ChE curriculum

OBSOLETE CURRICULA FOR AN OBSOLESCENT PROFESSION? OR

What about Chemical Engineering today?

WM. H. CORCORAN
California Institute of Technology
Pasadena, California

IN THE PRELIMINARY program for the 59th Annual Meeting of the American Institute of Chemical Engineers, the title of this paper was given as "Obsolete Curricula for an Obsolescent Profession." Actually the correct title has a question mark after it, and that was inadvertently left out in the printing. That question mark is a very important bit of punctuation inasmuch as it reflects the basic issue. We are bordering upon obsolescent curricula, but we do not have an obsolescent profession — hence the question mark. In this presentation obsolescent curricula are discussed relative to proposals for additional change, and then comments are given about the nature of chemical engineering relative to other engineering professions. Even though we are having a blurring of the lines among the engineering disciplines, specific separate goals still exist, and unless a great metamorphosis occurs, chemical engineering will continue to have a very special professional atmosphere because of its preoccupation with chemical change.

William H. Corcoran received his BS, MS, and PhD degrees from Caltech. Formerly he was ChE department executive officer and presently is Vice-president for Institute Relations at Caltech. He is past-chairman of the Chemical Engineering Division of ASEE and was a leader in expanding the present journal of Chemical Engineering Education. Corcoran is active in many professional and academic societies and has received many honors for his work, e.g., the Educator-of-the-Year Award ('68) and the Western Electric Fund Award ('69). His research interests continue in applied chemical kinetics. He is a member of the ECPD Ad Hoc Accrediting Committee.

OUR PAST AND PRESENT

Very roughly it would appear that the history of chemical engineering education and associated research can be divided into decades almost as if we have a decade law. Table 1 shows the decade law applied to our history. To 1926 our focus in teaching and research was mainly on applied chemistry, and then we began to have an overlap with development of semi-empirical correlations in areas of energy, momentum, and material transport. Somewhere in the region of 1936 we developed more interest in the actual mechanisms in transport phenomena. Subsequent to World War II, about in 1946, we entered a period of significant developments in applied mathematics relative to chemical engineering. Around 1956 the applied mathematics began to focus more on system development which we are still following and which certainly has not yet received the peak attack. In 1966 one could say within reason that we entered a period of great focus on interdisciplinary efforts. What changing interest we will pursue in ten years is beyond view.

There is a thread through all this change inasmuch as teaching and research in chemical engineering have concerned themselves continually with the control of chemical reactions for some benefit of mankind. This goal will not

. . . the recommendation should be made that every undergraduate in science and engineering be required to take a two-year chemistry program which does integrate inorganic and organic chemistry in the matrix of physical chemistry.

quickly change nor should it change. On the other hand, our abilities to deal with the goal have changed, are changing, and will change. The main point, then, is that we have a very clear goal, and this focus keeps us in a special place in the study, teaching, and practice of engineering. Some of the engineering professions are blurring their lines unnecessarily because they have lost sight of their goals. We are not suffering from that dilemma. The styles in chemical engineering indeed have changed, but the changes continually have made the goals more clear.

RESEARCH AND EDUCATION

In the change of educational style in engineering, the lead has almost always been taken by research interests. Our applied and fundamental interests in the laboratory today become a part of tomorrow's teaching. That is somewhat contrary to critics of research who do not see clearly where leading educational procedures are born. An examination of research programs in various chemical engineering schools in the country today shows an amazing breadth of interest. We are conducting research in plasma chemistry, plasma physics, transport in biological and non-biological systems, optimization of chemical reactions, system synthesis and control, physics of liquids, physics of solids, and in many other fields. These interests have done many things for us in keeping our profession filled with vitality, and today, especially, it must be said that these interests have led us into close association with other disciplines with a resultant strong emphasis on interdisciplinary efforts. So our teaching must take that emphasis into account, and bit by bit it is. The prime purpose of this paper is to suggest that we should effect, however, changes in teaching that are more than bit by bit.

