel for process design and its evaluation. It is important in this course to illustrate the difference between the scientific approach and engineering approach to a problem. The scientist will tell you what additional studies must be done or information obtained before an answer can be obtained. The engineer will, from a paucity of data, give an approximate answer and then tell you what must be done to improve upon it or verify it. It is also important to show that there are many adequate designs for any given product. Usually it will never be known which design is best since only one plant will be built and the engineers will do whatever is necessary to make it work. This is the place to wean the student from the concept that every problem has one and only one right answer. In fact some accreditors have insinuated that the essential difference between analysis and design is the difference between single answer and multiple answer problems.

The design course at Ohio lasts two quarters (20 weeks) and is a four hour credit course (each quarter). Most of that time is spent on the preliminary chemical engineering plant design of a specific process. The remainder is spent on short design problems and economics.

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Each year a different process is selected. I always choose a process which the class will be permitted to visit and have an opportunity to discuss with practicing engineers. It is at this meeting with those intimately familiar with the process that the student can have answered all the questions I could not answer in class. (I do not pose as an expert on the plant being designed. However, because I know the process of design and it is that process that I want them to learn, I am qualified to teach the course.) Here they can ask whether some design variation they have proposed is likely to work. Often, whether it will work or not depends on trace quantities of material which may precipitate at those conditions, or on whether an acid may be formed. These are things which a designer may fail to consider and which require process modification after startup. They are the things the university instructor cannot be expected to be familiar with and which often do not appear in the literature. This is what makes design an art.

The capacity I choose for the students' design is usually the same as the nominal capacity of the plant we will visit. This allows them to visually compare their calculated results with actual ones when the plant trip occurs. The benefits of this type of feedback are great. A person must be present during the plant tour to appreciate it.

Since the students will design only one type of plant, the plant trip is expanded into a three day event and we visit an average of six facilities. To prepare the students for this trip each of these plants is discussed from a process design standpoint prior to the visit. The trip, besides being educational, is also fun, promotes class cohesion and provides a needed break in a very rough quarter. The plant trip is a required portion of the course and one hour of credit is given for it.

The only information given to the class about

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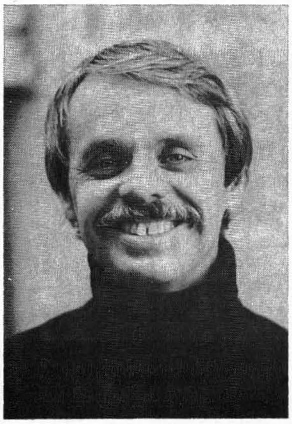

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the plant they will design is the product, the type of process to be used, and the nominal capacity of the plant. Everything else must be obtained from a search of the literature by the students. (Prior to the first class period I place on reserve all books related to the process which are available in the library. This gives all groups equal access to the volumes.) This brings the student into direct contact with the literature they will need in the future and it points out that finding information is often more difficult than performing calculations. As a result they learn that they can obtain estimates even when critical data are missing; very valuable experience because they will need to do this in the real world. My experience at both Dow and EPA is that many times the engineer will be called upon to obtain answers with no more information than the average student group obtains from the literature.

The students work in groups of three. Nearly every week they complete a written group report on a portion of the design. The sequence repeated below follows the chapters of my text [1] and their reports are similar to those presented there in the case study:

- **Background Report on the Process (2 weeks allowed)**
- **Site Selection**
- **Scope**
- **Unit Ratio Material Balance and Flow Diagram**
- **Major Equipment Specifications**
- **Plant Layout**
- **Instrumentation**
- **Energy Balance and Pumping Sizing**
- **Energy Equipment Sizing and Manpower Requirements**
- **Pollution Abatement Equipment Sizing**
- **Cost Estimation**
- **Economic Evaluation**

The plant trip usually takes place around the time of the instrumentation report. Ideally it would be a week or two later but a plant trip in mid or late November may encounter bad weather and safety considerations rule against it taking place then.

Working together in groups is a valuable experience for the students. This is one of the few times where their grade is very dependent upon how well the group cooperates. Plant design is usually too time consuming for one person to do it all. Even when this is possible and actually done, it is very annoying for the student doing the work to realize that two other individuals received a high grade solely because of his or her efforts. Still more annoying to other groups can be the feeling that their group received a low grade because one member of the group shirked his duty.

These group experiences are simulations of the types the student will encounter in industry and government . . . working in groups also promotes learning. In this situation the student is in an active rather than passive mode.

I encourage the students to see me if they are having personal problems within their groups. A number of times students have taken me up on this offer. It usually occurs because a student is not pulling his own weight. In this case I meet with the whole group and we decide what should be done. The usual result is that the student not working receives a lower grade on the group work than the others.

These group experiences are simulations of the types the student will encounter in industry and government and this introduction to group dynamics is very important. Much of their professional life will be spent working with others and getting others to work with them.

Working in groups also promotes learning. In this situation the student is in an active rather than a passive mode. He is taking part in the direction of the project. Others will criticize his ideas and he will have to defend them. It permits him to see how the others approach problems. Pedagogically, being in an active mode with ones

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At times I have let the students choose their groups. However this often has an adverse effect on minorities, like women and foreign students. The best overall result seems to occur when the faculty member selects the members of the group.

Each week two hours of class time are devoted to oral reports by the students. At this time two groups give a report on their progress for that week. There are a number of reasons for requiring oral reports. One is, of course, to give them experience giving reports. A second is to illustrate that there are design possibilities which most groups didn't consider. A third is to point out problems that might arise if certain approaches are used. Last, it is an excellent place to point out erroneous assumptions and incorrect calculation procedures and to correct mistaken impressions. It is an excellent time to reinforce the concepts presented in unit operations, kinetics, automatic control, thermodynamics and other courses. Forcing the student to express these is an excellent reinforcement of basic principles and can firmly place them in a student's mind. It should be a major secondary goal of all plant design courses.

