Positive comments with good advice: e.g., "students should choose positions with a mixture of chemical engineering, chemistry;" "student quality more important than education;" "should use these people to replace chemistry Ph.D.'s."

A second conclusion which can be drawn from Table III concerns the students' effectiveness. This effectiveness is largely inherent in the students themselves. If they are bright, smart and aggressive before entering a program, they remain so afterward. As a result, their performance has more to do with their own character and ability than with any educational gloss. These students apparently perform a mixture of tasks. Certainly industrial jobs require a continuum of skills: they are not balkanized between science and engineering as are the university departments. However, industry recruits within the departmental structure and recruiters seek not specific individuals but people with specific types of certification. The students are being hired as engineers, but are working as hybrids.

AT YOUR UNIVERSITY.....

AS THE ABOVE paragraphs show, there is now extensive experience on how to start a graduate program for teaching ChE to non-chemical engineers. If you decide to develop such a program at your university, you should do three things. First, decide on a strategy. If you plan to use open admissions, be sure you assemble sensible arguments defending the quality of your program. If you decide to require a significant number of remedial courses, think about how you plan to attract and retain smart students. If you decide to use special summer courses, you must discover a source of money to pay the additional cost.

The second thing you need to develop is a scheme for recruiting students. Any program which has an enrollment of less than about half a dozen will inevitably attract administrative criticism in hard times. You must decide whether to recruit locally or nationally. You should decide whether you are more attractive as ChE department or as a university. Moreover, the mailing list that you use to attract students should take advantage of undergraduate chemistry newsletters and local ACS meetings. Advertisements in *Chemical Engineering Education* won't help because chemists don't know this journal exists.

The third thing you should do is to talk to others with experience. Most, if not all, of the departments mentioned in this article are willing to send to any who are interested detailed material, including hour-by-hour course outlines, and copies of lecture notes. It would be foolish not to take advantage of the experience of others.

Finally, I wish you good luck. I find rigidly structured departments a real discouragement to free thought. I look forward to the time when it is easier for students to move back and forth between disciplines to develop unique skills which will make them professionally more interesting, interested and effective. □

EXPERIENCE AT ONE UNIVERSITY

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AT THE HEART of our accelerated expansion program lies the premise that the holder of any baccalaureate degree has demonstrated intellectual maturity, and, with sufficient motivation, should be able to undertake almost any study of his choice. If such study were to be at the graduate level, he would have to have the background information to follow the advanced study, and, equally important, he would have to have enough "skill" in the discipline to compete at the graduate level with holders of the bachelor's degree in that major. With the foregoing in mind, we examined the course content of each departmental undergraduate course required for the B.S. Ch.E. to determine what topics a person entering our graduate courses would need as an absolute minimum. We also examined our undergraduate requirements in science and mathematics in the same light.

The chemical engineering component of our

TABLE 1. Ch.E. 5301 Analysis of Chemical Engineering Problems

Course Content

A. Stoichiometry[a]
  1. Units, dimensions, dimensional analysis
  2. Basic laws: Raoult, gas laws, corresponding states, Henry, Avogadro, non-ideal behavior
  3. System/surrounding concepts
  4. Driving forces/potentials
  5. Chemical equations/stoichiometry with generation and consumption rate expressions
  6. Composition/flowrate units, fluxes
  7. Accumulation/depletion expressions
  8. Multistream systems with recycle, bypass, purge
  9. Thermal variables: C_p, $\triangle H_R$, $\triangle H_M{}^o$, Q, w

B. Fluid Flow[b]
  1. General energy balance
  2. Pump work
  3. Prime movers
  4. Flow measurement
  5. Fluid-solid systems

Course Scheduling[c]

A. 1-4, 1 week; A. 5, 1 week; A. 6-8, 1 week; A. 9, 2 weeks; B. 1-3, 2 weeks; B. 4, 1/2 week; B. 5, 1/2 week

a. Text: Basic Principles and Calculations in Chemical Engineering, D. M. Himmelblau, 3rd Edition, Prentice-Hall.

b. Text: Unit Operations of Chemical Engineering, W. L. McCabe and J. C. Smith, 3rd Edition, McGraw-Hill.

c. Lectures 5 hours per week plus 2 to 4 hours problem-solving session.

accelerated program consists of twelve semester hours presented in four three-hour courses. The courses are designated as graduate courses, and are suitable for use as a graduate minor. The first six hours are offered in the fall semester in series. The first course covers material and energy balances and fluid flow. The second covers equilibrium- and rate-controlled processes, including separations techniques and heat transfer. The second six hours are offered as two parallel courses in the spring semester. One of them covers thermodynamics and kinetics, while the other includes design and practice oriented topics ordinarily thought of as "design". *viz.*, dynamic behavior, economic analysis, process simulation, and optimization techniques. Course outlines are presented in Tables 1 through 4.

