ChE Curriculum

THE CHEMISTRY-CHEMICAL ENGINEERING MERRY-GO-ROUND

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THE MAJOR CHARACTERISTIC WHICH distinguishes the chemical engineer from all other engineers is the foundation in chemistry which is required. There is a generally accepted statement, the origin of which has been lost in antiquity, that says "The day mechanical engineers dropped physical chemistry from their curriculum, chemical engineering was born." Since the birth of the AIChE, the question of chemical engineering education has been uppermost in the minds of its members. One of the first acts of the new Society was to establish a committee on Chemical Engineering Education, under the Chairmanship of C. F. McKenna. There was much debate on the curriculum content for chemical engineering but little consensus until after World War I, which has been known by many people as the "Chemists' War." Prior to that war, there was little chemical industry in this country. As a matter of fact, the United States was so dependent on foreign imports of chemicals that the Germans were encouraged in 1915 to deliver a supply of dyes to the United States by submarine to avoid the Allied blockade. Following the "Chemists' War" there was a major increase in the chemical industry. Along with the growth of that industry, there was a demand for chemists and chemical engineers to staff these industries.

The fundamental educational debate at that time was whether or not there really was such a thing as chemical engineering. That chemists were employed in the chemical industry was unquestioned. That engineers were employed in the chemical industry was unquestioned. The German concept was to have a team of a chemist and a mechanical engineer perform most of the functions that are today thought of as chemical engineering. It remained for the team of William H. Walker, W. K. Lewis, and W. H. McAdams to publish a textbook "Principles of Chemical Engineering" in 1923, to clearly and succinctly delineate, for the first time, the place of chemical engineering. This book made a clear distinction between the industrial chemists on the one hand and all other engineers on the other. The most significant contribution of Walker, Lewis and McAdams was to focus the attention of chemical engineers on the unique place of the unit operations. While the term 'unit operation' had been used earlier and is credited to Arthur D. Little, who based a curriculum study on unit operations as early as 1915[1], the concept did not take hold until after the publication of this book. Dr. Little, while he was Chairman of the Chemical Engineering Education Committee of AIChE, made the first steps towards the establishment of accredited chemical engineering curricula. This initial list appeared in 1925, eight years before the rest of the engineering profession established the Engineers' Council for Professional Development. Only fourteen institutions appeared on this list. In 1933, the chemical engineers joined ECPD, but they retained a certain amount of autonomy. They were the only ones who, because of their previous experience, saw the necessity for greater emphasis on the basic sciences in the undergraduate curriculum followed by advanced work at the graduate level. This occurred before World War II, commonly known as the "Physicists' War."

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[1]"Highlights — the first 50 years of the American Institute of Chemical Engineers, pg. 56, (1958 published by AIChE).

IN ORDER TO EVALUATE WHAT HAS happened to the chemistry content of the undergraduate curriculum over the past 30 years, the 14 institutions on the original accredited list augmented by those institutions which were deemed to have either distinguished or strong faculties in the American Council on Education study[2] have been reviewed. The conclusions in this paper have been confirmed by reviewing what has happened to the chemistry content of these twenty-four institutions.

From 1925 until accreditation was temporarily abandoned during World War II in 1943, there was general hauling and pulling among the proponents of more chemistry and basic sciences as opposed to those who preferred more applied and more practical engineering emphasis in the curriculum. Dr. Albert B. Newman[3] summarized the situation as it existed in the late 1930's very well. Quoting from that paper[4]

"In modern practice, it seems clear that the chemical engineer must not only have a working quantitative knowledge of the unit operations, but he must have a sound knowledge of chemistry, physics, mathematics, thermodynamics and economics. He must have facility in applying physical chemistry to plant processes, particularly in relation to reaction velocities and the graphical calculus used in the interpretation of laboratory and pilot plant data on kinetics of chemical reactions."

As a result, in order to try to satisfy the two opposing views, more engineering and applied courses versus more chemistry and basic sciences, the credit content of the undergraduate chemical engineering course rose to an almost intolerable level at many of the institutions. In some cases, an average of 20 semester credit hours for a total of eight semesters was required for graduation. The four year curriculum was reaching the bursting point. Most of the stronger accredited institutions, in that period, insisted on four years and a summer session, usually between the junior and senior years, to lessen this unrealistic load. The Chemical Engineering Education Committee was far ahead of the education committees of the other engineering societies and of the philosophy of ECPD in two respects in the 1930's. The chemical engineers did not consider the four year undergraduate course as terminal education, but rather "that education[5] has just begun at the end of the four year course. No student should prepare for chemical engineering unless he is enthusiastic about the idea of a lifetime of study." The Committee further believed that research activity by the chemical engineering staff and graduate students is important and was usually found in those institutions which qualified for accrediting.

