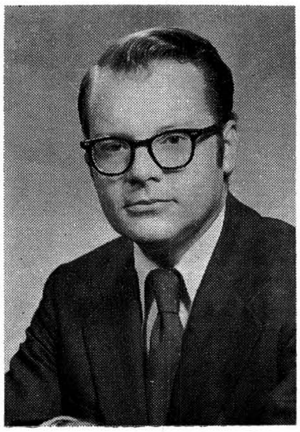
A Freshman Course

THE CHEMICAL ENGINEERING PROFESSION

RICHARD ALKIRE
University of Illinois
Urbana, Illinois 61801

IN ORDER TO PROVIDE better and earlier awareness of the nature of chemical engineering, a freshman course has been developed at the University of Illinois at Urbana-Champaign. The objective of the course is to provide a qualitative picture of ChE and to describe the scope of professional activities into which chemical engineers enter. Too often, choice of a curriculum is difficult for beginning college students because they do not have good information about the consequences of their choice. For example, the traditional first technical course in ChE (material and energy balances) is at the end of the sophomore year. As a consequence, important career decisions are often made by prospective chemical engineers on the basis of their interest, or lack thereof, in chemistry, physics and mathematics instead of on the basis of knowledge about ChE.

The content of a freshman orientation course depends upon such things as the individual teaching the course, the class size and composition, the number of credit hours, the style and nature of the ChE department concerned and the relation among engineering departments through core programs. This paper outlines one route which has been found effective.



Professor Alkire studied Chemical Engineering at Lafayette College and at the University of California at Berkeley. He has been on the faculty of the University of Illinois since 1969. In addition to teaching, he carries out a research program in the area of electrochemical engineering.

TABLE 1: Course Outline

Introduction
(a) The Nature of Chemical Engineering: chemical reactions, separation of chemicals, large-scale processing
- **Nitrogen fixation**
- **Synthetic rubber**
- **Moonshine**
- **Penicillin**
- **Soap and detergents**

(b) The Activities of Chemical Engineers
- **Research and development**
- **Process evaluation and design**
- **Plant operation**
- **Sales and Marketing**

(c) Defining Engineering Problems: common sense, the scientific method, and economic awareness
- **Engineering and chemistry**
- **Economics of alternative reaction paths**
- **Material balances and species allocation**
- **Choosing separation methods**

COURSE DESCRIPTION

THE COURSE, "The Chemical Engineering Profession," is required in the second semester of the freshman year and has as prerequisite one semester of college chemistry. The 1-hour course meets fifteen times during the semester. There is no required text. Grades are based upon homework problems, a field trip report, and a semester paper.

Lecture content, outlined in Table 1, includes use of slides as well as demonstration experiments performed by the instructor or his assistant. The lectures are grouped into three general topics:

a) **The characteristics of chemical engineering which distinguish it from other disciplines.**
b) **The activities of chemical engineers.**
c) **The importance of combining common sense, the scientific method, and economic awareness in defining engineering problems.**

TABLE 2: Demonstration Experiments

Soapmaking

Soap is prepared from lye and lard by the assistant following the instructions on a lye bottle purchased in a grocery store.

Nucleate vs. Film Boiling

A copper tube containing a thermocouple is immersed in liquid nitrogen and the cooling curve is recorded on a strip-chart. The tube is then removed and coated with a thin layer of vaseline and immersed again. The insulated tube cools faster because nucleate boiling occurs instead of film boiling.

Cooking Hot Dogs

A thermocouple is inserted along the axis of a hot dog which is plunged into boiling water, and the increase of temperature at the centerline is recorded and compared with theoretical unsteady-state heat conduction calculations.

Time Bombs

Cans are prepared according to instructions in the reference and filled with natural gas. The gas is ignited and the time before explosion is recorded and compared with theoretical models.

Polyurethane Foam Demonstration

Ingredients from a commercially available foam kit (Mobay Chemical Co., Penn Lincoln Parkway West, Pittsburgh, Pa. 15205) are mixed and the exothermic process occurs. After two minutes the foamed plastic is rigid.

Nylon Rope Synthesis

6-10 Nylon is synthesized from sebacoyl chloride and hexamethylenediamine by interfacial condensation. The nylon skin is removed from the interface, forming a rope, and is wound upon a rod.

Additional experiments planned for the near future include demonstrations of viscoelastic behavior [12], pseudoplastic flow [13] and a model Solvay tower [14].

The demonstration experiments which accompany the lectures are outlined in Table 2.

The first lecture emphasizes the economic need for chemicals and how a ChE background gives access to many business areas in addition to the purely technical aspects which are seen by the students in coursework. An introduction to the department is always of interest: the layout of the building and labs, the faculty size, number of students in the curriculum, the nature of employment and salaries of recent BS graduates, and the fraction going on to graduate education. A list of trade periodicals (CEP, C&E News, *etc.*) is provided along with the library location and procedures. It is also useful to provide information about applications for scholarships and loans which might be available.

