ChE classroom

USAGE OF MULTIPLE-CHOICE EXAMINATIONS IN CHEMICAL ENGINEERING

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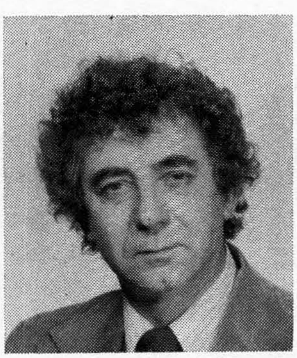
It is most disturbing . . . to hear from students, near or upon graduation, that they have earned their engineering degree on the basis of partial credit.

THIS ARTICLE DESCRIBES extensive experience with the usage of multiple-choice examinations in various undergraduate chemical engineering courses at Georgia Tech over the past four years. A number of factors, quantitative and qualitative, have led the author to experiment with such examinations.

First, the student/faculty ratio at Georgia Tech is higher than at most other schools and this ratio has increased over the past five to six years. The addition of nine faculty last year (six new slots and three replacements) has brought some relief but the student/faculty ratio is still high.

Undergraduate enrollment in chemical engineering at Georgia Tech today is about 1000, up from just over 300 in 1974-75 [1]. A full-time work load is defined by the Board of Regents of the University System of Georgia in terms of 100% teaching as 15 hours per week. Since most engineering courses carry three credit hours, this official load translates to five courses or sections per quarter.



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Teaching loads in chemical engineering are reduced below this five-course level based on faculty efforts in student counseling, research and direction of graduate students, paper and proposal preparation, administration and service. Thus, most chemical engineering faculty have been responsible for one or two courses per quarter during the past year.

The combination of increased student numbers, not enough faculty and a commitment to improve our graduate program has led, however, to large class sizes (one or two classes per quarter have in excess of 100 students). Thus the grading of examinations in our engineering courses has become a rather ponderous task, particularly if the examinations are to be returned to the students within a reasonable period of time. The usage of multiple-choice examinations, especially when computer scoring of the examinations is employed, obviously facilitates the grading process, in comparison with conventional problem-based engineering examinations. It should be appreciated, however, that a considerably greater amount of effort is required at the front end of the process, that is, in the actual construction of multiple-choice examinations for engineering courses. This point should become quite apparent in later sections of this article.

From a qualitative point of view based upon several years of experience, the author feels that multiple-choice examinations are superior to conventional problem examinations for a number of chemical engineering courses. Using a larger number of relatively brief exercises in a multiple-choice format allows the instructor to examine the students on more concepts. Admittedly, complex problems cannot easily be handled with such an examination format, but they can be accommodated through homework assignments and classroom discussion. Another positive feature of a multiple-choice format is that it encourages students to arrive at correct answers, a facility that is all too often lacking in many engineering students. It is most disturbing to engineering professors to hear from students, near or upon graduation, that they have earned their engineering degree on the basis of partial credit. Most practicing engineers, after all, are employed or engaged to provide correct or reasonable answers given economic or other constraints.

The computer scoring of multiple choice examinations is completely fair; the computer is not biased by the neatness of the problem solutions nor is it influenced by the personality of the student. "Grade bargaining" at the conclusion of each examination is eliminated since no partial credit is granted. The learning process of the examination is enhanced when the exercises are assigned for homework immediately following the examination period. The student records his/her methodology for solving the exercises; at the next class period the students may then compare their solutions to the correct solutions as presented in class.

EXAMINATION FORMAT

THE NUMBER OF EXERCISES used in a given multiple-choice examination obviously depends upon the level of the associated course and on the duration of the examination. Lecture periods in engineering at Georgia Tech are of nominal length of 1 or 1-1/2 hours. Thus, for a 1-hour examination period, a total of 20-25 exercises would typically be employed in the construction of a multiple-choice examination. If the examination period is 1-1/2 hours long, then a total of 25-30 exercises would be more typical. Final examination periods at Georgia Tech are of nominal duration of three hours. Thus, a typical figure for the number of exercises in a multiple-choice final examination would be 50.

The instructor must also assign values or weights to correct answers and, if desired, penalties to incorrect answers. There is, of course, no requirement that the weights and/or penalties be identical for all exercises. Commonly used values of weights for correct answers are 4 or 5, while a typical penalty value is 2 (there is some discussion as to whether such a penalty value is too high). Unanswered questions neither add or detract anything to or from the student's score. While most such multiple-choice examinations are usually designed so that a perfect score corresponds to a convenient value such as 100, 150 or 200, this facet is not absolutely essential. Examination scores can always be normalized to a reference value such as 100. Again, if the scoring is performed via computer, this normalization procedure represents no additional effort. Below are presented typical exercises which have been employed in multiple-choice examinations in four of the required chemical engineering courses in the curriculum here at Georgia Tech.