WHAT ARE WE TO do then in our educational programs as we consider this beginning decade of superposition of great interdisciplinary interests upon all the other areas that have been of interest to us in chemical engineering? Obviously we cannot prepare our men to be experts in each one of the interdisciplinary efforts. Nevertheless we can prepare them to have the willingness and confidence to study and develop in these areas. That should be our main goal in undergraduate education in chemical engineering. How are we to achieve this goal? A suggestion is that it is not necessary to have a five-year undergraduate program in chemical engineering but that a four-year program will suffice if we build upon the quality of the student as he enters the university. That in turn implies that students will be of high intellect and that the high schools will continue to do their job in continued development of improved programs as they have been doing in the past several years.

Table 1. DECADE LAW IN TEACHING AND ASSOCIATED RESEARCH IN CHE

DATE	*EMPHASIS*
To 1926	Applied Chemistry
From 1926	Semi-empirical Correlations
1936	Mechanisms of Transport
1946	Applied Mathematics
1956	Systems
1966	Interdisciplinary

So we must carefully analyze the nature of our undergraduate program, and we have been slow in such analysis and in subsequent change. We must continue to provide principles for the undergraduate to consider. Those principles can be the warp in his educational rug, and yet we cannot neglect the woof of technological developments. That woof can provide excitement and incitement in a situation that otherwise could be dreary. The technological detail cannot be too extensive but must be sufficient for transmission of the realities of engineering. Major attention must be given to principles and the mounds of technological data left to time after formal education.

SPECIFIC PROGRAMS

The change of prime concern as we face new demands upon our abilities in education in chemical engineering is one that must be made in chemistry. We in chemical engineering at Caltech have been concerned with this change for some time[1] and are pleased to observe that significant changes are being considered. Specific evidence is given in the issue of *Chemical and Engineering News* of November 14, 1966[2], which describes an

[1]Corcoran, W. H., "Departmentalized Curriculum Based on Chemical Change," Presented at 57th Annual Meeting of A.I.Ch.E., Boston, December, 1964, and published in *J. Chem. Eng. Ed.*, 3, 32-41 (1965).

[2]Anon., "Proposal Revamps Chemistry Curriculum," *Chem. and Eng. News*, 48-54, November 14, 1966.

. . . there is no reason why freshman and sophomore physics cannot be more integrated with studies in freshman and sophomore chemistry. Here is a major source of obsolescence.

undergraduate program in chemistry proposed by Professor George Hammond of our school. We have hoped for some time for a combination of inorganic, organic, and physical chemistry in teaching. Professor Hammond has come forth with a suggestion for a combination on a three-year basis. A hope is that the bringing together of inorganic, organic, and physical chemistry can even be done on a two-year basis with the realization that further advanced courses would have to be taken depending upon the discipline being followed by the student. As an added step, the recommendation should be made that every undergraduate in science and engineering be required to take a two-year chemistry program which does integrate inorganic and organic chemistry in the matrix of physical chemistry. There would be significant effort required in the classroom, and the laboratories would be much different from those that are currently used. There would be a series of required experiments and then there would be elective experiments which could focus in the general direction of the student's most probable long-term interests. Achievement of that state would require a significant upheaval in the teaching of chemistry in this country. Hopefully this upheaval will come and come rapidly. The two-year program in the new chemistry should be of interest to all engineers, not just to chemical engineers.

To implement Professor Hammond's suggestion for integrated style in the teaching of chemistry and the additional radical step of dealing with his suggestion in two years, a new attack in the teaching of freshman and sophomore physics is required. There is no reason why freshman and sophomore physics cannot be more integrated with studies in freshman and sophomore chemistry. Here is a major source of obsolescence in our curricula and where major changes in education must be achieved.

WITH THE PRESUMPTION that we could achieve the millenium and have the integration of organic and inorganic chemistry in a two-year chemistry course and intensive cooperation between chemistry and physics in the instruction of engineering and science majors, we could then look to the third year in the education of the chemical engineer. A required third-year course for chemical engineers in the application of physical chemistry would be very helpful. This course would build upon studies in chemistry in the first two years and begin to shift into applications of engineering interest. It would, however, allow study of appropriate principles in quantum mechanics, statistical mechanics, thermodynamics, and chemical dynamics. Probably, the chemistry departments will more and more concern themselves with problems of quantum and statistical mechanics to the exclusion of giving the breadth that we must have in looking at the combination of modern chemistry and classical chemistry in applications in engineering and science. Most chemical engineering faculties are admirably equipped to provide appropriate teaching in this bringing together in the third year of modern chemistry and classical chemistry in an applied style. Chemical engineering thermodynamics could also be taught as a required course in the third year.

