# THE TEACHING OF UNDERGRADUATE MASS AND ENERGY BALANCES

A Paper Presented at the Annual Meeting
American Institute of Chemical Engineers
Chicago, IL
November 14, 1990

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# INTRODUCTION

This survey is the nineteenth in a series on undergraduate chemical engineering courses that began in 1971. Each survey attempts to present the current text materials, course credits, curriculum placement, student enrollments, topical content and special features of one of about ten standard chemical engineering courses. The first cycle began with Mass and Energy Balances in 1971 and ended with Chemical Engineering Electives in 1980. The second cycle began with Mass and Energy Balances in 1981 and ended with Chemical Engineering Electives last year. This 1990 survey on Mass and Energy Balances begins the third cycle.

A three-page questionnaire was mailed to the chairman of each chemical engineering department in the United States and Canada in March, 1990. A follow-up letter was sent in August to those departments which had not replied. Of the 174 departments contacted, 136 replied (78%). There were 140 responses to the 1989 survey on Chemical Engineering Electives and 132 responses to the 1988 survey on the Capstone Design Course.

The analysis of the responses is presented at the Undergraduate Free Forum at the Annual Meeting of AIChE. A copy of the analysis is mailed to each chemical engineering department submitting a completed questionnaire. The questionnaire is included in this report.

The results from this survey will be compared with the 1980 survey on Mass and Energy Balances as appropriate.

# I. COURSE MECHANICS

This section of the report summarizes administrative factors. These include student enrollments and the time allotted to the course.

## Course Length.

About 19% of the departments responding operate on the quarter system. In every earlier survey, about 24% of the departments used the quarter system. Perhaps this reflects a trend from the quarter system to the semester system. The quarter lasts just over 10 weeks while the semester is less than 15 weeks long. Both time periods exclude final examinations.

**COURSE LENGTH**
(Quarter Basis)

| Length | Departments |
|---|---|
| 9 weeks | 1 |
| 10 weeks | 18 |
| 11 weeks | 4 |
| 12 weeks | 6 |
| Average | 10.5 weeks |

**COURSE LENGTH**
(Semester Basis)

| Length | Departments |
|---|---|
| 13 weeks | 12 |
| 14 weeks | 31 |
| 15 weeks | 47 |
| 16 weeks | 9 |
| 17 weeks | 1 |
| Average | 14.4 weeks |

## Number of Courses

80% of the departments on the semester system offer one course while 20% offer two courses. Departments on the quarter system are about evenly split between having one course and two courses.

**NUMBER OF COURSES**
(Quarter Basis)

| Number | Departments |
|---|---|
| one | 12 |
| two | 13 |

**NUMBER OF COURSES**
(Semester Basis)

| Number | Departments |
|---|---|
| one | 86 |
| two | 22 |

## Course Level.

The Mass and Energy Balance course is usually taught at the sophomore level. Within the sophomore year, there is a preference for the first semester and the first quarter.

**COURSE LEVEL**
(Semester Basis)

| Semester | Courses |
|---|---|
| Freshman, Semester 1 | 6 |
| Freshman, Semester 2 | 4 |
| Sophomore, Semester 1 | 63 |
| Sophomore, Semester 2 | 45 |
| Junior, Semester 1 | 7 |
| Junior, Semester 2 | 2 |

(Quarter Basis)

| Quarter | Courses |
|---|---|
| Sophomore, Quarter 1 | 20 |
| Sophomore, Quarter 2 | 13 |
| Sophomore, Quarter 3 | 5 |
| Junior, Quarter 1 | 4 |

Class Sessions.

In 70% of the departments, the course meets for three hours lecture per week. In 20% there are two hours per week. Just under half the departments offer no "laboratory" hours. 26 departments have 1 laboratory hour and 22 departments have two laboratory hours each week. Questionnaire responses show that the laboratory sessions are devoted to problem sessions.

**LECTURE HOURS PER WEEK**
(Based on 50-minute periods)

| Hours | Departments |
|---|---|
| 1 | 2 |
| 2 | 26 |
| 3 | 89 |
| 4 | 11 |
| Average | 2.85 |

**LABORATORY HOURS PER WEEK**
(Based on 50-minute periods)

| Hours | Departments |
|---|---|
| 0 | 62* |
| 1 | 26 |
| 2 | 22 |
| 3 | 15 |
| 4 | 0 |
| 5 | 2 |
| Average | 1.92 |

*excluded from average

## MATERIAL COVERED IN THE PROBLEM LABORATORY

Homework
Computer programming instruction
Case studies
Approaches to problems

## ADDITIONAL TEXTBOOK TOPICS

Safety
Computers
Open-ended problems
Environmental concerns
Combined mass and energy problems
Psychology of problem solving
Economics
Ethics

## TEXTBOOK SELECTION

| Author(s) | Courses |
|---|---|
| Felder, Rousseau | 96 |
| Himmelblau | 18 |
| 8 other texts | 20 |

Class Sections and Enrollment.

