IDENTITY, BREADTH, DEPTH IN A COOPERATIVE PROGRAM

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EARLY IN THE HISTORY of Chemical Engineering at Waterloo it became apparent that the popularity of the Cooperative Programme would cause the department to become quite large and, in so doing, provide many good opportunities for innovation in curriculum development.

Firstly, there was the opportunity to offer a wide variety of specialist courses. In addition, a concentrated technical and non-technical curriculum was possible because the cooperative work terms would provide the practical experience needed by the chemical engineering undergraduate. In developing such a curriculum in a very short time there was the danger that it would lack cohesion and purpose. Also the departmental size and the inevitable on-off discontinuity of the cooperative system could cause the students to have a lack of identity. The Waterloo programme was developed to exploit the advantages and to anticipate and avoid the disadvantages.

COOPERATIVE ChE PROGRAM

One hundred and twenty first-year students enroll in September of each year in Chemical Engineering. (This is in contrast to the approximately five hundred other engineering students who enroll in General Engineering. One other department, Systems Design, also enrolls into its first year programme.) One advantage of a first year chemical group is to provide a sense of identity for the students, who are often lost in the vastness of a large university and need "to belong." The effects of this identity advantage are intangible, but there are a few indications: for example, in the level of the ChE mathematics marks which more often than not are higher than the rest of engineering, which takes exactly the same course. Certainly the ChE first year students get to meet and know their professors early in their first term. For example in September of 1974 the ChE class is being taught in one way or another by at least ten ChE faculty members. In this 1A term the students receive the same Mathematics, Chemistry and Physics (see Table I for curriculum content) courses as the rest of engineering. In addition, they obtain a course in Measurement and a course given by and for Chemical Engineers, namely, "Introduction to Engineering Concepts I" which is an introduction to the basic methods and principles used by engineers in the analysis and design of physical processes. Topics covered by means of lectures, case studies and problem assignments are: units, dimensions, measurements, mass balance, behaviour of fluids, non-technical and social implications of the engineers work, freehand sketching and blueprint reading. One non-technical elective can also be selected from a choice of three specially designed for the freshman student.

In January, the ChE class divides and one stream goes to industry while the other (1B class) continues for a second term of studies. This streaming has the advantage of reducing the class size, and ensuring the subsequent year-round use of the university physical plant and teaching resources. The courses taught during this term are again general to all of engineering except, "Introductory Engineering Concepts 2" which extends the topics covered in the previous course to include energy balances, unsteady state behaviour of engineering systems, and laboratory experiments to illustrate the physical principles discussed.

In the term beginning in early May, the students who were in industry return for their 1B term and the group which has already taken the 1B term now moves out into industry. Thus, the classes alternate with terms on-campus and terms

TABLE I Curriculum of the 1974 Freshman

1A Fall 1974	1B Winter and Summer 1975
Introductory eng. concepts	Introductory eng. concepts cont'd.
Calculus 1	Calculus 1 cont'd.
Algebra 1	Algebra 1 cont'd.
General Chemistry	Digital Computation
Mechanics	Electricity and Magnetism
Topics from scientific thought	
Introduction to the sciences of man	One of these courses in each term
Topics from the arts and humanities	
2A Fall and Winter 1975-76	**2B Summer and Fall 1976**
Calculus 2	Differential equations
Statistics	Transport processes 1. Fluids
Organic chemistry 1	Organic chemistry 2
Physical chemistry 1	Physical chemistry 2
Inorganic chemistry 1	Physical chemistry lab.
Non-technical elective	Non technical elective
3A Winter and Summer 1977	**3B Fall and Winter 1977-78**
Applied mathematics	Chemical engineering laboratory
Transport process 2. Heat transfer	Transport processes 3. Mass transfer
Inorganic chemistry 2	Chemical reaction engineering
Instrumental methods of chemical analysis	Technical elective
Chemical engineering thermodynamics	Non-technical elective
4A Summer and Fall 1978	**4B Winter 1979**
Process dynamics and control	Research-design project or
Engineering economics	Process systems design or
Process design and technical seminar	Technical elective project
Technical elective	3 Technical electives
Technical or non-technical elective	Technical or non-technical elective

in industry until they combine again in the final 4B term before graduation. Table I shows the curriculum facing the 1975 Freshman and the way in which he is expected to progress through the B.A.Sc. programme.

Some special features are contained in the programme which reflect the earlier discussion of our concern with the advantages and disadvantages associated with the large department.