To aid the students in improving their presentations, one of their oral presentations is videotaped. Immediately after the class this tape is played back for them and they can then note any mannerisms which are distracting or annoying. Generally, no comments from me are required. Their strengths and weaknesses are obvious.

Because all the students are involved in the design of the same process, their oral reports to the class are potentially more interesting to other class members than the usual student reports. To encourage active discussion rather than passive listening I give the students two bonus grade points for each oral presentation session in which they enter into the discussion. (The written reports are graded on a twelve point scale.) I encourage those students who are shy or have difficulty speaking to prepare statements in advance so they get accustomed to speaking.

As another experience in group dynamics, instead of giving oral reports for the site selection topic, the students spend the class time selecting the best site. Each group is charged with coming up with a specific site in advance of the meeting and the class is then charged with picking a site before they leave the classroom. No directions are given as to how this should be done. They are told, however, that the site they select will be their plant location henceforth. After this meeting I discuss group dynamics and how it can affect decisions. I also discuss sensitivity training and how it was once used as a management training tool.

In addition to the time for oral presentations by groups, the class meets two or three times a week. During this time I answer questions, discuss problems that arise, give encouragement, lecture on topics not covered by the text, and expand on topics presented. Some of the topics presented are:

a) Design of Plants to be Visited during Plant Trip
b) Future Energy Availability
c) Siting Plants in Foreign Countries
d) Steady State Economics
e) The World Scene and the Chemical Engineer
f) Predicting the Future
g) Pollution Abatement
h) Environmental Assessments (to be added in the future)
i) Safety
j) CPM and PERT
k) Specification Sheets and General Specifications
l) OSHA and EPA Rules
m) International Economics
n) Instrumentation
o) Startup
p) Piping and Instrument Diagrams
q) Things That can go Wrong
r) Risk Analysis
s) Socioeconomics

Since no engineering economics is required as a prerequisite for this course, about three weeks is devoted to this topic. During these periods most of the class time is spent discussing the problems assigned. A test is given at the end of this portion of the course. It counts the equivalent of three reports. Grades are based on the weekly written group reports, the economics examination and the student's individual oral participation. No examinations are given other than the one in economics.

One of the major problems with this course is that it is very time consuming, both for the student and the faculty member. The student learns that he must plan his time or he will never finish. He is expected to do something which would take a professional engineer more time than he has available. I have tried to consider options as to how to reduce the time that they, and I, spend on the course. However, everything I have considered would significantly reduce the learning experiences of the students.

Short problems certainly could reduce grading time since graduate students could do the grading. However, they do not show how every decision made in the scope affects the result. They don't illustrate the interrelation of all parts of the design. By failing here they don't succeed in illustrating the total process of design. They are often single answer problems. They usually tend to be nothing but extensions of the types of problems given in other courses. There is also a tendency of short problems to provide the students with all the required information rather than forcing them to find most of it. This will not prepare the student for the vaguely defined problem with little or no data which he will confront in industry or government.

Some instructors feel time may be saved by using a computer program to do routine calculations. This certainly is true in industry where numerous calculations of the same kind are frequently repeated. However, before any computer program is used, all the assumptions must be understood so the program is not misused, and the format for entering data into the computer must be learned. Each of these takes time. The former takes the most time. Since most calculations are not repeated very often and various good sources of quick estimates are available [1, 2, 3] it does not appear that any time is saved. The potential loss is that the student doesn't have to review previous course material. Students will very happily plug into programs without trying to understand them. This prevents them from achieving one of my secondary goals, reviewing previous course material. They will also happily spend hours manipulating the programs. This time could be more profitably spent elsewhere.

With computers a more accurate, consistent design will result. It will be much easier to make changes, to perform numerous sensitivity analyses, and to optimize the design. None of these, however, are goals for my course. It is important for students to understand that these tasks can be done; however it is not necessary this be done in the context of the total plant design. These goals can be achieved just as well with simpler examples where the concepts do not appear as mysterious.

In summary, the major goal of the course is to give the student an understanding of the process called plant design. This is done by having the student perform a plant design and by completing the design the student shows he has obtained this understanding.

In addition to the major goal there are also many important secondary goals. These are:

- **Learning to work with others.**
- **Improving report writing.**
- **Improving oral presentations.**
- **Learning to find what is available in the chemical engineering literature.**
- **Learning to obtain answers when little data are available.**
- **Correcting mistaken concepts.**
- **Reinforcing course material to which they have been previously exposed.**
- **Learning there is more than one way to approach a problem and there usually is more than one solution.** □

REFERENCES

1. Baasel, W. D. "Preliminary Chemical Engineering Plant Design." American Elsevier Publishing Company, New York, 1976.
2. Aerstin, F, Street, G. "Applied Chemical Process Design." Plenum Press, New York, 1978.
3. Clark, J. P. "How To Design a Chemical Plant on the Back of an Envelope."
   (a) Ground Rules. Chem. Tech. November 1975, p. 664-667.
   (b) Facts and Their Interrelation, Chem. Tech., January 1976, p. 23-26.
   (c) An Example. Chem. Tech., April 1976, p. 235-9.

ChE book reviews

LABORATORY ENGINEERING AND MANIPULATIONS

By E. S. Perry and A. Weissberger
John Wiley, 1979

Reviewed by John R. Hallman
Nashville State Technical Institute

For the individual who has acquired a chemical (2-year associate) degree (engineering oriented), the chemical engineering technician or the graduate chemist with mechanical ability, this book would serve well in the intended use. However, for the chemist who is not mechanically oriented, usage would be limited; but with careful study the latter person could use the material in

Continued on page 41.