MATERIAL BALANCES

AS AT MOST OTHER chemical engineering schools one of the first required courses in our curriculum is a course on material balances. Additional related topics covered in this course include dimensions and units conversion, ideal and real gases, introductory material on phase equilibria and numerical methods. This course is normally taken by our students during the first quarter of their sophomore year. The text we currently use is that of Felder and Rousseau [2], and the first seven chapters are covered. During the past ten years, we have also employed the texts by Himmelblau [3] and by Hougen, Watson and Ragatz [4].

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A sample of four multiple-choice exercises employed in recent examinations of this course is presented in Table I. In the formulation of the alternate incorrect answers to these exercises, commonly encountered errors are incorporated. Thus, for example, in the first exercise of Table I, for which the correct answer is 308 kPa (or B) the value of 207 kPa (choice A) results when one fails to add the atmospheric pressure to the gauge pressure before performing the units conversion. Similarly, in the third exercise involving the ideal gas law, for which the correct answer is 219 ft^3

TABLE 1
Sample of Multiple-Choice Exercises Used in the Course on Material Balances

The recommended air pressure in the back tires of a late-model Toyota Celica is 30 psig. Assuming that the atmospheric pressure is 14.7 psia, what is the absolute tire pressure in kilopascals?
A) 207 B) 308 C) 2,310 D) 66,600 E) 308,000

A certain manufacturer of activated charcoal advertises that one pound of their product has 150 acres of surface area for adsorption purposes. How many square meters of surface area are there in one gram of this material (1 acre = 4840 square yards)?
A) 2.95 B) 34.0 C) 37.2 D) 148.7 E) 1338.

Assuming ideal gas behavior, calculate the number of cubic feet of carbon dioxide gas at 68°F and 2 atm pressure which may be obtained from 50 lbs of dry ice.
A) 1.14 B) 28.2 C) 219. D) 344. E) 438.

An aqueous solution containing 100 grams of dissolved $MgSO_4$ is fed to a crystallizer wherein 80% of the dissolved salt crystallizes out as $MgSO_4 \cdot 6H_2O$ crystals. How many grams of the hexahydrate salt crystals are obtained from the crystallizer?
A) 42.1 B) 80.0 C) 100.0 D) 151.8 E) 189.8

(or C), the incorrect value of 28.2 ft^3 (choice B) results when the temperature in °F rather than in °R is employed in the calculations (assuming all other steps are correctly performed).

UNIT OPERATIONS

ANOTHER COURSE IN WHICH we have used multiple-choice examinations is the second course in our three-course sequence on unit operations. Such stage-wise operations as distillation, absorption, extraction and leaching are covered in this course. The text we have used for some years now is that of McCabe and Smith [5]. Specifically, Chapters 17 through 21 of that text are covered in this course.

Obviously, graphical constructions (e.g., McCabe-Thiele or Ponchon-Savarit) cannot be easily incorporated into multiple-choice exercises, although some testing of graphical concepts can be incorporated. The requirement of complex graphical constructions, of course, also presents some difficulties, such as excessive time consumption, in conventional problem-based examinations.

REACTOR DESIGN

THE CONCEPTS COVERED by the multiple-choice exercises used in our reactor design course include activation energy, half-life, CSTR sequences and plug-flow reactors. This course is normally taken by our students during the second quarter of their senior year. The text that has been used for more than 10 years now is that by Levenspiel [6] (first 8 chapters), although the text by Cooper and Jeffries [7] was also employed for a brief period of time a few years ago.

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PROCESS CONTROL

SPECIFIC CONCEPTS COVERED by the exercises in our course on process control consist of controller settings, Routh test, Ziegler-Nichols method of tuning controllers and frequency response. This course is normally taken by our students concurrently with our reactor design course discussed above. The text currently used in this process control course is the one by Weber [8] (all chapters except 11), which superseded earlier usage of Murrill's text [9].

Examinations based upon multiple-choice exercises have also been employed in our senior-level elective course on computer-aided process design. A detailed description of this elective course and its contents was presented earlier in this journal [10].

COMPUTER SCORING

IN THE EARLY STAGES OF usage of multiple-choice examinations, manual methods were employed in the grading or scoring of the examinations. This is a simple enough task, but can become quite time-consuming in courses or sections thereof with large numbers of students. Thus, we have recently implemented computer scoring of these multiple-choice examinations. A brief description of this capability is given below.

The central computing center at Georgia Tech is based upon a Control Data Corporation CYBER 74-28 digital computer. Included in the support facilities of this center is a 7010 Mark-Sense Scanner, produced by National Computer Systems (NCS). This scanner will read forms (NCS Trans-Optic P099B-25 24 23 22 21) which have been filled out with a #2-1/2 pencil or softer. There are five choices (A through E) available for each question or exercise; a total of 240 such questions can be accommodated on a single form.

The scanner (an off-line device) assembles all of the information on the forms and produces a magnetic output tape. This tape is then fed to the central computer. The actual scoring of the examinations is then performed with a program known as SGRADER, written in the COBOL language by Georgia Tech's Office of Computing Services.