- **Each student can select from six to eight technical elective courses at least three of which must be taken from an option package (see below for details). Breadth and depth!**
- **The undergraduate student has the opportunity to select from four to six non-technical courses from offerings across the whole university. Breadth!**
- **A set of seven mathematics courses culminating in a course in "Applied Mathematics" (3A Term) are core content of the programme. Depth!**
- **A set of three transport processes courses and one chemical engineering laboratory is core content. Depth!**
- **Chemical engineering thermodynamics, instrumental methods, chemical reaction engineering, process dynamics and control, engineering economics and technical seminar are all core courses. Breadth!**

TECHNICAL ELECTIVES

Five to seven Technical Elective courses must be selected by the undergraduate. To ensure each student obtains a reasonably deep understanding of at least one area of interest, a minimum of three courses must be chosen from one of the option groups listed in Table II. These course groupings reflect the main interests of the faculty members in the department. The other technical electives may be chosen from other ChE offerings or from other science, mathematics or engineering courses offered within the university provided the associate chairman of the department approves.

GRADUATE COURSES

M.A.Sc. THESIS STUDENTS must take at least four graduate courses at least half of which must be taken from the list shown in Table III. Course work M.A.Sc. students must take eight courses and write an Engineering Report.

Early in the history ChE at Waterloo it became apparent the popularity of the Co-Op program would cause the department to become quite large, and provide many good opportunities for innovation in curriculum development.

Ph.D. students must take at least a further four courses beyond the M.A.Sc. requirement and in addition must pass the Research Proposal exam and defend a Ph.D. thesis. The Graduate course programme of the department fits again into the group pattern and students in collaboration with their supervisors may plan a personalized curriculum which will provide them with depth of knowledge in their own special area of interest and breadth of knowledge of some of the latest developments in the field of ChE generally.

TABLE II Undergraduate Technical Electives

1. **Transport Processes**
   - Selected topics in process applications
   - Physico-chemical properties of gases & liquids
   - Air Pollution
   - Non-Newtonian flow and heat transfer
2. **Mathematical Analysis and Control**
   - Chemical engineering analysis
   - Process dynamics and control 2
   - Process control laboratory
3. **Polymer Science and Engineering**
   - Introduction to polymer science
   - Physical chemistry of polymers
   - Polymer laboratory
4. **Extractive and Process Metallurgy**
   - Introduction to extractive metallurgy
   - Metallurgical chemistry
   - Principles of high temperature extractive metallurgy
5. **Biochemical and Food Engineering**
   - Introduction to biochemical engineering
   - Fermentation operations
   - Food processing
6. **Pollution Control Engineering**
   - Selected topics in process applications
   - Air pollution
   - Introduction to biochemical engineering
   - Water pollution
7. **Research and Design**
   - Research-design project 1
   - Research-design project 2
   - Process systems design
   - Technical elective report
8. **Non-Technical**
   - The Chemical Engineer as an Entrepeneur

MOST RECENT DEVELOPMENTS

RECENTLY THE PROVINCE of Ontario has been assessing all the Ph.D. programmes offered in the Provincial Universities. The Waterloo doctoral programme and its plans for the coming years was approved by the external consultants, however, a general recommendation was that "Ph.D. programmes in addition to the usual scholarly goals, have as one of their aims an effort to develop entrepeneurship in students since this is a quality so badly needed at present in Canada." At Waterloo we have taken this as a challenge and we have prepared a course entitled, "The Chemical Engineer as Entrepeneur." The course will be available to 4B undergraduates and graduates. "Engineering Economics" or its equivalent will be required as a prerequisite. The course is intended as an elementary introduction to the mechanism by which an individual may develop a small business for the purpose of supplying goods or services to the chemical or resource processing industries. The view presented is that of an individual engineer who must perform most of the technical and management functions himself, with the occasional help of professional specialists, rather than that of new enterprise management as practiced by large corporations. The main purpose of the course is to give a familiarity with the problems and methods of launching in Canada a new small enterprise in the chemical technology field. Technical, economic, legal and financial aspects will be outlined over a broad spectrum of topics. The proposed course has generated enthusiasm among many undergraduates and graduates and expected enrollments are high.

Curriculum development is a continuous process at Waterloo. Many iterations have been made for the curriculum to reach its present form in just a few years. Usually new ventures are first discussed at the Departmental Curriculum and Graduate Review Committee levels. Each of these committees contain active student representatives. Changes are less frequent now than they were three or four years ago and when they are made, questions such as whether or not they add breadth or depth to the programme or whether they can provide the student with a greater sense of identity with his chosen career and department, are of paramount importance.

A general recommendation was that, "Ph.D. programs in addition to the usual scholarly goals, have as one of their aims an effort to develop entrepeneurship in students since this quality is so badly needed in Canada" . . . we have taken this as a challenge.

