ChE curriculum

THE FUTURE ChE CURRICULUM

MUST ONE SIZE FIT ALL?

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In the soul-searching about the future of chemical engineering currently being carried on at great length in journals, symposia, and the Exxon suite, the one point of agreement is that new material *must* be infused into the undergraduate curriculum. The shopping lists include, in no particular order, biotechnology, computer applications, microelectronics, industrial chemistry, quantum chemistry, rigorous mathematical analysis, economics, statistics, aerobics, pipe threading, pump sizing, stress tensors, social sciences, several dozen synonyms for "culture," oral communication skills, written communication skills, problem-solving skills, critical thinking skills, and countless things that involve the words "real world."

Can we do all that? Well, there's something to be said for the twelve-year chemical engineering curriculum—I can think of at least three of our students at N.C. State who seem to have made the case for it for themselves. However, there are practical arguments against stretching the program out beyond four years, mostly having to do with the large student population that would result and the critical shortage of available parking for them. So, the questions: (1) Which proposed additions to the curriculum are really all that essential for the preparation of well-trained and well-rounded students? (2) Which currently covered topics are we willing to scrap to make way for the essential replacements?

I would like to propose several axioms by way of introducing my ideas on the subject—axioms meaning I think we can all agree on them, even if they don't necessarily lead us to the same conclusions.

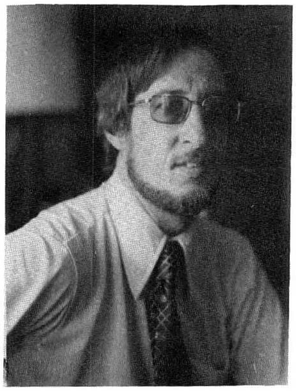
Axiom 1. No two of our students will be called on to solve an identical set of problems in their careers.

Our graduates will go into different industries, work on different products, provide different services. Some will go into petroleum-related industries, some into specialty chemicals, some into polymers, some into biotechnology, and some into microelectronics. Some will work in production, some in process design and development, some in product design and development, some in equipment design and construction, some in sales and service and computer-aided design and manufacturing and process control and quality control and project engineering and cost engineering, some in low-level management, some in high-level management. A few—5%, 10%—will go on to get PhD's and go into research or teaching. Which leads us to

Axiom 2. We can't possibly provide all the information our students will need to do all the things they will be called on to do in their careers.

We couldn't do it even if we did go to a twelve-year curriculum. Moreover, we have

Axiom 3. Our responsibility as educators is to try to meet the needs of the greatest possible number of our students. We should not short-change the many for



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the benefit of the few.

This may seem to be a self-evident truth, consistent with the principles of the American democratic tradition. However, what it means to me is that if 10% of our students are going to go on to get PhD's and 90% of our curriculum is designed to meet the needs of this 10%, then something is wrong with the curriculum. I'm not claiming that our present imbalance is as serious as the 90% figure I just gave—at least not yet—but I do think an imbalance exists, that it has been growing steadily over the past two decades, and that in the correction of the imbalance lies at least part of the answer to the question, "What should we take out?"

The cause of the imbalance is not hard to deduce. For at least the past two decades we have hired as faculty members almost exclusively individuals whose background, training, and interests qualify them as research scientists, not as engineers or educators. Clearly, faculty members will focus on what they know best when they develop and teach courses. The result is that the undergraduate curriculum has increasingly become a graduate school training program. Those who in the past provided the balance—engineers with industrial experience, men and women whose principal interest is teaching—are reaching retirement age and leaving, and are being replaced with more research scientists. Occasionally an experienced engineer who happens to have a PhD will be hired to take care of the unit operations laboratory, but for the most part such individuals can't get through the door when vacancies arise.

One more proposition.

Axiom 4. Our graduates who go into industry don't necessarily agree with us about the usefulness of all we have taught them.

The September 19, 1983 issue of *Chemical Engineering* contained the results of a survey to which 4,759 readers responded, of whom 3,599 were U.S.-educated chemical engineers. Of all subjects studied in college, the one considered most useful was communication skills, which was cited by over 80% of the respondents. The standard chemical engineering subject most often cited was material and energy balances (78.9%), followed by engineering economics (77.7%) and unit operations (76.5%). The other subjects fell below 70%, with reactor design trailing the pack at a dismal 44.5%.

