CHEMICAL ENGINEERING EDUCATION

OCTOBER 1965

A New View of Bifurcation

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CHEMICAL ENGINEERING EDUCATION
OCTOBER 1965

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EDITORS' CORNER

Chemical engineering education is a living, sensing, growing thing. It moves, it vocalizes, it has a distinctive if variable complexion. It ingests voraciously the thoughts and efforts, ideas and exercises, criticisms and inventions of its feeders — its educators, its students, the profession it procreates, the industry it serves; it matabolizes its intake into extending bone, enlarging muscle, and developing brain; it functions, complicated organism that it is, in a kind of organized and rational pattern of thought, action, and word. Like man, it speaks in many tones.

CHEMICAL ENGINEERING EDUCATION is one of the voices of chemical engineering education, in the United States the one with the most official accent. With this issue, the listener may be aware of a process that has gone on for some years: the voice is changing! The editors believe that it IS changing — not the animal so much as its vocal chords, which are lengthening and thickening and growing stronger.*

Chemical engineering education has plenty of forceful breath. Chemical engineering educators and the employers of their product have plenty of intelligent and precise word-forming skill by which to express their thoughts and beliefs. CHEMICAL ENGINEERING EDUCATION rededicates itself to the commission of converting breath to sound, deep and resonant, for the clearly audible broadcast of ideas articulated through it

* To allow a large audience of appropriate listeners to hear the voice of CHEM ENG ED as it has become, this issue is being sent with the compliments of CED to all non-subscriber members of the Division and to a number of other chemical engineering educators.

CHEMICAL ENGINEERING EDUCATION

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CED/AIChE NEWS

Chemical Engineering Education — a Reintroduction

George Burnet
Past Chairman, CED; Professor and Head of Chemical Engineering, Iowa State Univ., Ames, Iowa

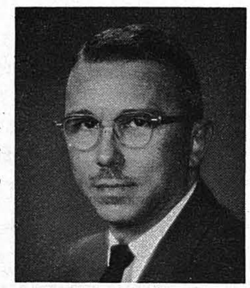
The Chemical Engineering Division, ASEE, was formed in 1936, an outgrowth of an earlier Chemical Engineering Committee directed by the late Frank C. Vilbrandt and Joseph C. Elgin. Dr. Vilbrandt was the Division's first chairman. It has functioned continuously ever since, and it has numbered some of the most distinguished chemical engineering educators among its leaders.

Prior to 1940, the Division sponsored no periodic publication, but the 1936 meeting at the University of Wisconsin resulted in the publication of a book, "Applications of Chemical Engineering" (Van Nostrand, New York, 1940), edited by the late Harry McCormick. In 1940 there appeared the "Proceedings of the Chemical Engineering Division," edited and published by Joseph H. Koffolt, then CED Chairman. The Proceedings were interrupted by World War II, and after the war reappeared under the title "Transactions of the Chemical Engineering Division" and under the editorship of Albert H. Cooper. The Transactions were issued almost every year between 1946 and 1961, and in 1962 gave way to a quarterly, CHEMICAL ENGINEERING EDUCATION, also edited by Dr. Cooper through 1964. For the quarter-century 1940-1964, CED publications were published, printed, edited and financed by the editors, Dr. Koffolt and Dr. Cooper, and the Division owes these two devoted members a greater debt of gratitude than it can ever repay.

By late 1964, the burden of publication had become intolerable for an individual. This fact and the acceptance of the increased responsibility of a deanship by Dr. Cooper led to his resignation as editor. The Executive Committee of CED deliberated the future of Division publications and, with ASEE approval, arrived at the following decisions: CHEMICAL ENGINEERING EDUCATION should continue as the quarterly journal of CED; publication should be by the Division, under the advisorship of a Publications Committee; financing of the journal should be achieved by subscription fees and advertising income, but in any event will be backed by CED; the editorial and circulation effort should be conducted by a group of editors. With this issue, then, CHEMICAL ENGINEERING EDUCATION is starting the next phase of its life under the editorship of S. A. Miller, J. W. Bartlett, and Dr. Cooper, who, under the conditions established by CED, felt that he could continue to lend his hand to the journal. For greater convenience, this and future issues will bear volume and issue numbers, and each volume will be paged continuously through the academic year in which it appears.

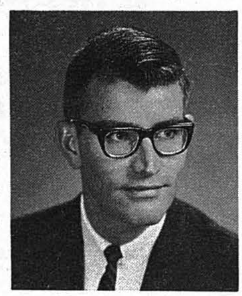
It is appropriate that we introduce to our readers the new staff of CHEMICAL ENGINEERING EDUCATION. They are:

Editor, Shelby A. Miller, B.S. Ch.E., University of Louisville; Ph.D., University of Minnesota; P.E.; Professor and Chairman of Chemical Engineering, University of Rochester, Rochester, N.Y.



Consulting Editor, Albert H. Cooper, B.S.Ch.E., M.S., University of Tennessee; Ph.D., Michigan State University; P.E.; Dean of the Graduate School, Tennessee Technological University, Cookeville, Tennessee.

Assistant Editor, John W. Bartlett; B.S.Ch.E., University of Rochester; M.Ch.E., Ph.D., Rensselaer Polytechnic Institute; Assistant Professor of Chemical Engineering, University of Rochester, Rochester, N.Y.



The Executive Committee of CED joins the editors in the pledge to provide in CHEMICAL ENGINEERING EDUCATION an attractive and indispensable part of every chemical engineering educator's personal library. To prove our point, we are sending a sample copy of this issue gratis to every DIVISION member who has not subscribed and to a number of other educators. Our intention, frankly, is to hook non-subscribers. If you have not yet placed your order, won't you do so now?

A Chemical Engineering Division Symposium presented at the 73rd Annual Meeting of ASEE in Chicago, Illinois, June 22, 1965. Symposium arranged by L. E. Burkhart, Professor of Chemical Engineering, Iowa State University, Ames, Iowa.

A New View of Bifurcation

Foreword

L. E. Burkhart

The following papers provide a study of one of the significant problems in chemical engineering education — how to prepare graduating chemical engineers with increasingly diverse ranges of interests to cope with the equally broad spectrum of work that they are likley to encounter during their careers.

Attempts to solve the problem take many forms, apparent from the curriculm changes that have taken place in recent years. One school will take the science vs. practice approach; a second will abandon traditional engineering fields in favor of a completely interdisciplinary approach. A third school might choose simply to continue revising and upgrading its classical engineering curricula.

Much has been written about interdisciplinary programs and much about traditional chemical engineering curricula. However, little has been reported about bifurcation — the approach of providing alternate routes to the B.S. degree in chemical engineering. This practice is more widespread than might be commonly believed, for much of the experimentation with multifurcated curricula in chemical engineering remains unreported.

In the first paper, Dean E. Griffith, a member of the Subcommittee on Undergraduate Curricula of the Education Projects Committee of A.I.Ch.E., estimates the degree of penetration of the bifurcation concept into chemical engineering education in the United States. In the second, Glenn Murphy, a former member of the famous Grinter Committee and a past president of ASEE, discusses the history of bifurcation in engineering programs and presents his opinion of how engineering education will change.

The last two papers give accounts of two specific types of bifurcated curricula in chemical engineering, both current. First, T. D. Wheelock outlines the bifurcated chemical engineering curriculum which has been in use at Iowa State for several years. It is carried out at the undergraduate level within the Department and is not college-wide.

The final paper, by Yerazunis and Burr, describes a new multifurcation concept which involves the entire College of Engineering at Rensselaer and extends into the graduate level.

Curriculum Analysis and Multifurcation of Chemical Engineering Undergraduate Curricula

Dean E. Griffith
Consultant, Houston, Texas

The first really detailed survey of chemical engineering curricula was performed by Professor A. X. Schmidt of the City College of New York in 1956-7 (*3*). To quote from Schmidt's article:

> "The curriculum is often a factor of importance in discussions of engineering education and accreditation . . . [To determine what 'the curriculum' is,] the bulletins of eighty-seven United States colleges and universities were examined for the survey, . . . the complete roster of institutions accredited in chemical engineering at the time."

