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

T. D. Wheelock
Chemical Engineering Department
Iowa State University, Ames, Iowa

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