Although roughly 3/4 of the respondents to this survey thought they had been well-trained for their first job, many commented negatively on their training or the training of new engineers whom they supervised. To quote several of them:

- ***College prepared me almost not at all for my current work as a second-line supervisor of a chemical unit. Much of my engineering background was geared to how to create new plants, not how to keep 20-year-old plants on line in worsening economic times or how to manage the people who run them.***
- ***In general, I was totally ill-prepared to apply the theoretical knowledge gained from college to real world problems.***
- ***I know so little about fluid flow, material selection, equipment alternatives and cost estimating . . . which is what chemical engineering design is at my company.***
- ***Three years ago, I took a course titled "Intermediate Fluid Mechanics" . . . it should have been titled "Application of Second-Order Differential Equations." Navier-Stokes equations are fine in their place, but they're no help in finding friction factors in piping.***

And so on.

Now, what do we do with all this? Let's review the situation.

1. We have at least two populations to serve—industry-bound students and graduate-school bound students.
2. There are a number of specialty areas—biotechnology, microelectronics, computer-aided design, and so on—that we believe at least some of our students should be exposed to.
3. There is pressure from some quarters to give our students a more solid grounding in rigorous analysis in mathematics, chemistry, transport theory, *etc.*
4. There is equal pressure from other quarters to give our students less theoretical material and more background in industrial systems, economics, scaleup, communications, and so on.
5. You can't do everything for everybody in a four-year curriculum.

So what's the answer?

Flexibility!

We've all been exposed to a similar situation early in our academic careers—specifically, in high school. There are two populations there as well: college-bound and non-college bound. There is no way to put both groups through the identical curriculum in four years, and no one even tries. Through a system of electives and advising, each student winds up with a program tailored to his or her needs. Sometimes mistakes are made, but at least the odds are in the student's favor, whatever his or her post-high school plans.

We also have models to consider in our sister engineering curricula. Long ago, civil engineering departments decided that *all* of their graduates do not have to be experts in design and construction of bridges and dams, water treatment facilities, highways, and public transportation systems. Similarly, all electrical engineering graduates do not necessarily get training in communications, control theory, power systems, and artificial intelligence. Students in both disciplines take a few core courses and then branch out into diversified programs according to their interests and career goals.

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What would be wrong with doing something similar in the chemical engineering curriculum—abandoning the pretense that all of our students have the same needs and can therefore be served by the same curriculum, give or take a few electives? Why not institute a series of options or tracks in the curriculum, and design the courses to meet the needs of those pursuing these tracks? In structuring this flexible curriculum, we might proceed in something like the following manner.

1. *Decide what general subject areas and specific subject material are truly indispensable in the education of anyone who calls himself a chemical engineer.* As far as I am concerned, the basic freshman science, math, and English courses, the material and energy balance course, one thermodynamics course, one transport/separations course, and a minimal amount of social sciences and humanities are indispensable, and almost everything else—strength of materials, electrical circuit analysis, analytical chemistry, physical chemistry, the second semester of organic chemistry, process control, kinetics, the third course of the transport sequence, the second course of the transport sequence, any course involving the Navier-Stokes equations—is negotiable.

2. *Propose track titles.* Industrial chemical engineering? Pre-graduate school? Chemical engineering science? Biotechnology? Microelectronics? Computer-aided design and manufacture? Economics and management science? Material science? Aerobics?

The track titles will of course change with the times: the words energy and environment would have appeared on most lists of this sort a few years ago, the words nuclear and polymer would have been on earlier lists, and so it goes.

3. *List required and elective courses for each track.*

4. *Plan each course thoroughly,* deciding what really needs to be covered in lectures, what can be left for the students to learn in readings and homework, and what can profitably be left for graduate school or on-the-job training. Then cut down on the first category by a factor of two, and add the excised material to categories two and three.

5. *Plan a course schedule to minimize the number of offerings of elective courses.* One consequence of implementing this program—or any other program to accommodate demands for the inclusion of new material in the curriculum—is an inevitable increase in the number of courses being taught. To minimize the resulting teaching loads and/or need for additional faculty, offer courses that were formerly required but are now elective less often—*e.g.* once a year instead of once each semester or quarter.