This number of 87 in 1956-7 has increased steadily to 107 by mid-year of 1964-5. It is still growing. Schmidt continues:

> "It was felt that a knowledge of . . . the average accredited American B.S. Ch.E. curriculum of 1956-7 . . . would (1) permit comparison with past and future curricula, thus acting as an aid in evaluating changes and trends and (2) afford a ready means for comparing any particular curriculum with the current norm."

Schmidt immediately encountered problems in the treatment of his data. The curricula of six of the 87 institutions were omitted for one reason or another; e.g., some were presented in a manner that precluded inference of credits and student effort per course; others exceeded in content the upper limit for an alleged four-year bachelor's curriculum.

These problems have been somewhat alleviated. Universities are printing more readable catalogs now. The Subcommittee on Undergraduate Curricula of the Education Projects Committee of A.I.Ch.E. has split off five-year curricula for separate consideration, and Dr. J. J. Christensen of Brigham Young University recently reported to the Subcommittee the results of a 1964 survey of such curricula (*1*).

Schmidt also ran into other problems. To establish a common denominator:

> "The contents of all the curricula were reduced, as nearly as could be determined, to a common unit — what may be called an ECPD semester credit representing a total of approximately fifty hours of the student's time (recitation, lecture, laboratory, or outside preparation)."

Additional problems were found in comparing level of mathematics and in treating military science, physical education, religious courses, seminars, orientations, and asemblies. Even with reduction of data to a common ECPD credit unit, the curricula, adjusted to remove the variations just listed, still ranged in net credits from 118 to 160.

Two primary conclusions can be drawn from Schmidt's study. First, it was a work of tremendous labor without the use of today's large computers, and it made a really significant contribution to chemical engineering education. Second, one still can prove anything by statistics if the data are not on a common basis and if arbitrary inference may (or must) be introduced by the analyst.

A second survey of undergraduate curricula was done by a greatly enlarged A.I.Ch.E. Subcommittee in 1961-2 under the chairmanship of Dr. C. M. Thatcher of Pratt Institute. The results, published in 1962 (*4*), contained an analysis of 92 accredited undergraduate Ch.E. curricula. Thatcher wrote:

> "If it is to be completely meaningful, an analysis of chemical engineering curricula should properly start with a consideration of the objective sought, and only then examine the means by which the objective is achieved."

Quoting further from Thatcher in a private report to the A.I.Ch.E. Subcommittee on Undergraduate Curricula:

> "My own present feeling is that perhaps we have already put the cart before the horse: We have gathered data on what is being done before looking into objectives, and it is quite probable that there is a difference of opinion among departments [of chemical engineering] after you once get beyond the broad aim of turning out capable chemical engineers. For example, some departments may have curricula specifically tailored to prepare students for further study at the graduate level, some may emphasize practice as opposed to theory, etc."

This brings us to the problem of bifurcation, or perhaps more properly, multifurcation of curricula. It seems most important that each department whose curriculum is being considered for accreditation should specifically and clearly state its objectives. At a 1963 planning sesion of the Undergraduate Curricula Subcommittee of A.I.Ch.E., after strongly objecting to lumping all curricula into one category in our surveys, I was (needless to say) selected as Chairman of a Survey-In-Depth Committee to attempt to extract the changes taking place in accredited chemical engineering curricula in the United States. This study, still in progress, should be completed by June, 1966.

A complete curricula study, similar to those made by Schmidt and Thatcher, will not be conducted until 1966-7. It is my recommendation that only straight general chemical engineering curricula be included in that study because of the complications involved in reducing the data from multifurcated curricula to a common basis when the objectives are different. The conversion of raw curricula data should also be programmed on an electronic digital computer by the National Headquarters of A.I.Ch.E.

What can now be said about multifurcation of curricula in chemical engineering in the United States? On the basis of the limited analysis made thus far, the magnitude of penetration of multifurcation into accredited curricula can be seen.

Professor C. L. Mantell of Newark College recently listed all of the chemical engineering schools in the United States (including the non-accredited schools), the number of students receiving B.S., M.S., and Ph.D. degrees in chemical engineering from each school, and the total chemical engineering graduates in each school for 1963 and 1964 (*2*). Out of a total of 3028 B.S. Ch.E. degrees awarded by all schools in 1964, 297, or almost ten per cent, were awarded by non-accredited schools. This leaves 2731 awarded by accredited schools of chemical engineering.

It is now fairly common knowledge that less than 30% of the schools in chemical engineering award more than 50% of the B.S. Ch.E. degrees. In particular, there were 31 schools which awarded 1473 B.S. Ch.E. degrees in 1964. This represents approximately 54% of the undergraduate degrees from accredited schools. Of these 31 larger schools, 11 (more than one third) had multifurcated curricula. This high percentage probably would not hold among schools with smaller graduating classes for the simple reason that multifurcated programs mean offering more courses. This becomes expensive when the number of students is small. Of the 31 schools whose curricula were examined, only two offered five-year curricula and both of these had multifurcated programs.

The 11 schools having multifurcated programs in chemical engineering had an aggregate of 53 separate options specifically designated (including 11 chemical engineering options). The distribution of these programs by number of options, or multifurcation index, is shown in Table I.

TABLE I. Multifurcation Levels of Eleven Large Chemical Engineering Schools.

Number of Schools	*Multifurcation Index
5	2
2	3
1	6
1	7
1	10
1	14

* A multifurcation index is defined as the number of alternate routes in a chemical engineering curriculum. For example, a bifurcated curriculum would have a multifurcation index of two.

That multifurcation does exist to an appreciable extent in chemical engineering curricula today can be concluded from the number of curricula involved, the percentage of students graduating annually from such programs, and the magnitude of the multifurcation index. Lumping all programs leading to B.S. Ch.E. degrees into one category for statistical analysis should no longer be attempted, therefore, if the results of a curriculum survey are to be meaningful.

In conclusion, the remarks of Thatcher at the ASEE-A.I.Ch.E. Summer School for chemical engineering teachers at Boulder, Colorado, in 1962 are appropriate:

"There have been significant changes within a relatively stable curricula framework. The lamentable fact is that such changes are all too frequently not reported to groups such as this so that they can be tried elsewhere, perhaps adopted, and, most important, perhaps built upon to achieve even more satisfactory results."

Let us continually analyze our curricula and their courses, in terms of what we are trying to accomplish, how we are going about it, and how effective our efforts are. Let us experiment to identify new and more effective ways of achieving our objectives. And finally, let us report the results of both our analyses and our experiments.

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Science, Technology, or Both?

Glenn Murphy

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The term "bifurcation" was introduced into discussions of engineering curricula a little over a decade ago through the activities of the ASEE Committee on Evaluation of Engineering Education, known as the Grinter Committee.

About 1951 it became evident that a critical appraisal of engineering education was badly needed. Relatively few major changes had been made for many years. The general form of engineering curricula had become fairly well standardized some 50 years before; and as new programs, such as Chemical Engineering, were formed, they largely followed the traditional pattern. Modifications in response to the changing demands of the profession consisted mainly of updating technical information and introducing new methods of solving problems.

The impact of the war served to de-emphasize curricular programs and to emphasize research and development. Superimposed on this was the need for specialized training courses, and universities became more and more involved in project-oriented research.

As research results and sweeping technological advances were applied to peace-time industry following the war, broad changes were needed in engineering courses of study. Recognizing the urgent need to examine these problems, Dean Hollister of Cornell, then President of ASEE, set up a committee of about 40 under the chairmanship of Dean L. E. Grinter for the evaluation of engineering education. This Committee met for a total of about thirty working days during the three-year period 1952-5 and discussed every aspect of engineering education.