IN FACT, THE TRADITION OF GRADUATE WORK in chemical engineering was one of the close ties between chemists and chemical engineers which fostered graduate education in both disciplines following (World War I). The recommended content of an undergraduate chemical engineering curriculum in 1938 is shown in Table I. The percent figures are those taken from Newman's publication[6]. There was little dissension regarding the percentages, but the difficulty arose when such a curriculum had to be translated into a reasonable number of credit hours. For convenience, in Table I, the column of normal credits is given for comparison with present day curricula, but many of the actual curricula contained total credits up to 160. It appears, therefore, that in the 30's, most of the accredited curricula included four whole year courses and at least one additional one semester course in chemistry. The year courses were usually general chemistry, quantitative analysis, organic chemistry and physical chemistry. The additional courses varied widely depending on the interests, competence and backgrounds of the faculty at the various institutions. At this time, it was generally agreed that the undergraduate load was too heavy and further that graduate work was to be encouraged. Quoting again from Newman's paper[7] "The Committee is of the opinion that the tendency to extend chemical engineering study into graduate years, especially on the part of those students whose special aptitude in theoretical divisions, is one that should be

TABLE I — CHE CURRICULUM RECOMMENDED IN 1938

	Percent	(Normal Credits in) Semester Hours
Chemistry	25-30	36-44
Chemical Engineering	20-15	30-22
Other Engineering	12	18
Mathematics	12	18
Physics	8	12
Mechanics	6	9
Other Sciences	2	3
Cultural Subjects	15	22
Total	100	148

* Development of Chemical Engineering Education in the United States, Albert B. Newman (Trans. AIChE **34**, 3a (1938).

[2]An Assessment of quality in Graduate Education, Allan M. Cartter, American Council on Education, Washington, D. C. pg. 70, 1966.

[3]Development of Chemical Engineering Education in the United States, Supplement to transaction of the American Institute of Chemical Engineers, Volume 34, No. 3A, July 25, 1938.

[4]*Ibid.* Pg. 12

[5]*Ibid.* pg. 16

[6]*Ibid.* pg. 23.

[7]*Ibid.* pg. 23.

encouraged, because of the widely recognized difficulty of giving adequate instruction within a period of four years, especially if any attempt is made to teach methods of research in science or engineering." Thus, it appears that the Chemical Engineering Education Committee in 1938 reached the conclusion which apparently the rest of the engineering profession is tentatively approaching in 1967[8].

There was general agreement in the thirties that if the amount of chemistry in the chemical engineering curriculum is reduced drastically, then the need for chemical engineering as a separate entity becomes academic. This was about the situation when World War II intervened. A temporary cessation of the accrediting function took place between 1943 and 1946. When the ECPD Education and Accreditation Committee reconvened after World War II, the effect on the undergraduate engineering curricula was obvious to many. The engineering education of the 30's was found to be insufficient in its content of mathematics and the basic sciences. The need for adding large doses of the engineering sciences (which the chemical engineers had called unit operations in their area for many years) became obvious. The physicists became enamored with sub-atomic phenomena and tended to abandon classical physics. Thus, the engineering sciences and much of classical physics tended to merge. The resulting effect on the chemistry content of the chemical engineering curricula was serious and in some cases drastic.

It became obvious that a thorough re-study of the needs of undergraduate engineering education was in order. At the request of ECPD, ASEE undertook a study which has come to be known as the Grinter Report[9]. The report of this committee reads strikingly similar to the recommendations of the Committee on Education and Accreditation of AIChE as annunciated by its chairman in 1938[10] The obvious difference, however, is that when most of the members of the Grinter Committee talked about the basic sciences and the engineering sciences, they were almost uniformly talking about physics and almost uniformly neglecting chemistry. It was only through the valiant effort of the few chemical engineering members of the ASEE Committee that some of the normal chemical engineering unit operations were included as some of the engineering sciences. The publication of the Grinter Report was a signal for rather drastic revisions of engineering curricula throughout the country. The kind of dichotomy which was mentioned previously as occurring among the chemical engineers in the 30's, now infected all the branches of engineering, i.e., one group advocating more mathematics and basic science as opposed to those who recommend more applied courses and practical training. The course content recommended by the ASEE Committee[11] illustrates the dilemma. (See Table II) The whole four year curriculum allows less time for mathematics and all basic sciences than the chemical engineers thought was necessary for chemistry along in the 1930's. As a result, the chemistry content in 1966 of all of the curricula studied contains less chemistry than those same institutions had in the 30's or when they were first accredited by ECPD.