In the fourth year, and the final year, of the undergraduate program in chemical engineering there would be a transport course with greater emphasis on the role of chemical change than currently prevails. A fourth-year course to integrate chemical and engineering ideas encountered in the previous three years and being obtained in concurrent efforts in the fourth year could be designated as design, simulation, and control of chemical systems. In this course there would be a combination of education in applied mechanics, industrial chemistry, process control, process optimization, and systems engineering. That sounds like a tremendous bite, but it is a tractable problem if attacked properly by the whole staff in chemical engineering. There would be a fourth-year laboratory course given in cooperation with other engineering groups in which fluid mechanics, energy transfer, and chemical change would be treated in appropriate liaison with the design course. Electives in science and engineering and required and elective subjects in humanities would fill out the undergraduate program. A question that could be asked at this stage is how one could be so presumptuous as to believe that there could be teaching of principles to give the undergraduate a basic education and yet provide him with knowledge of representative interdisciplinary problems pertinent to the style of the day. Such a background can be achieved in a four-year program if, in addition to developing new courses, we make a significant change in the style of teaching. The most important step to take in that direction would be to establish firmly the concept of cooperative teaching. By cooperative teaching reference is not made to teaching of a course in alternate years in another department, but rather to an actual, mutual association of professors of chemical engineering, physics, chemistry, mechanical engineering, and other disciplines in the attack of communication in the classroom. Cooperative teaching is not new nor is the tandem style of alternative years.

IN THE COOPERATIVE TEACHING, course responsibility exists among several dedicated people at a given time. As various topics are presented in a class there can be tandem teaching in the particular semester. The point of view of the physicist, of the chemical engineer, and of the chemist, for example, could be maximized in the teaching by assignment of parts of the semester's work to the appropriate teacher. The student would be introduced to a significant breadth of technological application that is missing at the present time. We are not omniscient, and for optimum communication why not depend upon our associates to fill in those areas where we do not have specialties? In a course on process control and dynamics, for example, there indeed could be an association between electrical engineering and chemical engineering. The electrical engineers would gain from the effort as would the chemical engineers. This matter of cooperative teaching sounds difficult from an administrative and cooperative point of view, but it is achievable by people who have focus upon a goal.

Not only is the cooperative teaching an item that we must consider from the standpoint of the best education but it also has significance relative to improved economy in the handling of courses in a university. Examination of catalogues around the country shows that there is significant duplication of course work between aeronautical and chemical engineering, between chemical engineering and chemistry, etc. That duplication may be acceptable when there is sufficient time and money to indulge in electives which have the same foundation but branch out into very specialized application. Perhaps, though, the time for such indulgence has passed. Integration of effort in the framework of cooperative teaching is a goal for chemical engineering in particular. Imagine, for example, the educational opportunities existent in materials science for cooperative teaching of the undergraduate by the physicist, the electrical engineer, the chemical engineer, and the metallurgist. Maybe there is a new world of excitement for the undergraduate. Possibly one of the reasons for loss of some of our excitement in the past few years has been lack of sufficient breadth of new examples in the application of basic principles which do not change very rapidly.

These cooperative efforts can be even broader than just suggested. Not only can there be cooperation among people in the physical sciences and engineering, but there can be association, as an example, between those groups and medicine. Study of a transport problem in cooperation with an individual who is expert in hemodialysis would put transport in a completely new light in the classroom. Opportunities for technological development really are unlimited and yet do not require extension of undergraduate education to infinity.