The Committee reasoned that engineering graduates, although needing preparation for a broad spectrum of activity from sales to research, shared certain attributes: proficiency in mathematics and the physical sciences; mastery of those principles that make engineering more science than art (the engineering sciences); need for the understanding achieved through social-humanistic studies; and the key characteristic distinguishing engineer from scientist — the ability to synthesize, to design, to create new products for the needs of an ever-demanding civilization. To provide these attributes in a four-year program was judged to be no easy task; in fact, all the obvious methods of simple improvement (five-year curricula, better preparation of high school graduates, elevated standards of admission to engineering schools) appeared to be inadequate. The Committee made the preliminary recommendation, therefore, of curricular bifurcation to permit stressing either the operational or the research-development aspects of engineering.

There was immediate and widespread opposition to bifurcation on the basis of assumed increased instruction cost and administrative complications. Every department might be required to offer two separate curricula, it was feared. Furthermore the graduates of one of the two curricula might be regarded as second-rate citizens, and this would reflect badly upon the entire engineering profession. As a result of the violent reaction, the concept of bifurcation was not included in the final report.

Although bifurcation was rejected, the need suggesting it was real. Consequently, to meet this need engineering curricula have swung generally to the science side of the spectrum (with considerable opposition by some professional societies out of fear that graduates may have insufficient operating knowhow to enter jobs without additional training by employers).

The question now is whether there exists another solution to the problem — a solution that will enable a student to become knowledgeable in the practice of his job and also in the principles required to keep abreast of developments until he reaches his career peak (about 2000 A.D. for current undergraduates).

In considering a program that will be responsive to the spectrum of engineering activities, it may help to review the processes of invention development. A new idea — nuclear fission or the laser principle, for example — emerges from the inventor's shop or the laboratory, the result of discovery.

In order to exploit the idea, additional engineering research must often be performed to provide reliable engineering information. These activities phase into development and then into design. Design involves the selection of suitable materials and components, their optimum arrangement, and a thorough economic analysis. Next comes production, followed by sales and (inevitably) by servicing. The process is then repeated to improve the product.

The preceding steps, each requiring clear decision making and informed thinking, represent the range of engineering function, but one man seldom participates in all. Rather the engineering graduate tends to gravitate to one of three overlapping categories of specialization: (1) research and development; (2) development, design, testing, and possibly production; and (3) production, sales, and servicing. Should we train a student for all three categories, for one of them, or for two?

We observe, indeed, that currently there is a pattern of preparation for each category. Production and servicing are increasingly manned by graduates of Technical Institutes. The principal design, testing, and production aspects are usually supplied by BS engineers; and, traditionally, research and development are the primary outlet for men with advanced degrees. Experience teaches us, however, that what is in the graduate program now may be in the undergraduate a few years later.

We may approach this from another direction by considering what the engineer of 30 years from now may be doing. Such extrapolation of current activities is regarded as a primary sin by many engineers. However, for too long engineers have ridden facing backward as civilization has hurtled forward; experts in what has happened, they have not looked ahead to avoid such acute problems as atmospheric pollution and transportation.

In my opinion we may expect the following changes:

1. The systems with which engineers deal will become increasingly complex, as evidenced by today's communications systems and space vehicles.
2. Entirely new dimensions of research will evolve as more is learned about materials, energy, and the functioning of the human mind.
3. The mechanics of design will move rapidly toward automation, in response to the increased complexity of systems and the wealth of materials available for construction. Optimization offers additional possibilities. Design is becoming a programmed science rather than an art.
4. New methods of information communica-

tion will be evolved so that tools, techniques, and data available in one location can be transmitted instantly to the designer or analyst who needs them.

5. Advances in production techniques will permit factories to become completely automated.
6. Boundaries between the various engineering disciplines will erode. Interdisciplinary thinking will prevail over the narrow viewpoint of professional specialization. Boundaries between the physical sciences will break down. The trends of interdisciplinary cooperation between the engineering sciences and the biological sciences will extend to the other sciences as well.
7. Engineers will emerge as the planners and coordinators of the efforts of technological specialists in much the same way that project engineers today coordinate the efforts of engineering specialists.
8. We shall graduate engineers for two types of careers:
   (a) That of high-level planning and coordination, bringing to products and systems not only the basic physical and economic considerations but also far reaching environment and sociological implications.
   (b) That of special understanding of the nature of things and the provision of detailed information necessary for complete planning.

   This leads us to the conclusion that we must not force all engineering students into the same mold, but must have educational flexibility. Some students will have the aptitude for broad training, whereas others will be more qualified to delve into individual areas of technical specialization. However, such specialization will be of a different character from that now envisioned as the ideal for the engineering Ph.D. For example, with the ready availability of information on a scale only dimly envisioned today, generalization of knowledge may in itself become an area of specialization.
9. Much of what engineers today are doing will be done by graduates of technical institutes; much will be performed by machines.
10. A final item can be predicted with certainty — 30 years from now engineering educators will still be discussing how to improve their programs to prepare engineering graduates for the years ahead.

A Two-Option Curriculum In Chemical Engineering

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The field of chemical engineering has become so broad and diversified that a two-option plan for undergraduates was introduced at Iowa State University in the fall of 1961. The first class given full advantage of the bifurcated curriculum graduated in 1963. A description of the program and a discusion of some of the early results follow.

General Character of the Options

The two options are those of Design and Production (D & P) and of Research and Development (R & D). The first is for students who are interested in the design, construction, operation, and management of manufacturing plants in the chemical process industries. The second is for students who are interested in basic or applied research and development and/or graduate training. While the D & P Option is the more traditional in nature, the R & D Option involves more mathematics, science, and engineering fundamentals. Both lead to a B.S. degree in four years for qualified students.

This system makes the curriculum flexible and yet insures every student certain basic subjects essential for all chemical engineers. Limited substitutions are allowed for even greater flexibility in some cases. The abler student can take advantage of special Honors and Undergraduate Research Participation Programs to secure a more tailor-made curriculum.

Students are allowed a free choice of options. Both options are considered equally important and challenging. It is felt that a student should have the opportunity to base his election entirely on his personal interests and goals. Of course, the R & D Option would not be recommended to anyone displaying weakness in mathematics.

Time for Decision

Most undergraduate engineering curricula at Iowa State University are designed for completion in four academic years of three quarters each. The first year is a preprofessional program which must be completed with at least an average grade point of 2.0 (4.0 maximum) for admission into one of the three-year profesional curricula.

An option should be selected before winter quarter of the sophomore year since the following quarter is the first one differing between the options. However, a decision at this point is not irrevocable, because the fifth and sixth quarters differ between the options by only one course each. Should a student change his mind at the end of his sophomore year, he could substitute for electives in the second option the required course from the first option. Alternately, he could attend a summer session.

The Common Core

Of the total credits required for a B.S. degree in chemical engineering, about 15 per cent are electives. Of the required credits, a large core (80 per cent) are common to both options.

Mathematics courses through ordinary differential equations are part of the common core. Freshmen entering the University are expected to be sufficiently well prepared to start a one-year integrated sequence of calculus and analytical geometry followed by a one-quarter course in ordinary differential equations. Both options include general chemistry, quantitative analysis, general physics, organic chemistry, physical chemistry, English, speech, economics, and engineering graphics.

Both options require a set of basic chemical engineering courses which starts with material and energy balances in the sophomore year, continues with unit operations and computer applications during the junior year, and ends with thermodynamics, kinetics, and proces control theory and laboratory in the senior year. Each student must also take some work in chemical plant design and transport phenomena.

Differences in Options

Major differences in the required content of the two options are summarized in Table I.

The R & D Option is built on a full year of advanced mathematics including Laplace transforms, Fourier series, partial differential equations, Bessel and Legendre functions, vector analysis, and numerical methods. This mathematics is subsequently applied in an intermediate mechanics course in physics, an electrical circuit analysis course, and a chemical engineering course in energy, mass, and momentum transport phenomena. The option also includes some work in the new rate processes laboratory and in chemical engineering design.