Lecture Group (a) emphasizes three characteristics of chemical engineering:

- **Ch.E.'s understand chemical reactions.**
- **Ch.E.'s know how to separate chemicals.**
- **Ch.E.'s know how to carry out processes on a large scale.**

Slide presentations are used to show flow sheets and process equipment. Nitrogen fixation is a good example since ample material is available [1] to illustrate all three points. The manufacture of synthetic rubber is also well-documented [2] so that a slide presentation can be prepared. As a change of pace, a discussion on making moonshine [3] gives a good opportunity to point out dilemmas involving materials of construction, siting the facility, process engineering, production problems, quality control, marketing strategies, and ultimate plant recovery. The production of penicillin [4] is always impressive owing to the conditions under which the process was developed. The small-scale home preparation of soap [5] (Expt. #1, performed in class) can be compared with commercial manufacture of detergents.

IMPORTANCE OF INTUITION

Lecture Group (b) consists of examples ranging from R&D to marketing. The discussion of research emphasizes the importance of intuition and the ability to predict and to scale-up. Experiment (2) (nucleate vs. film boiling) usually tricks the student's intuition and leads nicely to a discussion of optimum heat exchanger fin design [7]. Results from Experiment (3) (cooking hot dogs) can be compared with unsteady-state heat conduction calculations for a rigid solid [8]; agreement within 10% is usually obtained. Experiment (4) (time bomb) is especially impressive [9] and demonstrates scale-up criteria by

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mathematical modeling. It is important to emphasize the value of graduate education for those interested in R&D endeavors.

Process evaluation and optimum design is nicely illustrated by the design of an overland sulfur transportation system [10]. To stimulate the imagination, Experiments (5) (polyurethane foam) and (6) (nylon synthesis) are good examples for drawing out further discussion. Problems of designing around hazards [15], and analysis of plant failures [16] always makes a sobering impression of the energy contained in chemical plants.

Plant operation, process engineering and process management topics can be brought out through presentation of slides of process equipment. For example, I obtained from a campus recruiter a detailed sequence of several dozen slides involving a pipe-still furnace. Of special value at this stage in the course would be a field trip to a local production facility.

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Marketing, sales engineering and higher-level management are areas where the importance of communication skill, personal style and business acumen can be emphasized. It has been difficult to obtain ancillary material for this portion of the course, and I rely upon personal experience.

Lecture Group (c) is based primarily upon materials contained in Ref. [17]. A good starting point is the discussion of different perceptions of advantageous routes for carrying out chemical reactions as viewed by a chemist *versus* a chemical engineer (Chpt. 2, Ref. [17]). The dichotomy emphasizes once again the chemical engineer's concern about large scale processing with impure substances under economic and safety constraints. For example, the evaluation of five different process routes for phenol production provides a good basis for extended discussion. Economic aspects of choosing different reaction paths (Chpt. 2, Ref. [17]) is impressive to students since it demonstrates the narrow profit margin involved in large-scale production. Related aspects include uncertainty of feedstock price, sudden application of pollution standards on by-product disposal, development of new processing technology, the economic nature of the market for the product, and establishing the optimum return on investment needed for competitive survival. Once the best process route is chosen, a discussion of species allocation and flow sheets (Chpt. 3, Ref. [17]) demonstrates the importance of common sense and good engineering intuition, including an awareness of corrosion and classical physical chemistry. An introduction to simple material balances is always of interest since the students know that the next ChE course will begin at this point. Once the process flow sheet is developed, the problem of choosing the best separation method provides another basis for a common sense approach (Chpts. 4 and 5, Ref. [17]).

Lecture Group (c) often motivates students by demonstrating the importance of learning their engineering and scientific fundamentals in order to develop their intuitive prowess. It becomes abundantly clear that the act of defining technical problems is central to good engineering, and that that act requires application of the scientific method, common sense, and economic awareness.

ADDITIONAL TOPICS

SEVERAL ADDITIONAL topics can be salted into the foregoing outline as the mood of the class dictates. An important topic is graduate education; students are usually interested in engineering, business, medicine and law. I outline the time-scale for making these decisions, mention the different financial arrangements involved and, within engineering, describe the different styles which departments may have respect to graduate program, the better students often begin thinking about their next move at this time. For detailed examples of research in engineering, I draw upon my own program and sometimes invite a graduate student to give a short presentation of his research topic.

Another topic concerns departmental affairs in which freshmen can participate such as A.I.Ch.E. Student Chapter Meetings. We also have an Engineering Open House for which freshmen often prepare demonstration experiments as a basis for their term paper. Such activities often create a sense of identity and pride which sustains student interest in ChE in face of challenges in other coursework.

EXPERIMENTAL RESULTS

THE COURSE HAS BEEN presented four times with class sizes ranging between 23 and 75 students. There was no difficulty in stimulating class discussion even with the larger class sizes. Students from other departments constituted about 14% of class enrollments.

