Evaluation of an Approach to Plant Design

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Plant Design is taught at McMaster University in two courses. The theory and design of pieces of equipment are discussed as part of a four credit course called Economics and Technology. This is taught to fourth-year students for both the fall and spring terms for two hours a week. In addition to this course, three credits are given to a senior project laboratory: an 80-hour workshop in the spring term. This paper evaluates a novel approach to the project laboratory. The major novelty arose in (1) the student's responsibility, (2) the time allocation, (3) the staff supervision, (4) the outside judging committee, and (5) the problem specification. These are discussed, and the evaluation follows.

Project Description

The Student's Responsibility:

Each student decides how he is going to make the quantity of specification material, designs his own plant, submits a complete report, and verbally defends his approach and design before an outside committee.

Time Allocation:

Eighty hours and only 80 hours are to be spent on this project. Each student draws up a time schedule for his calculations; then the students meet as a committee and draw up a work schedule that will be adhered to by each. The schedule breaks into a number of major stages. At the end of each of these, the students meet with the staff for an hour of constructive criticism about how each has handled the assignment.

The 80 hours are divided into a 12-hour/week design laboratory that simulates an industrial situation. A room is booked, a filing cabinet is placed at the student's disposal, and the design laboratory is not supervised; but the students are expected to be either in the booked room or in the library during the design laboratory time. We emphasize that they are not to work outside of class time.

Full marks are given for the most efficient use of the time the student allots himself for each calculation. Marks are deducted if he does not have each project finished on time; if he does a five-minute calculation for a three-hour period or if he spends time doing unimportant and unrelated calculations, he loses marks.

The marking scheme for each criticism session is based on a total of 10 marks for every hour of design laboratory that has elapsed since the last criticism session.

The Staff Supervision:

1. Give constructive criticism after each major design effort. While each completed project is fresh in the student's mind we explain how he could have saved himself time, and suggest reliable short cuts and good design technique. The staff members with the most experience in the given field criticize the effort.
2. Are prepared to present request-lectures *before* each major design effort. Any staff member will present a maximum of a one-hour workshop or discussion session provided such a workshop is requested by the students at least two days in advance of the lecture time and provided that hour is the first hour of the allocated project for the topic under consideration.

The staff are not consulted otherwise. All the staff are involved in this project.

The Outside Judging Committee:

The students design their plant for three outside judges, and not for the staff members.

To the judges we suggest a complicated marking scheme for the oral presentation. (The four page, typed report from each student that is given to the judges provides background information for the judges. We feel that it is too burdensome to ask them to mark the written reports). After each presentation, the judges are given as much time as they want to finish evaluating one speaker before the next starts.

The Problem Specification:

Little information is provided in the specification. The quantity and quality of a given product and the utilities available—these alone are given. Table I is a typical specification.

The students are informed also of the emphasis expected and the report specifications.

All calculations are to include assumptions and limitations and estimated accuracy for each answer. The calculations must be legible and easy to follow.

Specifications are required for each major piece of equipment. For heat exchangers, a standard 1-in. nominal tube is stipulated and details required include approximate tube count, tube length, and pitch; shell diameter; baffle spacing; pipe connections; material of construction; working pressure; and mounting instructions. A detailed calculation for the selection of one pump is needed. The types of control required must be indicated but not specified. The mechanical design of the reactor and of one of the major pieces of separation equipment is to be included.

The production and the capital investment costs are to be calculated.

The report:

The design report must be turned in one week before the presentation day and later is filed in

TABLE I. DESIGN PROJECT SPECIFICATION

Desired: A plant to produce

50 long tons/24 hr. of 95% pure monomeric styrene

or

300 long tons/24 hr. of 95% pure monomeric styrene

Utilities available:

Fuel oil

Natural gas

Electricity

Cooling water: Lake water 5°C. (winter) and 20°C. (summer)
City water (same average temperature)

Steam: 200 psig, 100 psig, and 50 psig (all saturated)

the chemical engineering department library. The report consists of two parts: the body and the appendix.

The body is a four- to five-page, double-spaced, typed summary report of what was done, why it was done, how it was done, and what conclusions were drawn from the calculations. The purpose of the report is to convince the outside committee that the best possible design has been turned out in the time available. The readers are the outside committee, a group with chemical engineering training who may or may not be familiar with the subtleties of the design topic. Four copies of the body of the report are required.

The appendix of the report is a well-indexed collection of all of the actual calculations done, together with appropriate summary pages interspersed throughout the work. The calculations need not be typed; but they must be legible and indicate the calculation approach. The purpose of the appendix is to supply a complete record of all of the calculations done on the design project so that anyone who had to do a more elaborate design can go one from where each student stopped rather than be forced to recalculate work that has been done. The average reader of the appendix will have a chemical engineering background, will probably know nothing about the design topic, and will be interested in learning what has been done and what are the limitations and assumptions involved in the calculations.