Whereas the last subject is a minor part of one option, it constitutes a major part of the D & P Option. The latter also includes courses in mechanics and electrical engineering, but these are of a different nature than the ones mentioned above and require less mathematical sophistication. In addition, the D & P Option provides a unit operations laboratory and an introduction to transport phenomena and statistics.

TABLE I. Difference in Course Content of Two Options.

YEAR	D & P OPTION		R & D OPTION	
Soph.	Principles of Statistics	3	Advanced Math.	6
	Statics of Engineering	4		
Jr.	Mechanics of Materials	5	Advanced Math.	3
	Elec. Circuit & Mach.	8	Physics: Mechanics	6
Sr.	Unit Operations Lab	2	Rate Processes Lab.	2
	Chem. Eng. Design	9	Chem. Eng. Design	3
	Transport Phenomena	3	Transport Phenomena	9
			Elec. Circuit Analysis	8

An analysis of the credit distribution for the two options is reported in Table II.

TABLE II. Per Cent Credit Distribution for Two Options

	D & P	R & D
Math., Chem., and Physics	35	41
Engineering Sciences	19	20
Engineering Analysis and Design	20	14
Humanistic and Social Studies	19	19
Free Electives	7	6
Total	100%	100%

Both options place great importance on mathematics and basic science and give equal weight to the engineering sciences. The R & D Option puts extra emphasis on mathematics and physics at the expense of engineering analysis and design.

Preliminary Results

The 1963 class, the first to fully utilize the option sytem, was smaller and had fewer students in the 3.0 to 4.0 grade-point range than the average for recent years. Nevertheless, 15 out of 34 chose the R & D Option; among them the top four students in the class and several who ranked near the bottom. On the other hand, several high-ranking students selected the D & P Option. The grade-point averages for the two groups were 2.8 and 2.4, the R & D group being the higher.

The 1964 class was larger and the proportion of outstanding students greater than for the preceding one. Eighteen out of 45 in the class selected the R & D Option. This represented a smaller proportion of the class than before and a group composed almost exclusively of higher-ranking students. The D & P group was composed predominantly of the lower-ranking students, but many of these were very good. Grade-point average for the two groups were 3.2 and 2.6, respectively. Although higher than the corresponding 1963 averages, they were further apart.

The 1965 class was similar in size and general characteristics to its predecessor and produced similar results. Only one of the R & D group missed ranking in the top half of the class, while the D & P group was quite heterogeneous — it contained both the third man from the top and the anchor man. Grade-point-wise, the two groups almost duplicated those of the previous year.

The future plans of members of the 1963, 1964, and 1965 classes at graduation time are summarized in Table III.

TABLE III. Future Plans of Graduates

	1963		1964		1965	
	D&P	R&D	D&P	R&D	D&P	R&D
Graduate School	1	9	4	10	3	8
Industry	16	5	18	7	26	6
Military Service	2	1	5	1	1	0

Similar trends were observed in each class. A majority of those in the R & D group planned to work on advanced degrees in chemical engineering, but a few planned to take graduate work in business administration. On the other hand, practically all of those in the D & P group planned to enter industry and the few exceptions who planned to enter graduate school were not continuing in chemical engineering. Two were contemplating post-graduate study in law, two in industrial engineering, two in business administration, and one in general science. Only one member of the 1965 D & P group actively sought admission into chemical engineering graduate school.

In general, the chemical engineering faculty at Iowa State is pleased with the way the two-option program has worked. Although the system provides two paths which are significantly different in content and objective, the teaching load has not increased appreciably and instruction efficiency has not suffered by having some classes too small and others too large. Most important of all, the needs and interests of individual students have been more nearly fulfilled.

The Rensselaer Program for Engineering Education

The Rensselaer Program for Engineering Education

Stephen Yerazunis
Professor of Chemical Engineering
Arthur A. Burr
Dean of Engineering
Rensselaer Polytechnic Institute, Troy, N.Y.

Engineering programs have undergone considerable modification in recent years in response to professional needs. However, the changes primarily involving the replacement of skill courses by basic and applied science studies appear to meet immediate rather than future requirements. At Rensselaer a planning committee has analyzed the long-range problem and has reached five conclusions (*2*):

1. The primary objective of the baccalaureate for the engineering student should be basic education of a broad character.
2. Pre-engineering education and professional engineering education should be recognized as separate phases. Admission to professional programs should be based on pre-engineering student performance which shows potential for the practice of modern engineering.
3. More emphasis should be directed to the development of the engineering approach in decision making, perspective, and attitude, and to the fostering of creativity.
4. The student's capacity to acquire specialized competence in his professional practice can be developed only through an experience of specialization in depth. However, such specialization must not be achieved to the detriment of breadth of education.
5. Programs of study in which specialization is to be acquired must be designed to meet the challenges of the future and must be sufficiently flexible to satisfy the demands of the evolving technology.

These conclusions, now in the form of five statements of principle, form the basis for the engineering program now being implemented and developed at Rensselaer. The new program is believed to be a significant departure from current engineering educational practices both in content and philosophy. All engineering students pursue a pre-engineering program for three academic years. At the conclusion of this phase the student must choose one of two paths to continue his education: (a) seek admission to the professional school in which the first-stage program of two academic years leads to the Master of Engineering as the first professional degree; or (b) complete a fourth-year program subjected to minimal curricular requirements, leading to the Bachelor of Science degree. At the conclusion of the first-stage professional program, students may pursue advanced studies leading to the doctorate with emphasis either in research or professional practice.

Prior to either of the bifurcation points (the end of the pre-engineering phase and of the Master of Engineering program), electives are permitted whereby the student may individualize his program in the light of his interests and long-range objectives. This opportunity must not be interpreted as an excuse for specialization at the pre-engineering level; this would be premature and out of keeping with the basic philosophy. The advantage of the elective opportunity is to remove from engineering education the curricular straightjacket all too often imposed on the student.

Although the educational concept has been determined and a prototype plan is now being implemented, additional development work is required. There are three phases of development: (a) the pre-engineering curriculum, (b) professional school programs, and (c) engineering perspective. Development of the pre-engineering phase requires identification of those science, mathematics, engineering science, and humanities and social science experiences which are basic to engineering endeavor and which will form the foundation for the professional practice of the future, say 10 to 20 years hence. In addition, it is necessary to determine the order and the manner in which these experiences are to be obtained. It will not suffice to seek the lowest common denominator of courses acceptable to the several professional specialties, nor would a compromise consisting of the most prized components of the specialties be adequate. What is necessary is a positive identification of the ingredients fundamental to meaningful engineering practice, not in today's framework but in that foreseen for the future.

For the professional phase the task is to define a rationale for identifying sectors of professional practice worthy of advanced study, and criteria for judging the suitability of proposed study plans. Programs must not only be relevant to future professional needs but must also develop the student's capacity to specialize rather than to narrowly compartmentalize his thinking. Professional school specialization must be directed primarily at developing a particular competence for further growth. Detailed knowledge of current technology, while useful in initiating a career, is of lesser importance.

Development of sound engineering perspective by the student with regard to the professional objective of "seeking optimal means of exploiting nature for human purposes within the framework of relevant restraints" is the third goal. The engineering process can be divided into four major steps:

1. Problem recognition, formulation, and delineation into manageable components. Relevant restraints such as economics, reliability, safety, space, etc., must be identified. Information applicable to the particular problem situation must be recognized.
2. Conception of all reasonable alternative solutions to the recognized problem.
3. Analysis of alternative solutions with regard to feasibility, performance, etc.
4. Selection and implementation of the best possible solution.

The overall process is basically iterative. The conceptual phase may feed back to problem formulation or constraint definition. The analysis step may in turn suggest new alternatives or even a complete revision of the original problem statement. Even the final decision step may result in repetition of parts or all of the sequence. It is this engineering process, or its equivalent as put forth by others (1, 3, 4), that is the very essence of engineering practice. The whole purpose of education in mathematics, physical sciences, humanities, and social sciences is to provide the means by which this process can be executed with distinction.