6. *Consider cross-listing courses between departments, and eliminate duplicate offerings.* The usual practice is for each department to offer its own courses, regardless of redundancy. Thus, engineering thermodynamics and heat transfer are each taught in both chemical and mechanical engineering, and fluid mechanics is taught by the same two departments and civil engineering. Eliminating these duplications is another way to keep the addition of new curricular material from imposing excessive demands on department resources.

7. *Devise a mechanism for reasonably frequent review and updating of the system to accommodate changes in the industrial economy, national priorities, etc.*

8. *Implement the changes.*

In addition, we should explicitly acknowledge that a flexible curriculum designed to meet the needs of a diverse student body can only be implemented by a diverse faculty. If research science is not to constitute 100% of the curriculum, the faculty should not be composed of 100% research scientists. *If engineering practice is to be taught, some people who are, or have been, practicing engineers should be around to teach it.*

Now, all we have to do is designate someone to answer all the questions explicit and implicit in this plan. What's indispensable in our current curriculum? What tracks should be considered? What are the likely short-range and long-range demands for graduates from each of these tracks? In light of the answers to the previous question, what tracks should actually be instituted? What should the required and optional courses be in each track? What really needs to be taught in each course? Who's going to design and teach all those courses? How much is it going to cost to do all this? Who will bear the cost?

Who will come up with the answers? Certainly not me—I'm just one person, and I'm not getting paid for this. If history is a guide, designing and implementing a plan of this magnitude demands no less than a blue-ribbon panel with three or more corporate executives at the vice-president level and at least $500,000 support over a three-year period from the National Science Foundation.

However, I really believe that the details of implementation are of secondary importance at this time. We're all struggling to answer the focal question of this paper—what should we remove from the chemical engineering curriculum to make room for new material? Sometimes when you can't come up with a reasonable answer to a question no matter how hard you try, you should consider the possibility that you haven't asked the right question.

I think that's the case here. The premise that underlies the question is that there's such a thing as "The Chemical Engineering Curriculum"—one size fits all. If we back off that premise, and acknowledge that those coming to us have a spectrum of needs—most of which don't involve preparation for the PhD qualifying examination—then we find ourselves asking a different question: "How can we structure our program to best meet the needs of most of our students?" Since a single rigidly-structured curriculum presided over by a faculty composed exclusively of research scientists can't possibly meet those needs, we should be led to seek diversity and flexibility in both our curricula and our faculties. I believe that in this direction lie our answers. □

ChE book reviews

BASIC PROGRAMS FOR CHEMICAL ENGINEERS
by Dennis Wright
Van Norstrand Reinhold Company, 1986, 340 pages, $32.95.

Reviewed by
Jeffrey J. Siirola
Eastman Kodak Company

The title of this book is to be taken both ways: a collection of very elementary chemical engineering computer programs, all written in the BASIC computer language. The stated purpose of the book is to provide engineers who have access to personal computers with ready-to-be-copied listings to enable solutions to problems in thermodynamics, mass and heat transfer, design, economics, *etc*. Included with each listing is a brief explanation of the equations on which the program is based and an example of typical input and output. In addition, many of the routines include tables of properties data for selected compounds or situations.

With less than three dozen routines, the book covers only a small fraction of chemical engineering computation. Included, however, are data regression, Newton-Raphson and Runge-Kutta equation solving, shell-and-tube and double pipe heat exchange, Fenske-Underwood-Gilliland distillation, plate efficiency and hydraulics, stoichiometry, chemical and vapor-liquid equilibria, prediction of critical and other physical properties of pure components, the design and economics of packed towers, heat exchangers, cyclones, and orifices, and a few other miscellaneous topics. To facilitate transcription, most routines are very short, averaging just over 100 lines of code. As much of the BASIC code is often associated with input-output and data, such short routines are of necessity quite simplified.

This book is not highly recommended for students. For computational situations appropriate to the sophistication of routines contained here, the effort to understand and transcribe listings error-free probably exceeds that required to code the simplified equations from scratch. For more serious work, far more complete and robust routines are widely available in the form of both software packages and listing. □

ChE letters

HOUGEN TRIBUTE APPRECIATED

Editor:

It was gratifying, indeed, to read the tributes to my brother, Olaf, written both by you and Bob Bird. Thank you for these testimonials and your role in their publication.

Joel O. Hougen
University of Texas at Austin