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TABLE II — COURSE CONTENT RECOMMENDED BY THE COMMITTEE ON EVALUATION OF ENGINEERING EDUCATION[11] 1952-1955

	Proportion of Curriculum
(1) Humanistic Social Studies	About 20%
(2) Mathematics and Basic Sciences (About equal weight)	About 25%
(3) Engineering Sciences	About 25%
(4) Sequenceof Engineering Analysis, Design and Engineering Systems, including the Technological Background	About 25%
(5) Options or Electives	About 10%
Total	Four years

TWO OPPOSING FACTORS FURTHER aggravate the current situation, the explosion of scientific knowledge since World War II, argues for the inclusion of more subject matter while the ASEE Committee recommends decreasing the total number of credit hours to lighten the burden on the student. This places engineering education squarely on the horns of two dilemmas: How to increase the science content of the

[8]Interim Report of the Committee on Goals of Engineering Education, E. A. Walker, Chairman, American Society for Engineering Eduction, April, 1967.

[9]Report of the Committee on Evaluation of Engineering Education, L. E. Grinter, Chairman, ASEE Pamphlet, June 15, 1955.

[10]*Ibid.*

[11]Report of the Committee on Evaluation of Engineering Education, L. E. Grinter, Chairman (ASEE Pamphlet 1955).

curriculum on one side, decrease the total number of contact hours on the other side and still make an engineering curriculum without going beyond four years. The conclusion is obvious. Sooner or later it must be recognized that an adequate four years curriculum in chemical engineering is a misnomer. The Goals of Engineering Education Committee realize that there are many ways to reach the desired objective of a well educated professional engineer. However, in each case the inescapable conclusion must be reached that an engineer has an insufficient background at the end of the Bachelor's degree program to fit him for a productive technical career in engineering. The report further contends that formal education to the Master's level followed by continuing education throughout his professional life is a must for the engineer of the future. Equating the Goals report to chemical engineering it appears that there is room for various kinds of chemical engineering curricula, all the way from a very "light" chemistry content at the undergraduate level followed by more chemistry at the graduate level to a "strong" chemistry content at the undergraduate level followed later by more engineering at the advanced level. (See Table III)

TABLE III — FOUR YEAR COMPROMISE BChE CURRICULA

	Light Chem. Semester cr.	Strong Chem. Semester cr.
Mathematics	21	16
Chemistry	24	36
Other Science	12	16
Chem Eng Science	34	28
Other Eng Science	10	10
Chem Eng Design	9	4
Other Eng Design (Electives)	6	6
Humanistic-Social	28	28
Total	144	144

IF A FOUR YEAR CURRICULUM IN CHEMICAL engineering is to continue to be the norm for first accreditation and if the student is not to be given an intolerable overload, then some compromises must be accepted. A reasonable compromise can be achieved among the relative amounts of basic science (in this case the amount of chemistry), the engineering sciences and the analysis, synthesis and design sequences. This compromise is coupled with the assumption that a course load greater than 18 credits per semester or 144 semester credit hours for four years is undesirable.

The "light chemistry" curriculum provides for a year course each in general, organic and physical chemistry. This is agreed as the irreducible minimum for a chemical engineer. The "strong chemistry" program allows for about three semesters of additional chemistry, but in so doing some mathematics, chemical engineering science and chemical engineering analysis, design and systems must be sacrificed. The twenty-three institutions in Table II with accredited undergraduate chemical engineering curricula in 1967 all come within these limits.

Once the young Bachelor's degree recipient from either of these curricula becomes engaged in technical work in industry, he will feel his inadequacy in one direction or the other depending on his needs. He will be encouraged by his employer to fill the gaps by proceeding to the Master's degree. A typical program (See Table IV) illustrates how either man can reach the same general Master's degree plateau by selecting the appropriate courses.