It is proposed that the overall engineering process can be delineated into identifiable and manageable components and that the student can acquire competence in these components through planned experiences. A thread of general engineering will be provided throughout the program, starting with a sophomore level course followed in the third year by a yearlong engineering laboratory. The thread will be continued in the first year of the profes-

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SPEAKING OUT

. . . about Chem Engineers in Industry

We introduce with this issue the department SPEAKING OUT, a page to be devoted to the personal views of spokesmen selected because they are eminent, or controversial, or articulate, or outrageous, or just plain interesting. You may not always agree with those who speak up in these columns — CHEMICAL ENGINEERING EDUCATION may not, either — but we think you'll not be bored by them.

It is a privilege to present Dr. T. H. Chilton as our first "speaker." Dr. Chilton needs introduction neither to academics nor to industrialists in chemical engineering, for after a long and distinguished industrial career (principally with DuPont) he has spent the past five years in education. His honors are many. He is a past president of A.I.Ch.E. He has been a member of ASEE (and SPEE) for over 25 years, and long before he officially became a professor he was involved deeply in the education of chemical engineers. He has made significant contributions to the technical development of our field — for example, as co-originator with the late Allan Colburn of the transfer-unit concept.

Dr. Chilton's opinions are excerpts from an address he delivered before the Conference on Chemical Engineering Education of the joint A.I.Ch.E.-I.Chem.Eng. meeting in London, June 17, 1965.

What is it a chemical engineer does? A fascinating variety of things, of course. A committee of the American Institute of Chemical Engineers has stated: The practice of chemical engineering may be in such fields as education, research, development, design, patent prosecution, economic appraisals, sales, contracting, construction, operation, maintenance, and management. But there is one of these activities for which I consider that the chemical engineer is uniquely qualified . . . process development. It is there that the chemical engineer comes into his own: in taking a process as conceived in the chemical laboratory and carrying it through the successive stages of semiworks evaluation, pilot-plant design and try-out, and full-scale plant design and construction, to a going manufacturing operation.

It is in process development that the skills of the chemical engineer have their full exercise. A knowledge of basic chemical principles, of the laws of thermodynamics, of the principles of the unit operations, will guide the way in setting up and conducting critical experiments which will serve to define the outline of a safe and economical operating process and the specifications of the most appropriate equipment.

* * *

There is another function uniquely performed by chemical engineers — economic evaluation. From its inception as an industrial possibility — as against a scientific curiosity — a process must be evaluated by the economic yardstick: "Will the probable value of the product leave sufficient margin over the cost of ingredients, of manufacture, and of selling, to yield a reasonable return on the probable investment in facilities and working capital?" . . . It is concern with economic feasibility that distinguishes the engineer from the scientist, and a feeling for economic realities and an understanding of the interrelationships of cost factors and profitability is something an employer might reasonably expect in a chemical engineer.

* * *

[Were I to] list the attributes that industry wants in its chemical engineers, such a list would include a knowledge of chemistry and related physical sciences, understood quantitatively with the aid of mathematics; a familiarity with the principles of engineering design; an appreciation of economic factors and of human motivation.

* * *

One summarizing attribute that would enable the chemical engineer to make his greatest contribution: versatility. Axiomatically, a chemical engineer's problems are always new ones — each different from the one before, and the ability to handle such a succession is what I designate as versatility. For what implication this has for chemical engineering education I will only say that it would not likely result from too high a degree of specialization; neither would it be effective if too great a range of studies were covered superficially.

The Teaching Aids Subcommittee of the Chemical Engineering Projects Committee, American Institute of Chemical Engineers, was authorized in 1959 to collect information on teaching aids (other than motion pictures and slide films) useful in chemical engineering instruction. The Subcommittee, consisting of R. M. Hubbard (Chairman), J. J. Salamone, J. R. Snyder, and D. L. Vives, prosecuted its charge by questionnaire solicitation of U. S. Chemical Engineering Departments and by subsequent specific investigation of certain aids that are in use. CHEMICAL ENGINEERING EDUCATION is pleased to present papers by Professors Hubbard and Snyder that constitute the final report of the Subcommittee on a subject of living interest to educators.

Teaching Aids for Chemical Engineering

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Many teaching aids have been devised by teachers of technical subjects such as chemistry and engineering. Some have been described in the literature; a few are more obvious and warrant only mention so that any instructor may prepare his own. The teaching aids covered in this report are grouped into several classes, and many have been tried and proved useful in instruction.

Industrial Products

Most companies supplying the chemical industry are willing to donate samples to educational institutions. Some mechanical items are available already sectioned and highly polished, plated or otherwise enhanced for display purposes. Examples of available products used by the chemical industry are valves of all types, pipe fittings in all materials, pine and tubing of all kinds and from all materials, steam and air traps, gaskets, orifice flanges with orifices, tower packing, distillation bubble caps, and mechanical components such as bearings, gears, couplings, and mechanical seals.

Charts

At various times manufacturers have prepared display charts describing operation of equipment. This has been true particularly in the field of instruments. The Foxboro Company prepared a series of large charts in 1957. The Knolls Atomic Power Laboratory has prepared a chart listing all of the Nuclides. With the advent of the overhead projctor and processes for making transparencies from catalog pages, charts or illustrations from manufacturers' literature can be shown to any class.

Laboratory Apparatus and Models of Equipment

An enterprising instructor having access to a good machine shop and a good mechanic can section some actual equipment used by the chemical industry when this is small in size. Examples of such equipment are centrifugal pumps, heat exchangers, valves, traps, etc.

Laboratory Demonstrations

This category can offer the most useful and interesting of all teaching aids. Much effort has been spent in some schools on devising simple but useful and interesting demonstrations. Some can even be carried out in the classroom. Examples of these have been described in the literature, sometimes in less well-known publications.

An early committee effort to assemble descriptions of short demonstrations resulted in the publication "Educational Aids in Engineering" by the American Society for Engineering Educaiton in 1955. Subjects of interest to chemical engineers are thermodynamics and heat transfer described in the section on Mechanical Engineering and fluid flow described under Engineering Mechanics.

One of the earliest descriptions of demonstrations to illustrate chemical engineering principles was by Johnson (*9*). Pressburg and Coates (*18*) described apparatus for demonstrating the Reynolds number, fluid metering, and film and drop-wise steam consendation. Robert Lemlich has described his "Two Penny" experiments in several publications (*12*), R. L. Huntington (*7*) (*8*) some laboratory experiments that may be classed as demonstrations, and Sami Atallah (*2*) a boiling heat transfer experiment. Potter (*17*) covered equipment for obtaining the Joule-Thompson coefficient.

The Journal of Chemical Education has been an important source of material. Descriptions have been published for demonstrations on fluidization by Fan (*5*), P-V work by O'Driscoll (*14*), thermal diffusion by Whalley (*20*), kinetics by Lemlich (*11*) and by Baginzki and

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The Overhead Projector . . a Teaching Aid

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The overhead projector has a 10″ x 10″ horizontal glass stage upon which the material to be projected, the transparency, is placed. The transparency can be any tranparent plastic sheet upon which are printed, pasted or developed figures and images. Each figure or image must either absorb or dispense light. A vertical light beam (500 to 1000 watts) originating from beneath the stage casts the image into a lens mounted about 18" above the stage. This overhead lens permits focusing and also projects the beam upward and to the rear of the projector. Th resulting beam produces a uniformly bright-screen image, so bright that normal room lighting does not reduce clarity.

From the above description, it is obvious that the overhead projector was designed to be operated from the front of a lecture room. Thus, the operator reads the transparency on the stage exactly as the student views it on the screen. Of course, the projector must be kept low enough to prevent blocking of the student's view. The screen should be matte and white in order to obtain up to sixty degrees of effective viewing angle. Generally, it is most convenient to place the screen to the left of the students (for a right-handed instructor) or above the chalkboard. The screen should be tilted forward slightly at the top to prevent "keystoning" of the projected image.