Aside from the forms filled out by the students and a master key form, the following information is also supplied in card form to the SGRADER program:

- **Department identification and course number**
- **Total number of exercises**
- **Identification of the specific examination**
- **Numerical identification of the key**
- **Values or weights for each correct answer**
- **Penalties for each incorrect answer**

The latter two input items are optional; default values for the weights and penalties are 1 and 0, respectively. The capability exists to input different weights and/or penalties for the various exercises.

The output from this program consists of the following information:

1) **Listing of the students in alphabetic order and their raw scores and scores normalized to 100, plus the number of correct answers, incorrect answers and omitted questions (no weight or penalty associated therewith) for each student.**
2) **Same information as in 1) above, but ordered by student scores from high to low.**
3) **Mean and standard deviation of the examination results.**
4) **Breakdown of the student response to each question (correct, incorrect, omitted).**
5) **Tabular distribution of the raw scores (individual and cumulative).**
6) **Histogram of the scores and frequency thereof.**

The entire process of reading the optical forms, transferring the magnetic tape to the computer, running the program and printing the output takes about ten minutes, and is often done while one (generally a teaching assistant) waits.

STUDENT REACTION

The reactions of our chemical engineering students to these multiple-choice examinations can be described, at best, as mixed. These examinations have been referred to as brutal, dehumanizing and criminal, among other descriptive adjectives. Many of our students become quite upset when forced to come up with a correct answer, with no partial credit given. Of course, the argument for partial credit loses some of its merit when a sufficiently large number of multiple-choice exercises is employed in a given examination.

It has been our experience that using the choice of "none of the above" in these exercises is a mixed blessing. Certainly, it is a salvation to the instructor whenever he has erred and not supplied the correct answer. On the other hand, with quantitative exercises and particularly if a graph (such as a compressibility factor chart) has to be read during the solution process, the usage of "none of the above" can lead to difficulties associated with accuracy and judgment. Thus, we generally try to avoid "none of the above" in the construction of such exercises.

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FUTURE PLANS

Based upon 3-4 years of experience using multiple-choice examinations as described in this article, it is clear that such examinations are a valid and useful testing tool in many of the standard chemical engineering courses in the undergraduate curriculum. Accordingly, we plan to continue using them, and look forward to further refinements and improvements. Specifically, we plan to investigate the feasibility of computer-aided generation of such examinations. This capability has become a distinct possibility with the recent improvements and developments in the area of test processing. At least one chemical engineering school reports the usage of text processing as an aid to students in the preparation of laboratory reports [11].

For a specific course, the plan is to create a large computer file of stored multiple-choice exercises. The number of such exercises for a given course should probably be of the order of 500-1000. These exercises would then be divided in modular form into the various concepts covered in that course, e.g., dimensions, units conversion, fractional conversion, recycle, ideal gases, phase rule, etc. In constructing an examination for this course then, the instructor could scan the contents of this file, perhaps using a CRT terminal in his office. He could copy the exercises he wants to use onto a temporary working file. This file would then be fed, along with a canned text-processing program, to a typewriter terminal (with upper- and lower-case capabilities, along with subscripts and superscripts). The original copy of the examination would then be typed, additional copies made as required by conventional means, and the working file could be destroyed. Obviously, there will be a need to address the security aspects of this plan. Given a large enough master file of such exercises, however, security problems would be minimized. It is conceivable, again given a sufficiently large number of exercises for a given course, that the master file could be placed in the public domain as a study aid to students. □

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REVIEW: Polymer Processing

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ology). In reality, however, the majority of beginners (for instance, B.S. degree holders in chemical engineering) do not have adequate backgrounds in all of these subjects. Therefore those who wish to write a textbook of polymer processing at the elementary level should make a special effort to introduce the reader to the background materials necessary for understanding the basic principles of polymer processing operations. In this connection, the authors are to be congratulated for the commendable job done in putting the very complex subject into a single volume in an easily readable form.

The textbook consists of three major parts: Part I covers the preparatory materials that include the structure-property relationships in polymeric materials, a review of basic equations describing the fluid flow and heat transfer, and a brief introduction to rheology; Part II covers the plasticating extrusion operation that includes the melting (or softening) of solid polymers, conveying of molten polymers, and the design of plasticating screws; Part III covers the principles involved in various polymer processing operations. Problems are given at the end of each chapter. The authors have made an earnest attempt at treating the subject of polymer processing from the point of view of unit operations in chemical engineering and have succeeded in doing it.

I feel that somewhat too much emphasis is put on the plasticating extrusion operations, occupying almost one half (over 300 pages) of the book, which certainly covers the material beyond the elementary level. While the subject of mixing is discussed and emphasized, little is discussed about applications of the knowledge of mixing to polymer processing operations. It would have been very instructive if some practical examples were discussed of the consequence of poor mixing, yielding poor mechanical properties of the product. Such a discussion would have introduced the reader to the processing of two-phase systems (e.g., polymer blends, polymers with particulates).

As a whole, the textbook is well organized and well written. I recommend highly that the book be used either for a technical elective for the Senior class in chemical engineering, or for the first level course of Polymer processing for the graduate program of polymer science and engineering, or of chemical engineering. □