63% of the departments offer one section of Mass and Energy Balances annually. 25% offer two sections. Half of the sections have enrollments of 11 to 25 students.

**NUMBER OF SECTIONS**
(1989-90)

| Sections | Departments |
|---|---|
| 1 | 85 |
| 2 | 34 |
| 3 | 9 |
| 4 | 3 |
| 5 | 2 |
| 6 | 2 |

**COURSE ENROLLMENT**
(1989-90)

| Enrollment | Courses |
|---|---|
| 1 - 10 | 17 |
| 11 - 15 | 28 |
| 16 - 20 | 26 |
| 21 - 25 | 26 |
| 26 - 30 | 16 |
| 31 - 35 | 15 |
| 36 - 40 | 9 |
| 40 - 50 | 5 |
| 51 + | 26 |

## II. BACKGROUND

This section examines the technical background of students enrolled in Mass and Energy Balances.

### Prerequisites.

The position of Mass and Energy Balances in the first semester or quarter of the sophomore year is reflected in the courses student have taken during their freshman year. Most students have completed general chemistry and calculus. Many have completed physics and a course in computers.

**PREREQUISITE COURSES**

| Course | Departments |
| --- | --- |
| General Chemistry | 123 |
| Calculus | 116 |
| Computers | 82 |
| Physics | 80 |
| Organic Chemistry | 17 |
| Thermodynamics | 15 |
| Physical Chemistry | 13 |
| Other | 11 |

### Computer Preparation.

Three questions in the questionnaire dealt with the computer skills of the students. About three-quarters of the departments offer a course in computers, usually in the freshman year. This usually includes a high level programming language such as FORTRAN or BASIC, spreadsheets and word processing.

Do you offer a formal course in computers to chemical engineering students?

| | Departments |
|---|---|
| Yes | 101 |
| No | 22 |

In which year is the course offered?

| | Departments |
|---|---|
| Freshman year | 71 |
| Sophomore year | 28 |
| Junior year | 8 |

Which classes of programming are covered in the computer course?

| | Departments |
|---|---|
| FORTRAN | 96 |
| Spreadsheets | 50 |
| Word Processing | 36 |
| BASIC | 30 |
| Pascal | 17 |
| Symbolic Math | 15 |
| Other | 17 |

# III. COURSE CONTENT

This section deals with several aspects of the course content. These include textbook selection, problem solving and design content.

<u>Textbook.</u>

In almost every survey conducted over the past 20 years, one textbook is used in a majority of the courses. This survey was no exception. The text by Felder and Rousseau was used in 96 courses. Nine other texts were mentioned. The usage by chapters for Felder and Rousseau is given below.

**CHAPTERS COVERED IN FELDER & ROUSSEAU**

| Chapter | Courses | Chapter | Courses |
|---|---|---|---|
| 1 | 74 | 9 | 82 |
| 2 | 84 | 10 | 24 |
| 3 | 86 | 11 | 41 |
| 4 | 89 | 12 | 5 |
| 5 | 86 | 13 | 6 |
| 6 | 82 | 14 | 5 |
| 7 | 86 | 15 | 0 |
| 8 | 79 | 16 | 0 |

## STRENGTHS AND WEAKNESSES OF THE TEXTBOOK

Clarity
Example problems
Typographical errors
Case studies
Greater detail
Language
Problems
Notation
Computer problems
Tables

Most departments (90%) encourage their students to use the computer in solving assignments in this course. However, most text problems are more appropriately solved with a calculator than a computer. Thus most courses (85%) utilize the computer for less than 30% of the assignments. PC ownership is not widespread among chemical engineering students. 60% of the departments report that 10% or fewer of their students own PC's.

Do you encourage students to use the computer in their homework assignments?

| | Departments |
|---|---|
| Yes | 112 |
| No | 14 |

What percent of assignments were done with the computer?

| Percent | Departments |
|---|---|
| 0 | 13 |
| 10 | 72 |
| 20 | 40 |
| 30 | 13 |
| 40+ | 9 |

What percent of the students own a PC?

| Percent | Departments |
| --- | --- |
| 0 | 30 |
| 10 | 60 |
| 20 | 27 |
| 30 | 12 |
| 40 | 4 |
| 50+ | 18 |

The SI system is more widely used than the English system in solving problems. Many departments use both systems equally. Where one system is favored over the other, the SI system is usually favored.