The letter grading of the course is necessary because it is a required course. The grade is usually based on homework (50%), term paper (25%) and plant trip report (25%). Because the plant trip is not required for the course, those students who do not attend are asked to imagine what they would have seen and submit a brief report of their imagined observations. The average grade distribution to date has been: A–53%, B–30%, C–11%, D–3%, E–3%. I suggest that the D and E students drop ChE, and that the C students think carefully about their career choice. Grading by pass-fail would be attractive if it were possible.

Homework problems were chosen so that the students had the opportunity for extended pursuit of the problem if they wished. For example, instructions were provided for the home-made production of soap by the batchwise process demonstrated in class in Experiment (1); in addition, the chemistry for a two-step (hydrolysis/neutralization) process was provided. Students were asked to evaluate which process makes it possible to design for continuous, not batchwise, operation, to estimate production rates for one million people, to develop a flow sheet for a continuous process and discuss the overall engineering design. Three or four homework problems were usually assigned during the semester. The response was very conscientious, with the better quality problems often running ten pages of discussion.

In defining the term paper, the students were instructed to choose any appropriate topic which interested them and pursue it in whatever manner they saw fit. I offer to help discuss paper content if the students come to me with a topic in mind. The papers were surprisingly articulate, well-poised and conscientiously executed. In many cases, students performed experiments, did calculations or literature reviews, and submitted physical props in support of their work. Preparing the term paper was the most valuable experience to many because it got their feet wet.

A good starting point is the discussion of different perceptions of advantageous routes for carrying out chemical reactions as viewed by a chemist versus a ChE. The dichotomy emphasizes the ChE's concern about large scale processing with impure substances under economic and safety constraints.

A teaching assistant is essential for preparing lecture demonstration experiments, grading, and developing course improvement topics. For the range of class sizes encountered, a single assistant was adequate.

The course content, including slides and demonstration experiments, was developed without excessive effort in a period of about six months. During this time the ChE trade journals were scanned regularly, along with the standard texts on chemical processing. The major difficulty was in developing demonstration experiments and obtaining slide sequences of process facilities.

A crucial aspect of the course lies in sensing the mood of the class, and not proceeding too quickly into detailed discussion if their interest is not yet aroused. Because the course met only once a week, each lecture had to be complete in and of itself.

Although it is difficult to measure success of freshman courses, one can claim that the retention of freshmen into the sophomore year is a useful measure of whether the course succeeds in developing interest in the curriculum. For the six years prior to offering the freshman course, the average retention of second-semester freshmen into the sophomore year was 57%. For the period during which the course has been offered, 86% of the students who took the course continued into the next semester in ChE. Although such data are influenced by any number of other factors, it seems reasonable to suggest that the course has contributed to increased retention to a considerable extent.

SUMMARY

A ONE-HOUR FRESHMAN course for chemical engineers has been developed in order to provide qualitative information upon which career decisions may be made by students. Discussion topics, including lecture demonstrations, are chosen to illustrate the wide scope of ChE activities. Students have open-ended avenues of response through homework and term projects.

Freshman courses could also be built around the development of quantitative skills through which insight into engineering methods may be gained. However, with respect to the goal of career orientation, the development of quantitative skill to sufficient depth would be difficult to achieve in a one-hour course. The qualitative

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DOUGLAS: ChE Educator

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university research administrators. He prepared a proposal for submission to NSF without the usual overhead funds in the budget. The document managed to clear all but the Treasurer's Office. When news of the attempt filtered back like a water hammer, there were an awful lot of red faces, but not Jim's.

DOUGLAS AS ENTREPENEUR

ONE ROLE AN ENGINEER often plays is that of an entrepreneur. An outgrowth of Douglas's interest in sailing brought him into partnership with two other engineers from U. Mass., seeking to develop new metal forming procedures useful in forming hulls. His avocation energized an interest in Engineering Entrepreneurship and developed course material for both undergraduate and graduate courses.

We began this article with a clear exposition that James M. Douglas is an uncommon man. This we have shown as true in all his pursuits of scholarship and of leisure. His intensity fires the interest of students and of some colleagues, and the passions of others. "L'éminence grise" (for the gray hair) continues to be a major contributor to the growth of this department and the chemical engineering profession. □

ALKIRE: The ChE Profession

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course described here achieves its purpose in an efficient manner. □

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WILLIAMS & COSART: Freshman Analysis

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has been enthusiastic. We feel that they have a much better understanding of chemical engineering and are certainly much better equipped to handle a rigorous stoichiometry course in the next semester as a result. □

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ChE news

WORCESTER, Mass.—Dr. Imre Zwiebel has been appointed head of the Worcester Polytechnic Institute chemical engineering department, effective Sept. 1.

He has been a member of the WPI faculty since January, 1964, when he came to Worcester after three and a half years as a research and development engineer with Esso Research and Engineering Co., Linden, N.J.

A native of Budapest, Hungary, he came to this country in 1948 and was educated in New York City. Following graduation from University of Michigan with a bachelor of science degree in chemical engineering, he was employed for three years by E.I. DuPont Demours & Co. in Wilmington, Delaware.

He held four fellowships at Yale University where he received both Master of Science and Doctor of Philosophy degrees.