THE PRODUCT OF THE CURRICULUM AND TENSION IN ITS PRODUCTION

Mr. Peter Ellwood in an article entitled "Educating Tomorrow's Chemical Engineers" and presented in *Chemical Engineering*[3] noted on page 105 that "For the educators, the problem is also how to make the curricula—already jammed with subjects and under pressure to accept more — more attractive and less arduous for incipient engineers. The trend at present is the industry-regretted one of throwing out the subjects that are least amenable to the teaching process: to replace practice-oriented subjects such a shop work, machine drawing, and even old chemical engineering standbys such as unit operations and heat and mass transfer, with science-oriented subjects such as transport phenomena, process dynamics, and computer calculations. Alongside this juggling with technical courses is a strong desire for both shorter hours and

[3]Ellwood, Peter, "Educating Tomorrow's Chemical Engineers," *Chemical Engineering*, 103-124, September 26, 1966.

more humanities." Suggestions presented in this present discussion would within reason solve this problem of jammed curricula. In the same paper, Mr. Ellwood gives a table which shows how the chemical process industry regards the competence of its engineers. That table is excerpted

Table 2. CPI EXAMINES ENGINEERS' COMPETENCE[3]

RECENT GRADUATES

STRENGTHS	*WEAKNESSES*
Mathematics	Report Writing
Theoretical Principles	Oral Reporting
Engineering Science	Practical Ability
Programming Computers	Supervisory Skills
Willingness to Consider New Ideas	Graphics and Engineering Drawing
	Willingness to Take Risks and Experiment
	Liberal Education
	Technical Economic Analysis
	Engineering Design

EARLIER GRADUATES

STRENGTHS	*WEAKNESSES*
Practical Problem Solving	Programming Computers
Engineering Drawing and Graphics	Report Writing
Engineering Design	Oral Reporting
	Liberal Eduction
	Technical Economic Analysis
	Supervisory Skills
	Mathematics
	Physical Science

in Table 2. The weaknesses shown for recent graduates could also be treated in the framework of the program suggested here. Especially can the cooperative approach to teaching mitigate the cited weaknesses.

John R. Whinnery, Professor of Electrical Engineering at the University of California at Berkeley, published in "The World of Wiley" in the spring of 1966[4], the thought that "The inclusion of design in an engineering education is only part of the larger problem of constructing an engineering curriculum, which is really a staggering task. For an engineer's education, a good case can be made for including all the courses taken by a physics major and a mathematics major, an increase in the amount of chemistry, new courses in the biological and geosciences, and a marked increase in the number of humanities and social science courses. All the while, the engineering point of view must be communicated along with some selection from any one of the rapidly exploding bodies of knowledge in the fields of engineering. Such a curriculum cannot be given in four years or even eight years. The problem of selection is a difficult one, requiring understanding and cooperation by all segments of universities." Professor Whinnery's very appropriate statements again focus upon the tension that exists as we consider our curricula. We cannot be all things to all men, and there is no reason why cannot examine our situation carefully and achieve the education of the student at the Bachelor's level in the four-year program. The key to the matter is just exactly the point mentioned by John Whinnery, namely, there must be understanding and cooperation by all segments of the university. With that understanding we can achieve quality in engineering education that we have not touched before at all.

. . . A third year course in applications of physical chemistry to be taught by ChE faculty . . .

THE REPORT ENTITLED "The Dynamic Objectives for Chemical Engineering," presented in 1961[5], also alludes to the problem of time and technological explosion. The report notes that ". . . there has been a decline in the amount of chemistry in the undergraduate curriculum, owing primarily to the elimination of analytical chemistry courses and failure to substitute compensating chemistry courses." That problem should not be a great worry to us if we can get the people in chemistry to make some significant changes in their educational program. That change is possible.

The Dynamic Objectives report goes on to state " . . . This unfortunate trend should be reversed. It is imperative that chemical engineering undergraduates receive a thorough grounding in inorganic, organic, physical, and instrumental chemistry. Indeed students might well take additional courses in polymer chemistry, surface chemistry, biochemistry, or electrochemistry. Chemical engineering students should receive the finest chemistry instruction available on the

(Continued on page 78)

[3]From Peter Ellwood, "Educating Tomorrow's Chemical Engineers," *Chem. Eng.*, 116, Sept. 26, 1966.