There is considerable question in this writer's mind whether the graduate from the "strong chemistry" curriculum (which contains the minimum amount of chemistry recommended by AIChE in the 30's) has sufficient engineering content to justify a designated degree (or an accreditable degree) in chemical engineering. The "light chemistry" curriculum has a reasonable engineering content but is shy in chemistry. The problem has now come full circle. When the AIChE Committee on Accreditation published its first accredited list in 1925, the concern was to

TABLE IV — THREE POSSIBLE ROUTES TO THE MChE DEGREE

	Basic Gen. Eng Degree BE	Light Chem. 1st Prof Degree BChE	Strong Chem. 1st Prof Degree BChE
Mathematics	22	21	16
Chemistry	28	24	36
Other Science	16	12	16
Ch.E. Science	22	34	28
Other Eng. Science	18	10	10
Ch. Eng. Analysis, Design and Systems	4	9	4
Other Eng. Analysis, Design and Systems	6	6	6
Humanistic-Social	28	28	28
	144	144	144

	1st Prof Degree MChE	2nd Prof Degree MChE	2nd Prof Degree MChE
Mathematics	0	3	6
Chemistry	8	12	0
Chem Eng Science	6	3	6
Chem Eng Analysis, Design and Systems (includes thesis)	16	12	18
	30	30	30

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. . . This writer favors a compromise solution in which all engineers will be given a Bachelors degree in engineering undesignated.
. . . the first designated degree would be at the Master's level.

distinguish the chemical engineer as an engineer distinct from the industrial chemist. Now the problem appears to be to provide the chemical engineer with enough chemistry to distinguish him from other engineers.

AS EARLY AS THE 1900'S, NEWMAN[12] AND his Committee recognized that education beyond the Bachelor's level was required if the chemical engineer were to have both sufficient chemistry and engineering. The intervention of the Physicists' War showed everyone the need for basic physics for all engineers. Thus, at the time of the Grinter Report in 1955, the amount of basic science in all engineering curricula was raised for the first time to the level required by the chemical engineers as early as 1933. The net result has been that chemical engineering, in order to increase the physics content, had to decrease the chemistry content. The Grinter Report recommended that an engineering curriculum include in the more general engineering science courses much of the material that in the 1930's the chemical engineer covered (less thoroughly to be sure) under the unit operations label. The result is a squeeze in the chemical engineering sequence in favor of engineering science courses in other departments, i.e. fluid dynamics in place of the unit operations fluid flow. Conversely, some very fine courses in high temperature chemistry are being conducted by departments of astronautics and aeronautical engineering and some courses in radiation chemistry are being taught by departments of physics and nuclear engineering rather than departments of chemistry. Thus, many of the old labels are being confused.

At this point, it does not seem desirable to debate the virtues and vices of these changes, but merely to report them as facts. The result is similar to the meeting of the immovable body and the irresistible force. Somebody has to give or the result is chaos. This writer favors a compromise solution in which all engineers will be given a Bachelor's degree in engineering undesignated. Each student in the general engineering curriculum (See Table IV) would be given sufficient latitude in electives so that he can choose the basic science and the engineering science that will give him a sufficient flavor of his proposed major. At the same time, the concentration in his major would be limited so as to permit his getting a broader engineering education than would be the case if there were a designated degree at the Bachelor's level. With this type of broad engineering degree, the first designated degree would be at the Master's level. It should be a stronger degree with a broader background than would be the case with a Master's degree built on either the "light chemistry" BChE degree or the "strong chemistry" BChE degree. (See Table IV for comparison).

Nevertheless, it seems perfectly clear that there are at least three routes toward the Master's level in chemical engineering, any one of which will produce a satisfactory product. It is also evident that more chemistry is needed by the chemical engineer than he is now getting in many of the "light chemistry" BChE curricula in institutions listed in Table III. It is further assumed, however, that the better students are wise enough to get that chemistry either by taking additional courses after they graduate or are being exposed to this material by taking courses otherwise labeled in other departments.

The inevitable conclusion is that the explosion of knowledge since World War II has emphasized the importance of giving to the present day chemical engineer at least as much chemistry as he had before World War II. In addition, his curriculum must include more from the other basic sciences plus more mathematics as well as new and expanded engineering sciences. If he is to be an engineer, he must have his share of courses in analysis, and design. All this material cannot fit in the old standardized package.

There will be ample jobs for anyone who wishes to terminate his formal education at the traditional Bachelor's level. All three routes, the "light chemistry" BChE, the "strong chemistry" BChE and the general engineering with chemical electives BE, will find many opportunities for productive careers. But in 1967, as in 1938 the chemical engineer has just begun at the end of four years of formal study. No student should prepare for chemical engineering unless he is prepared for a life-time of study — with a maximum of chemistry.

[12] *Ibid.* pg. 23