The chemistry, physics, and mathematics components of our accelerated program do not vary significantly from those of the B.S. Ch.E. requirements. Engineering physics, organic and physical chemistry, and mathematics through differential equations are required, and can be taken in parallel with our accelerated ChE courses. Many students converting to chemical engineering have already had enough science and mathematics to meet our requirements, *e.g.*, the organic chemistry requirement is waived for those who have had biochemistry.

To compensate for the lack of ChE laboratory work in our accelerated courses, the students in this program are strongly urged (virtually required) to seek summer jobs in the chemical process industry. This three-month "practicum", combined with the previous year's work, embarks the students on our structured M.S. program with qualifications that we hope will enable them effectively to compete with B.S. Ch.E.'s.

The students' need for background information and skills to make them competitive with B.S. Ch.E.'s in graduate courses are kept uppermost in mind in teaching our accelerated courses. The first course (stoichiometry and fluid flow) is the first taste that most of the students have had of any type of engineering course. Considerable drill, both in study sessions and in home-

The chemical engineering component of our accelerated program consists of twelve semester hours presented in four three-hour courses. The courses are designated as graduate courses and are suitable for use as a minor.

TABLE 2. Ch.E. 5302 Analysis of Equlibrium and Rate Operations

Course Content

A. Equilibrium—Dependent Processes[a]
  1. Phase equilibrium
  2. Potentials versus equilibrium
  3. Ideal contactor concept
  4. Multicomponent, multistage contacting

B. Rate-Dependent Operations[b]
  1. Potentials and fluxes
  2. Transfer coefficients
  3. Analogies: heat, mass, momentum
  4. Mass applications
  5. Energy applications

Course Scheduling[c]

A. 1-2, 1 week; A. 3-4, 1.5 weeks; B. 1-3, 2 weeks; B. 4, 1 week; B.5, 1.5 weeks

a. Text: Stagewise Process Design, E. J. Hanley and H. K. Staffin, Wiley.

b. Text: Unit Operations in Chemical Engineering, W. L. McCabe and J. C. Smith, 3rd Edition, McGraw-Hill.

c. Lectures 5 hours per week plus 2 to 4 hours per week discussion/problem-solving session.

TABLE 3. Ch.E. 5303 Analysis of Physical and Chemical Behavior of Matter

Course Content

A. Thermodynamics[a]
   1. Philosophy and historical approach
   2. Applications: minimum, maximum, available work
   3. Chemical potential
   4. Criteria for phase equilibria
   5. Chemical equilibria

B. Chemical Reactions[b]
   1. Molecularity and rate expressions
   2. Order of reactions
   3. Mechanisms of reactions
   4. Effects of temperature and pressure on reaction rates
   5. Continuous stirred-tank reactor and tubular reactor
   6. Introduction to gradients and backmixing
   7. Engineering design

Course Scheduling[c]

A. 1, 2 weeks; A. 2-5, 4 weeks; B. 1, 1 week; B. 2-3, 2 weeks; B. 4, 1 week; B. 5-6, 4 weeks; B. 7, 1 week.

a. Text: Theory and Problems of Thermodynamics, M. M. Abbott and H. C. Van Ness, Schaum Outline Series, McGraw-Hill.

b. Text: Chemical Reactor Theory, K. G. Denbigh and J. C. R. Turner, 2nd Edition, Cambridge University Press.

c. Classes meet 3 hours per week plus 2 to 4 hours per week discussion/problem-solving session.

work assignments, is utilized. The students became at least familiar with, if not proficient at using, the various systems of units employed in engineering calculations, and become aware of the importance and significance of quantitative answers. Computational skills are reinforced in the second course (separations and heat transfer) but the amount of drill is reduced.

The two courses offered in the spring semester are taught on alternate days, the same as standard three-hour academic courses. Whereas the second of the fall-semester courses depended very heavily on the first, the two spring-semester courses are independent of each other. As it turned out, the students seem to benefit from the forty-eight hour stretch between classes which allows for mental induction of the information covered in the classes.