Preparation of Transparencies

There are a host of commercial materials suitable for the preparation of transparencies. The following four examples are taken from my own experiences and are not meant to be exhaustive.

1. Grease pencil drawings are made on clear 8-1/2″ x 11″ acetate sheets. If desired, color can be added by use of "magic markers." If reprocessed untinted x-ray films are obtained, no cardboard mounting frames are necessary. Smudging is not a problem so long as the finished films are stored with a tissue-paper protective covering.
2. Prepare drawings with Acetograph pens and inks on reprocessed untinted x-ray film. Use pressure-sensitive tapes of varying colors, widths and designs to highlight curves on graphs, to represent process lines on flow charts, etc. Whole areas can be highlighted by use of overlays cut from colored film.
3. Copy (reproduce) printed material from books, periodicals, advertising literature, etc. While many different copying processes are commercially available, the best procdure at any given school will depend upon available equipment. For example, if a page in a book is to be reproduced, the page might first be "lifted" by preparation of a Xerox copy. The Xerox copy can then serve as an "original" and from it a positive transparency can be made directly, e.g. on Thermo-Fax standard positive type 123. It might also be noted that Xerox copies of transparencies are generally excellent. By this means, borrowed transparencies can be copied easily.
4. Colored transparencies can be "lifted" from clay-coated color prints in magazine illustrations (e.g. those in Fortune magazine) onto transparency positives (e.g. Thermo-Fax type 123).

Procedures and Techniques.

In the teaching of any course in which equations, tables, diagrams, charts, etc. are developed, presented or discussed, the use of overhead projection will prove effective. All pre-planned chalkboard presentations can be delivered more efficiently and effectively by predeveloped transparencies. Some of the advantages offered by overhead projection follow.

1. There is no lost time writing on the chalkboard. The instructor faces the class and so can discuss directly the subject matter presented on the transparency. Eye contact with the students need never be lost. Teacher-student communication is enhanced.
2. More subject matter can be presented and

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Jr. Knows Best . . . or Does He?

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Six years ago, Carl Milanovich and Jack Sherick stood on a street corner of Butte, Montana, talking about next year's prospects. High school seniors at Butte Public, both ranked in the upper quarter of their class. Sons of Serbian workingmen in the Butte copper mines, they had heard all their lives that a college degree was the passport to enter the good life. High school career days had given them a rosy view of every field from agriculture to zoology. Any and all fields seemed to lead to Mickey Mantle's salary with the Yankees or Clyde Weed's with the Anaconda Company.

The scuttlebutt around the high school was that either Business Administration at the University in Missoula or the Commerce course at Montana State in Bozeman was the easiest and the surest, safest way to that essential college degree. Carl assured Jack that this was the smart thing to do; get that degree and have a good time while doing it. Jack was tempted to agree but had been offered a $250 scholarship by Montana State if he would take Chemical Engineering. The scholarship money had come from the Continental Oil Company, the State people told him, and it made him feel good that a big outfit like Conoco considered him that important. The scholarship was not large but it did cover the tuition fees for the freshman year. He felt he would immediately be earning part of his college expenses.

So Carl went to the University to major in Business Administration. A full 25% of the 4500 students there were doing the same. Jack enrolled in Chemical Engineering at Bozeman; about 3% of the students there were in that field. Today Jack, a capable engineer, is at the Reactor Test Station in Idaho developing an atomic-powered engine designed to push a space craft to the moon, Mars, and beyond. Carl too has his degree. He is clerking in the Butte J. C. Penney store and considers himself very lucky to have a job.

* * *

Bob Young climbed aboard the Northern Pacific's crack North Coast Limited at Bozeman, Montana, and settled down in his seat for the long ride back to Chicago. Bob was discouraged and failed to share his fellow passengers' enthusiam for the magnificent mountain scenery that slipped by as the train climbed to the summit of 6000-foot Bozeman pass. Bob Young is Universal Oil Products Company's chief recruiter and his recent tour of colleges in the Northwest looking for engineers had been very disheartening. The trip started badly. Winter storms over the Rockies and the Great Plains had caused the cancellation of Bob's flights and forced him to cover this immense territory by train. That wouldn't have bothered Bob, a seasoned traveller, if the trip had been more fruitful.

Bob's problem: to find scores of engineers, mostly chemicals, for UOP's burgeoning projects. UOP had just negotiated a contract to build several units of a refinery for the Rumanian government. A project of great national importance—President Johnson's plans for improved East-West relations and the weaning of Rumania away from dominance by Russia hinged upon projects like this —, it would require the full-time service of many UOP employees for the next three years. And UOP has more than a hundred other projects under contract.

Bob's experiences at Bozeman were typical of what he encounters everywhere now-a-days. When he arrived at the campus, he was greeted cordially by Placement Director Brick Breeden. Breeden had prepared a schedule of interviews, one every 30 minutes for a day and a half. Breeden asked Bob if he would talk to Commerce, General Studies and Industrial Arts majors — there were hundreds of them available — but Bob declined saying he was looking only for chemical, mechanical and electrical engineers and a few chemists. Bob lunched with faculty members from the Departments whose students he interviewed. The students Bob talked to were all well-dressed and conversed freely and easily with him — too easily perhaps, thought Bob. These boys know all the answers. "What salary do you want?", asked Bob. "The going salary for a man of my qualifications", they answered to a man. "What kind of a place are you looking for?", he asked. "A company in which my capabilities will be developed to the fullest and where I

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Chemical Engineering Professorial Staff As a Function of Student Load

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Data from 70 United States universities were analyzed to determine the possibility of a reasonably reliable correlation between student load and the size of professorial staff required. Specifically, P, the total number of chemical engineering (full-time) personnel in the three professorial ranks was correlated with B, M, and D, where these represent respectively the number of bachelors, masters and doctors graduated per year in chemical engineering. It was felt that such a relationship might prove of particular interest when expansion into a graduate program was being contemplated. The 70 institutions included in the study were all accredited and were schools for which B+M+D exceeded 19.

The working relationship among these variables was taken in the form

$$P = a_0 + a_1 B + a_2 M + a_3 D \qquad (1)$$

and the coefficients a_0, a_1, a_2, and a_3 were found to be

	WORKING RANGE	CENTRAL VALUE
a_0	1.7 to 2.7	2.2
a_1	0.07 to 0.13	0.10
a_2	0.07 to 0.21	0.14
a_3	0.29 to 0.61	0.45

These values and the correlation yielding them are discussed in the Appendix.

Thus, in order to grant

8 to 14 additional bachelor's degrees per year
or 5 to 14 additional master's degrees per year
or 2 to 3 additional doctor's degrees per year

calls, on the average, for one additional (full-time) staff member of professorial rank.

Interpretation

Master's degrees, it is seen, require only slightly more professorial time than bachelor's degrees, while, as expected, doctor's degrees demand much more. The coefficient a_0 indicates that professorial time equivalent to about two to three full-time persons is given over to administration or general research.

Heavy Commitment To Graduate Program

For comparison with these overall results, ten universities very heavily committed to graduate instruction and to research were analyzed along the same lines. The corresponding coefficients a_0, a_1, a_2, a_3, listed in the Appendix, have excessively broad ranges of uncertainty. They are, however, quite consistent with the overall values as regards the allocation of professorial time to bachelor's degree work, and to total work towards graduate degrees. The research-minded institutions do seem to assign more professorial time than the average to doctor's degree work (at the expense of the master's degree), and more professorial time than the average to administration and general research.

Appendix

The data for this study were collected from 'Chemical Engineering Faculties of Canada and the United States For 1962-63" (A.I.Ch.E., New York).

For the linear regression model

$$P = a_0 + a_1 B + a_2 M + a_3 D$$

the regression coefficients a_0, a_1, a_2, and a_3 were estimated by at least squares calculation, each university being given equal weight. The central values were as shown in the table following Equation 1.