Evaluation

The advantages and the weaknesses of this approach to design teaching are outlined as follows.

Advantages

We have found the following advantages:

1. The outside committee adds reality to the project for the students. The students' emphasis is shifted so that they are working against the outside committee and its evaluation, rather than against a staff member for a grade. The students feel their reputations are at stake. Twenty percent of the final class mark depends on the outside committee's judgment. Our outside committee members not only have been very learned in the field but have asked stimulating and probing questions. The committee for the styrene project included a senior process designer from Dow Chemical (who produce styrene), a senior chemist in the petrochemicals division from Polymer Corporation (who also make styrene), and a University of Toronto colleague who ran the plant project design there.
2. The students enjoy the individual responsibility. Since we do not form companies, each student has to do his own creative design and

justify it on the basis of economics.

3. The students enjoy the diversity of responsibility, including choice of process, design, and cost estimation. They say they prefer to make an overall, high-spot design of a complete process rather than a detailed design of an element of a process.

   Twelve hours of design laboratory time are free between the time the students hand in their reports and the oral presentations. We use this time to build a scale model of one student's plant. For the degree of accuracy required, we found that this could be done for a styrene plant for about $10. The scale was 1/4 in = 1 ft.
4. Lectures are given only at the students' request. Most want to get on with the job; few lectures are required. This pleases the students and the staff alike because we feel that they are asking and answering their own questions.
5. The criticism periods after each major design effort give rapid feed-back of suggested improvements and the type of assumptions to make. Since any lectures are at the request of the students, we want strong feed-back on their approach as they proceed.
6. The limitation for the time spent on this project is worthwhile. The students do not jeopardize their standing in other courses by devoting excessive extra time to this course; they learn to match their designs to the time available. The marking scheme for the criticism sessions accentuates matching time with accuracy.
7. The marking scheme specified to the judges requires about 10 minutes per speaker. Although the judges think the marking scheme cumbersome, we find it very helpful to the students.
8. It is easy to rate each student.
9. Staff load for the course is distributed among the staff members. Furthermore, the students gain from the background experience of staff specialists in the criticism periods.

Weaknesses

Some weaknesses of this approach are:

1. An apparent lack of understanding of the role of plant design in an economics analysis. The students do not seem to realize that the preliminary plant design is done to improve their accuracy in their economic assessment of the process. We think that the onus of this is not upon the design course but rather on the economics and technology course which one of us also taught. In the future we plan to be more specific in the students' purpose in doing the plant design.
2. Inadequacy of decision-making theory. The students do not fully appreciate the consequences of the various decisions made. More emphasis will be given to this topic in the economics and technology courses in the future. For example, not only will we creatively look at process flow sheets as we do now, but we will do exercises on getting quick numbers for equipment cost for several different flow-sheets. This training in cursory equipment costing should help them to allocate their design time for any preliminary design project itself.
3. Inadequacy of the criticism sessions. Whether the improvement is achieved by converting the sessions into a verbal presentation to the combined staff after each sub-project or by supplying more staff manpower to correct and criticize individual efforts, the whole key is the constructive criticism of the student's effort at various stages along the way immediately after he has completed his work.
4. Poor distribution of staff responsibility. The staff coordinators sometimes do not call on other staff members to help out enough.
5. Paucity of time available for the design. The completeness of the project could be improved either by requiring the students to do some work outside the specified hours, by forming companies of design engineers, or by reducing the scope of the project. Increasing the student's homework is easy to justify because our fourth year, second term load is relatively light. The formation of companies requires careful consideration. The advantages for individual design that both the staff and the students have appreciated are
   (a) each student is completely responsible for all of the decisions and calculations.
   (b) each sees all facets of the design rather than working on his specialty with figures that are handed to him by someone else.
   (c) each realizes that the individual mark can be given at the end of the project.

   It would be interesting to see if we can incorporate all of these advantages by forming companies of two students and by insisting that each student be able to defend *any* part of the final design. The suggestion of reducing the scope of the project has received a negative reaction by the students.
6. Poor technical communication. Although the general reaction to the student's oral presentation has been favorable, the written reports are poor. We have introduced a two-credit course in technical communication into our second-year program in an attempt to remedy the situation.

Summary

A novel approach to teaching plant design is being developed at McMaster University. The uniqueness of this approach lies in the method of handling the student's responsibility, the time allocation, the staff supervision, the judging committee, and the problem specification.

An evaluation of the approach, based on its application to one project with a class of fourth-year students, shows that it has many advantages and several weaknesses. With the correction of the latter, the approach should offer great promise as a powerful method of teaching design.