[4]Whinnery, John R., "Engineering in the Multiversity," *The World of Wiley* 1, New York, Spring 1966.

[5]"The Dynamic Objectives for Chemical Engineering," *Chem. Eng. Progress*, 57, No. 10, 69-100 (1961).

CONCLUSION

The purpose of this article has been to present a case for upgrading the graduate chemical engineering course in kinetics and reactor design, particularly for the intermediate size schools which cannot support the development of more sophisticated courses in all of the contemporary areas. The course outline presented is an example of a successful program presented as a one-semester course at the University of Toledo. Selections of the course can obviously be changed to accommodate the needs and interests of students and faculty.

If sufficient interest is shown to support the expansion of one of the areas in particular, it could be given as a special topic course or as a seminar. Graduate students in the Chemistry Department should also be contacted as potential candidates for such courses.

CORCORAN ON OBSOLETE CURRICULA

(Continued from page 71)

campus. Generally this requires that they be trained side by side with majors in chemistry rather than be placed in service courses with non-chemists. It is important not only that the chemistry training be up-to-date but also that it be used in the subsequent chemical engineering courses. This means that the chemical engineering staff too must keep itself informed on modern chemistry." Those ideas are excellent, but in keeping up with chemistry, we must insist that chemistry keep up with itself. Also we as chemical engineers must see that the chemistry training is used in the subsequent chemical engineering courses. We have no other choice.

SUMMARY AND CONCLUSIONS

The conclusion is that we must change our style in chemical-engineering education. If we do not, we will not as chemical engineers make the contribution to society that we must. A good fraction of our goal is to provide people who have the ability to work in the area of optimum control of chemical reactions for the benefit of mankind. If we are not careful, we will lose that ability and even franchise to deal with one of the most important needs of society. How de we meet our responsibility? Specifically, the following changes are suggested as the avenue to capture our new style:

1. A two-year course in chemistry be given by the chemistry department, for chemists and engineers alike, in which inorganic and organic chemistry are combined in the framework of physical chemistry. Appropriate laboratory work would be given, with required experiments plus optional experiments which would be of special interest to the student as he looks ahead to his future.
2. There be a requirement that all engineering and science students take the two-year course in chemistry.
3. A real association of the first two years of physics and chemistry be effected.
4. A third-year course in applications of physical chemistry be taught by the chemical-engineering faculty. This third-year course would focus upon the first two years of chemistry and consider chemical principles in terms of applications in real systems. In this course, modern chemistry and classical physical chemistry would be combined in the study of applications. A course of this type probably will not be taught in the framework of chemistry's interest in these days. The responsibility is ours, and we must meet it.
5. Major emphasis on chemical change be established in the transport change.
6. A senior course in design be more encompassing than envisioned to date. It should be a course with a title such as "Design, Simulation, and Control of Chemical Processes." This course would bring together the students' training in chemistry with added information in industrial chemistry, process dynamics, applied mathematics applied mechanics, and other areas of engineering endeavor. In particular the focus would still be control of chemical change.
7. Cooperative teaching of key courses be introduced as a must in engineering training and especially in chemical engineering. There is no reason today for a compartmentalization of courses and especially no reason for use of the older style of tandem teaching of courses of mutual interest. Rather courses of mutual interest must be taught in a mutual way. In the interest of conserving time and improving quality of education, the cooperative teaching must expand in a way that we really do not even dream of at this moment. The cooperative teaching requires not only cooperative effort within a school but cooperation between schools such as engineering and medicine.
8. There be a fourth-year, all-engineering laboratory with elective experiment in chemical change.

Finally, it is necessary to emphasize that our curriculum efforts are obsolescent, not obsolete, and that our profession is not obsolescent but very much alive. We must make changes, nevertheless, in our programs that we have not dared to make before. We must elicit the cooperation of all parts of our schools. These changes are not changes that can be made internally in the departments of chemical engineering; they encompass the attitude of the whole university. Let us not be shaken by such a goal and step ahead and lead, because we have a unique position of leadership in our concern with chemical change.