What percent of the problems you assign are solved in the SI system?

| Percent | Departments |
| --- | --- |
| -40 | 19 |
| 50 | 46 |
| 60 | 14 |
| 70 | 15 |
| 80 | 20 |
| 90+ | 20 |

What percent of the problems would you like to see solved in the SI system?

| Percent | Departments |
| --- | --- |
| -40 | 12 |
| 50 | 57 |
| 60 | 10 |
| 70 | 15 |
| 80 | 15 |
| 90+ | 24 |

The inclusion of design in the Mass and Energy Balances course was examined through the next four questions. Most departments (63%) would use design problems if present in the text. 28% assign projects lasting one month or longer and 32% use case studies from the text. 36% of the departments claim no ABET design credit for the course. 40% claim 1/2 or 1 credit and 16% claim 1 1/2 or more credit.

If open-ended design problems were included in the text would you assign them

| | Departments |
|---|---|
| Occasionally | 80 |
| Often | 31 |
| Never | 16 |

Do you assign a project lasting one month or longer in this course?

| | Departments |
|---|---|
| Yes | 37 |
| No | 97 |

Do you use case studies from the textbook?

| | Departments |
|---|---|
| Yes | 43 |
| No | 90 |

How many ABET design credits do you assign to this course?

| Credits | Departments |
|---|---|
| 0.0 | 48 |
| 0.5 | 11 |
| 1.0 | 44 |
| 1.5 | 4 |
| 2.0 | 6 |
| 3.0 | 9 |
| 4.0 | 1 |

# CASE STUDY IMPLEMENTATION

The following responses from the questionnaire indicate how different case studies are used at different universities.

We solve several case studies (at least two per semester) that involve students working in groups of 2 to 4 to solve large (in scope) open-ended problems with technical and non-technical constraints.
Example: Explore the acid rain issue.
Technology: Power plant mass and energy balances; decide between coal cleaning or flue gas desulfurization given economic and environmental constraints; consider ethics of environmental degradation.

An overall plant or production process is examined by groups of 2 to 4 students. Initially the problems involve material balances over several systems in the plant. The later problems involve more specific material and energy balances on individual systems. About 5 assignments are given corresponding to the material being covered at the time.

Each student is assigned one of the old AIChE Case Studies to evaluate and to examine new technologies that have arisen. Also a safety examination of the process is carried out.

Students work one of the three case studies in the text in groups of three or four students during the last five weeks of the semester. A report is required from the group.

Sketch a process flow sheet for a complex process and prepare a written description of each unit operation.
Prepare an oral presentation for class describing a "real life" chemical engineering process (based on a description in Shreve's Chemical Process Industries and similar references).

Three students form a design team to solve a problem. They are encouraged to brainstorm and devise as many solutions as possible. Then they select the "best" solution using rational criteria They write a joint report to describe their ideas and recommendations. Typical problems are to develop sensors which measure flow, pressure, etc. and can transduce a signal for a computer.

I assign one of the case study problems in the text. It usually involves the mass and energy balances for the preliminary design project of a chemical process. The problem is assigned at the beginning of the first semester and continues through the second semester. The students are required to draw the flowsheet of the process from a written description, to do a literature search on alternative processes and then compare them and make a decision. This process is facilitated for the students by discussions in the problem laboratory. They then proceed according to the problems in the book, first with mass balances in the first semester and then energy balances in the second semester. The students are required to turn in informal progress reports every two weeks and also to make oral presentations during the problem laboratory. At the end of each semester, a formal final report is submitted by each student. They are encouraged to use the computer for iterative solutions and required to use the library for any missing information.

## COMPARISONS WITH THE 1981 SURVEY

The 1981 questionnaire asked fewer and different questions, compared with the 1990 questionnaire, so comparisons are limited. The course level for the Mass and Energy course has changed very little. It is still an early sophomore course. In both years, a problem laboratory was included in 51% of the courses.

**COURSE LEVEL**
(Semester Basis)

| Semester | % of Courses 1990 | % of Courses 1981 |
|---|---|---|
| Freshman, Semester 1 | 4 | 4 |
| Freshman, Semester 2 | 3 | 8 |
| Sophomore, Semester 1 | 50 | 45 |
| Sophomore, Semester 2 | 35 | 34 |
| Junior, Semester 1 | 6 | 8 |
| Junior, Semester 2 | 2 | 2 |

A more significant difference occurs in the prerequisites for the course.

**PREREQUISITE COURSES**

| Course | % of Departments 1990 | % of Departments 1981 |
|---|---|---|
| General Chemistry | 91 | 68 |
| Calculus | 86 | 50 |
| Computers | 60 | 8 |
| Physics | 59 | 8 |
| Organic Chemistry | 13 | 4 |
| Thermodynamics | 11 | 6 |
| Physical Chemistry | 10 | 8 |

## TEXTBOOKS

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