The multiple correlation coefficient for this regression was calculated at 0.83, which is rather good. One may accordingly say that the linear relationship accounts for 69 percent (0.832—0.69) of the variation actually found in the data from university to university. Taking the residuals in the regression Equation 1 to be independent Gaussian (normal) deviates, permits the calculation of tight confidence regions for the regression coefficients. On the Gaussian assumption, the 90% confidence intervals are

$$\begin{aligned} a_0 &= 2.2 \pm 0.5 \\ a_1 &= 0.10 \pm 0.03 \\ a_2 &= 0.14 \pm 0.07 \quad \text{for 70 departments} \\ a_3 &= 0.45 \pm 0.16 \end{aligned} \qquad (2)$$

the true underlying value of a_0 falling in the range 2.2+0.5 with probability 0.9, etc. The data are not in fact just Gaussian, but even with the (overly conservative) Chebychev bounds, the ranges of Equations 2 for the regression coefficients are at least 63% confidence intervals. They are in any case the working ranges of the coefficients quoted in the body of this paper.

For the 10 highly research-oriented chemical engineering departments, the least square estimates of the regression coefficients are

$$\begin{aligned} a_0 &= 5.5 \\ a_1 &= 0.1 \\ a_2 &= 0.0 \\ a_3 &= 0.6 \end{aligned} \qquad (3)$$

These seem to have too high a sampling variability to warrant much confidence, but the

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A Survey of 5-Year and Cooperative Chemical Engineering Curricula of 1963-1964

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A survey was made of the undergraduate chemical engineering curricula of schools having programs that require either five years of academic course work or cooperative work programs. The results were compared with those from similar surveys of four-year curricula by Schmidt (*2*) and Thatcher (*3*).

A list of schools falling into the two categories was compiled from catalogs, bulletins, and the 31st Annual Report of the Engineers' Council for Professional Development. Ten were included in the five-year category: Brigham Young, Columbia, Cornell, Florida, Louisiana Polytech, Louisville, Minnesota, Ohio State, Rice, and Virginia. Seventeen were in the co-op category: Auburn, Cincinnati, Denver, Detroit, Drexel, Fenn (now Cleveland State), Florida, Georgia Tech, I.I.T., Louisville, Missouri Mines, New Mexico State, Northeastern, Northwestern, R.P.I., Tennessee, and V.P.I.

An initial breakdown of subject matter was made with the same subject classifications used by Schmidt and by Thatcher so that direct comparisons were easy. All credits were reported in semester hours. This initial information was sent to each of the respective schools with a request that it be checked and appropriately corrected. The corrected forms were then used for the final tabulations.

Separate summaries were made for schools having curricula that require five years of course work and one for those having a cooperative work program. The results for the major subject classes are shown in Table I, along with those from the Schmidt and Thatcher surveys. A complete summary with detailed breakdown may be obtained from the author.

The following observations are offered:

1. The five-year curricula† have a higher number of credit hours than "four-year" curricula, but not in the proportion of 5 to 4. The five-year schools appear to be using part of the "extra year" to reduce the number of semester hours taken per semester.
2. There is a higher emphasis on cultural courses by approximately eleven credits in the five-year curricula. The percentage of the curriculum devoted to cultural courses is 16% for the five-year schools of 1963-4 compared to 12% for the "four-year" schools of 1961-2. Twenty percent was suggested by the 1955 ASEE Committee on Evaluation of Engineering Education (*1*).
3. The total of mathematics, chemistry and physics is five credits higher for the five-year schools of 1963-4 than the four-year schools of 1961-2.
4. In chemical engineering subjects, the five-year curricula carry eight more credit hours than the four-year curricula. The increase is general and distributed, and it does not represent an increase in one particular subject area.
5. Cooperative curricula of 1963-4 show no statistically significant departures from the four-year curricula of 1961-2.

TABLE I. Average Semester-Hour Distribution in Four and Five-Year Curricula

	FOUR-YEAR		THIS STUDY	
	Ref.2	Ref.3	5-yr.	Co-op
Total Gross Credits	147.0	146.2	172.5	148.6
Mathematics	17.3	17.9	19.6	19.6
Chemistry	30.8	28.9	30.8	28.0
Physics	11.1	11.3	12.2	11.8
Graphics	4.7	3.8	3.1	4.5
Chem. Eng.	32.9	32.8	40.6	33.1
Materials, Mechanics	9.1	8.3	9.0	9.8
Elec. Eng.	5.0	5.0	6.3	5.0
Tech. Elect.	3.6	5.2	6.5	5.8
Other Technical	1.8	0.8	1.1	1.2
Cultural	14.7	17.2	28.2	17.7
Other non- Tech.	9.9	8.6	8.1	10.3

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3. Thatcher, C. M. Chem. Eng. Education, **1962,** [Sept.] 1-2.

* The author is a member of the A.I.Ch.E. Committee on Undergraduate Curricula, and this survey was made under the Committee's auspices.

† The term "four-year" as used throughout the text applies to the data compiled by both Schmidt and Thatcher. It includes schools at which the students need an extra term and/or summer work to complete the baccalaureate requirements in four calendar years.

A NEW VIEW . . .
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sional school with an advanced course in engineering in which the student will be guided through challenging assignments, and will culminate with a project experience on a worthy engineering problem as a requirement for the Master's degree. The project will serve as a capstone, for here the student's ability to discharge his professional obligation will be judged by an examining committee of faculty and practicing engineers of acknowledged reputation.

Sound and implementable programs for engineering education cannot be developed by a simple rearrangement of the blocks of knowledge and of analysis currently available. The knowledge must be organized into more basic elements and the subtle interrelationships that bring about new arrangements more suited to future needs must be identified. One must inquire as to the longevity of each particular element, its relationship to other elements, its role as a foundation for still other elements, its breadth of applicability, and its contribution as a base for future learning beyond a man's formal education.

The program for engineering education described possesses several features which may be viewed as advantages over current practice. The pre-engineering concept will insure that all students have had the opportunity to acquire the essential background in those fundamentals underlying engineering as a single field. The student's intellectual awareness of the unifying themes of nature will not be confined by the expediencies of current specializations. The graduate should be better prepared to meet the shifting challenges of the future.

Selection of those students wishing to pursue the serious practice of engineering will allow the fourth-year programs of professional school students to proceed at advanced levels and to probe more deeply into the subject area than is feasible now in a typical terminal year. Coherent programs leading to the Master's degree will eliminate the almost inevitable duplication of effort in much course work now encountered in the one-year graduate program following the baccalaureate. This feature suggests that a more effective utilization of the student's effort may be obtained even with a liberalization of the pre-engineering requirements.

Finally, the proposed baccalaureate program will produce men whose intimate awareness of modern science and technology in combination with a broader and more liberal perspective will permit meaningful and significant careers outside of engineering, per se, in a society markedly affected by technological consideration.

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2. Burr, A. A., L. S. Coonley, J. V. Foa, E. C. W. A. Gueze, W. R. Hibbard, and A. H. Nissan, "Long Range Planning for Engineering Education," a Report of the School of Engineering, Rensselaer Polytechnic Institute, Troy, N. Y., December, 1962.

3. Krick, E. V., "An Introduction to Engineering and Engineering Design," John Wiley and Sons, New York, 1965.

4. Rosenstein, A. B., "Design of a Unified Engineering Curriculum," paper presented at 72nd annual meeting, ASEE, Orono, Maine, June 22, 1964.

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TEACHING AIDS . . .
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Zak (*3*) and dynamic equilibrium by Wergang (*19*). Osburn has described a visual demonstration of fractional distillation (*15*) and a plug-board teaching aid for analog computer instruction (*16*).