The last word on the curriculum is given to students who have been through it all!

STUDENTS VIEWPOINT

Peter Douglas and Gordon Hayward (Class of '74)

"Like any first year students, the ones at Waterloo

TABLE III Graduate Courses

1. **Transport Processes**
   - Theory and applications of transport phenomena
   - Behaviour and properties of particulate material
   - Statistical theory of matter
   - Special topics in transport processes
   - Selected applications of the statistical theory
2. **Mathematical Analysis and Control**
   - Process optimization
   - Advanced mathematics in engineering research
   - Statistics in engineering
   - Chemical reactor analysis
   - Selected topics in analysis of chemical processes
   - Heat and concentration waves
3. **Polymer Science and Engineering**
   - Principles of Polymer Science
   - Physical properties of polymers
   - Polymer synthesis and characterization
   - Solution properties of macromolecules
   - Selected advanced topics in polymer science and engineering
4. **Extractive and Process Metallurgy**
   - Applied physical inorganic chemistry
   - Hydrometallurgy
   - High temperature metallurgy
   - Special topics in hydrochemical metallurgy
   - Special topics in high temperature metal extraction
5. **Biochemical and Food Engineering**
   - Principles of biochemical engineering
   - Advances in biochemical engineering
   - Special topics in biochemical engineering
6. **Research and Design**
   - Oral exam for the Ph.D.
   - Research proposal for the Ph.D.
   - Graduate research seminar
   - Engineering report for the course work M.A.Sc.
   - Thesis for M.A.Sc.
   - Thesis for Ph.D.
7. **Non-Technical**
   - The Chemical Engineer as an Entrepeneur

initially find themselves a little lost or confused and overburdened with work in their new environment. With the ChE class smaller and separate from the other engineering disciplines the first year students are usually a more closely-knit group which is helpful. In addition, the ChE faculty (28) make themselves very approachable to the students. This is encouraged with "coffee and donuts talk sessions," and class professors assigned to first year classes. Class professors act as resource persons, counsellors, and motivators. Sometimes they give a few lectures. For example, ours spent time teaching us speedy slide-rule pushing. Generally, the first two years of the programme included many courses in the fundamentals of chemistry, physics and mathematics. Looking back over the years, we remember these courses to have been uninteresting because they seemed to lack apparent ties to practical applications. For this reason, these first two years were probably the most difficult for us. A major improvement now has more ChE professors teaching first and second year courses. An introduction to ChE through a programme provided for interested high school students in which first and second year students participate also helps relate pure science and math to ChE problems [1].

In the third and fourth years, heat, mass and momentum transfer are taught. In addition, the student may choose technical electives and begin to specialize in the specific area of his choice. We choose both the transport and control options hoping that we would be better suited to a variety of chemical industries rather than just the polymer or food industry. In the fourth year the student is required to work on either a research or design project and is able to effectively apply many of the tools which heretofore (in his academic career) have been limited to text book problems. The research projects provide for specific interests beyond the scope of the other electives. In this way, one of us studied turbulent heat transfer in a wind tunnel, a project which is rather unconventional for chemical engineers.

Aside from academics, the co-op programme plays an important role in the development of a chemical engineer at Waterloo. Although highly technical jobs may be difficult to come by in the first year and may employ more body than mind there are enough jobs for everyone who wants to work (one of us spent one work term unloading box cars, a somewhat unusual work term). In the final work terms most of the students are performing as graduate engineers in their chosen field. For example one of us spent his final work term designing heat exchangers for the chemical industry.

Work reports are written after each work term. They describe a project which was conducted during that term. They seemed to be a chore at the time but looking back they helped develop skills in writing which is often a weak area of engineers. Work term jobs are usually located in Ontario with a few scattered across Canada and the odd jobs in the U.S. and Europe. Major employers are pulp and paper, petrochemical, chemical, food and steel processing companies. In 1974 averaged salaries ranged from \$615/month for first year students to \$670/month for fourth year students.

The social life at Waterloo depends on the individual. Our leisure time was somewhat curtailed by a heavy work load but a host of on-campus activities were available. These ranged from a well developed intramural sports programme to drama, concerts, pubs, dances, movies, etc. Kitchener-Waterloo and the surrounding communities have many fine pubs with the German culture very predominant (typical of this area).

In summary, our years at Waterloo were not the easiest, but were very rewarding. We found that although we were taught to be chemical engineers, the underlying discipline of applying the laws of nature to design may be applied to just about any field. In this way we think we are well prepared for a wide variety of careers." □

REFERENCES

"Waterloo Program for High Schools," E. Rhodes, Chem. Eng. Education, 44-47, Winter (1974).