COURSE SCHEDULES

A TYPICAL SCHEDULE for a student with prior credit in organic chemistry or biochemistry for our accelerated expansion program is shown in Table 5. The first year is tailored for the requirements of each individual student. All, however, take both of the accelerated ChE courses each semester. At the conclusion of the first academic year of the program and their summer's experience in either industry or research, the students are ready to enter the master's program in our department. The core courses are shown in the second year of the typical schedule in Table 5. The second fall term consists of the same graduate courses in thermodynamics, heat transfer, and applied mathematics for chemical engineers as required of any master's candidate, regardless of background. We also anticipate that during the fall semester, each student will consult with all of our faculty with regard to research areas of mutual interest, and will select a major professor and a specific research topic. The student should complete any necessary literature search before initiation of the experiental portion of his program in late fall. During the spring term, the student will enroll in graduate-level mass transfer and fluid dynamics. He will also take a graduate technical elective on a subject chosen by his major advisor or graduate committee as being most beneficial to his research and career objectives. The experimental portion of his thesis will be undertaken no later than the start of the spring semester, and should be essentially complete by the end of the following summer. He will also be expected to take a graduate elective during the summer, leaving him free to write his thesis

TABLE 4. Ch.E. Analysis of Chemical Processes

Course Content

A. Economics[a]
   1. Time value of money
   2. Profitability criteria
   3. Amortization
   4. Capital and other costs

B. Optimization[a]
   1. Single-variable search
   2. Multi-variable search

C. Unsteady State[b]
   1. LaPlace transforms
   2. System dynamics
   3. Interacting systems
   4. Controllers
   5. Stability criteria

D. Simulation[b]
   1. Streams and modules
   2. Generalizations
   3. Network analysis

A. 4 weeks; B. 3 weeks; C. 5 weeks; D. 3 weeks.

a. Text: Class notes.

b. Text: Process Systems Analysis and Control, D. R. Coughanowr and L. B. Koppel, McGraw-Hill.

c. Classes meet 3 hours per week plus 2 to 4 hours per week discussion/problem-solving session.

TABLE 5. Typical Schedule

Fall I	Spring I	Summer I
Calculus I Physical Chemistry I Analysis of Ch.E. Problems Equilibrium and Rate Operations	Calculus II Differential Equations Physical and Chemical Behavior Analysis of Chemical Processes	Job in CPI or Research at TTU
Fall II	**Spring II**	**Summer II**
*Thermodynamics *Heat Transfer *Applied Math for Ch.E.'s Thesis Research	*Mass Transfer *Fluid Dynamics Technical Elective Thesis Research	Technical Elective Thesis Research
Fall III		
Technical Elective Write and Defend Thesis M.S. Ch.E. awarded		

*Core graduate course required for any M.S. Ch. E. candidate.

Although many of them may have had some calculus, chemistry and physics, their thought processes were definitely qualitative rather than quantitative, as is required in engineering education.

during the fall semester, simultaneously taking his final course.

Participation in our accelerated expansion program for the fall semesters of 1975 and 1976 is shown in Table 6, along with the backgrounds from which the students came. The physical chemists were in the accelerated courses for their graduate minor.

While the accelerated expansion program was developed with chemists and biologists in mind, we genuinely hoped that some students from non-technical fields would take advantage of it. The music major came to us in the summer of 1975 after completing the mathematics, physics, and chemistry courses usually needed for the B.S. Ch.E. degree. He was elated when we apprised him of the opportunity to earn the M.S. Ch.E. in about 28 months.

PROBLEMS AND PROGNOSTICATION

THE GREATEST DIFFICULTY was the non-quantitative background of most of the students. Although many of them may have had some calculus, chemistry, and physics, their thought processes were definitely qualitative rather than quantitative, as is required in engineering education. Special care had to be given in instructing these students in problem definition and interpretation of the answers.

The necessity of making assumptions was a difficult concept for many of these students. The assumptions could take the form of simplifications without which the problem was unsolvable, or of values of physical properties needed to complete the solution. In some cases, the students were exceedingly reluctant to assume an answer and then show that answer to be correct, or to use a difference between a calculated and an assumed value to predict a better assumed value, as is so often required in trial solutions.

Abundance of information in the form of data tables, graphs, equations, correlations, etc., as they appear in textbooks, handbooks, and the technical literature was a source of confusion. Use of information sources was an integral part of the course work.

Our experience with students from other fields pursuing graduate study in ChE has been most rewarding. Those who have completed the year of accelerated work are now holding their own in our regular graduate courses in thermodynamics, heat transfer, and applied mathematics. We shall continue to publicize our program both among potential students and potential employers. Nine students have accepted assistantships to start in the program this fall. □

TABLE 6. Enrollment in Career Expansion Program

Major	Fall 1975	Fall 1976	Fall 1977
General Chemistry	2	5	4
Organic Chemistry		2	1
Physical Chemistry	2	1	1
Polymer Chemistry		1	
Microbiology	1		
Music	1		
Physics			1
Pre-Medicine		1	2
Zoology	1		
Industrial Engineering		1	