Professor Hubert N. Alyea has reviewed all the demonstrations appearing in the Journal of Chemical Education, abstracted them, and grouped them by subject. Two series of abstracts appeared, the first covering the period 1924-56 was printed in J. Chem. Ed. from Vol. 34, No. 1, January 1957 through Vol. 37, No. 8, August 1960. The second series covered the years 1957-59 and was printed in Vol. 37, Nos. 2-8 (1960). Subjects of interest to chemical engineers, although largely physical chemical in nature, and the location of abstracts (in the first series only) describing demonstrations are given in Table I.

In the field of instrumentation or process control analysis, Larson and Heng (*10*) described a process dynamics experiment. In a series appearing in ISA Journal, descriptions by Balise (*4*) and Hubbard (*6*) are most useful. Major (*13*) described an instrumentation teaching aid.

Recently the National Science Foundation has sponsored a project of Professor Fred Landis, Department of Mechanical Engineering, New York University, New York 53, New

TABLE I.
Abstracts Describing Chemical Demonstrations
Journal of Chemical Education

TOPIC	VOL.	PAGE
Physical properties of water	34	A188
Industrial uses of water	34	A188
Three states of matter	34	A289
Motion of molecules	34	A288
The gaseous state	34	A288, 289, A313 A359, A391
The liquid state	34	A314
The solid state	34	A391, A392, A487
Electrodeposition and electrolysis	35	A21, A22
Heat energy	35	A57, A58
Electrical energy	35	A58, A117
Mechanical energy	35	A171
Rate of reaction	35	A172, A215
Reversible reactions, shifting equilibrium	35	A216, A71
Metallurgy	35	A401, A517
Inorganic chemical processes	35	A549, A550, A625
Inorganic chemical processes	36	A53, A54, A115 A116
Organic chemical processes	36	A179, A180, A235 A236, A297, A298 A377, A378
Colloids	36	A409, A410, A463 A464
Corrosion	37	A49

York, to assemble "Laboratory Experiments and Demonstrations in Fluid Mechanics and Heat Transfer." The report by this title (Final Report of Grant 18764, January 1964) is available from Professor Landis at $2.50.

This report describes 38 experiments or demonstrations on the following subjects in fluid mechanics:

(a) A conservation law in fluid mechanics, Bernoulli equation
(b) Rotating systems and vortex motion
(c) Transient fluid mechanics
(d) Transition from laminar to turbulent flows
(e) Viscous effects
(f) Compressible flows and gas dynamics
(g) Miscellaneous experiments and demonstrations

Thirty-two experiments or demonstrations are on the subject of heat transfer covering:

(a) Temperature, heat transfer coefficient, and heat flux measurements
(b) Conduction heat transfer and fin analyses
(c) Conduction heat transfer analog experiment
(d) Radiative heat transfer
(e) Convective heat transfer
(f) Two-phase heat transfer
(g) Heat exchangers

Twenty-eight miscellaneous ideas, instruments and equipment are also described.

The National Science Foundation lists all activities in aid to engineering education in the publication "Science Course Improvement Projects" of which two issues have appeared in October 1962 and May 1963. Reports of some of these projects include apparatus that may be used in classroom demonstrations.

Plant Models

In recent years the chemical industry has made great strides in using plant models for preliminary planning, engineering design, operator training, and display advertising. It was thought that many surplus plant models would become available for distribution to chemical engineering departments.* Inquires to major chemical manufacturing and engineering companies proved that models generally would not become available for several reasons—they were used first for engineering design and then were needed for operator training for long periods of time, they contained details that companies would not want displayed to the public, and models made by engineering contractors became the property of the plant owner, usually a different company.

Undoubtedly, plant models will become available to chemical engineering departments for display and instruction. They are widely used and almost every chemical plant has one. When their usefulness to their owner diminishes, it may be possible for a school to obtain one for the asking; but each department must make its own contact with a source. Plant model construction has been undertaken by many chemical engineering departments. For those wishing to build a model, parts may be purchased from the following sources:

Engineering Model Associates
5265 Poplar Boulevard
Los Angeles, California 90032

Industrial Model Suppliers, Inc.
2311 Sconset Road
Wilmington, Delaware

Projection Equipment

Modern projectors have greatly simplified teaching. In chemistry, many laboratory demonstrations have been revised so they may be performed on the stage of the overhead projector. Equipment for such experiments, some of which may be useful in chemical engineering, has been described by Professor Hubert N. Alyea in a series appearing in Journal of Chemical Education in 1962(*1*) and in occasional later issues. A reprint describing this equipment is available from the publisher.

* The Subcommittee acknowledges with thanks the gift of several plant models by the Procter and Gamble Company which were distributed to nearby schools—University of Cincinnati, University of Dayton, Ohio State University, University of Louisville, Indiana Institute of Technology, and Rose Polytechnic Institute.

A new continuous motion picture projector is now available from the Technicolor Corporation, 123 South Hollywood Way, Burbank, California. Special 8-mm motion picture cartridge films are being produced for this machine and are available from the National Committee for Fluid Mechanics Films, Educational Services, Inc., 47 Galen Street, Watertown 72, Massachusetts. Since both the projector and the film are special and different from standard motion picture films and equipment, inclusion of this teaching aid in this report is regarded as justified. In the future, additional films will certainly become available and teachers must be on the watch for reference to such teaching aids.

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OVERHEAD PROJECTOR . . .

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discussed per unit of class time. The time "saved" can be used for reinforcement of material already presented or for greater coverage of the subject.

3. Transparencies can be filed and so are available to students outside of class, or for later reuse in class.
4. Student home-work assignments prepared on transparencies allow ready discussion before the entire class. (The student is supplied with plastic sheets and a grease pencil when the problem is assigned to him.) By this procedure, more problems can be discussed and the entire class benefits from the resulting exchange of ideas.
5. Use of colored transparencies can make complex material easier to understand. For example, in discussing the "tie-element" concept in chemical calculations, a colored tape will clearly indicate the flow of the tie element through the process. (For greatest impact, this could be presented as an overlay.)
6. Judicious use of color can make otherwise dull material come to life. For example, the various pieces of equipment on a flow sheet can be presented in different colors.
7. Class announcements, surprise quizzes, etc. can be displayed immediately to everyone in the class. Such matters can just as quickly be "undisplayed" by the flick of a switch.

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1. Technifax Corporation, Holyoke, Mass. (Equipment and material suppliers.

2. a) Charles Besler Co., 219 S. 18th Street, East Orange, N. J.

b) Minnesota Mining and Manufacturing Co., St. Paul 6, Minn. (Thermo-Fax visual products.) (Equipment and transparency development film.)

3. Ozalid Company, Johnson City, N. Y. (Transparency materials.)

4. American Optical Co., Instrument Division, Buffalo 15, N. Y. (Projection equipment.)

JR. KNOWS BEST . . .

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will ultimately attain a position where I contribute to company policy", they all replied.

After the interviewing, Bob went over to the Chemical Engineering office to talk with Professor Berg, the Department head. Berg told him that of the 1115 seniors at Montana State, only twenty-six were chemical engineers and nine of these were unavailable due to plans for graduate study or military commitments incurred via advanced ROTC. Berg showed Bob the employment scorecard for the current recruiting campaign. With the season barely half gone, thirty-one companies had already been on the campus looking for chemical engineers. The list included such formidable competitors as Conoco, Shell, Humble, Esso Standard, Standard of California, Texaco, Dow, 3M, FMC, Union Carbide, Dupont, and Monsanto. Berg's scorecard showed that every boy that Bob had sized up as a good prospect already had at least six offers, and it was only February. No wonder these kids knew all the answers during the interview. They had been practicing since last October.

* * *

These two true stories point up a bleak fact in American education today. The ever-increasing college enrollment is not producing enough people trained in the areas where the demand is. It is being left up to the high school kids to decide the quantity and type of trained people needed, and the evidence is piling up that they are guessing wrong.

PROFESSORIAL STAFF . . .

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qualitative comparisons in the body of this paper are based (for what they are worth) on a comparison of these central values with those of Equations 2.

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