Perhaps one way to look at this would be to examine what chemical engineers are doing at the Dow Chemical Company.

All Chemical Engineering	Per Cent	No./1,000
Research	30	300
Production	30	300
Technical Service and Development	10	100
Sales	10	100
Design & Process Engineering	10	100
Non-engineering Management	2	20
Miscellaneous	8	80

Although the number actually exceeds a thousand, it is close enough to give us an understanding of the numbers of individuals involved rather than the per cent. From these figures, it is evident that basic chemical knowledge is desired, but engineering is essential.

Of course, if we take the Ph.D.'s alone, the statistics change markedly.

All Chemical Engineering	Per Cent
Research	76
Production	3
Sales	1
Technical Service and Development	3
Design	5
Non-engineering Management	3
Miscellaneous	9

What do we want? A good grasp for fundamentals, an adequate engineering background to fit into our organization, the ability to think systematically, dedication to the profession so that there is a desire to keep abreast of developments persistence, perseverance, and sustained drive to accomplish solution of technical problems of considerable complexity.

One of the strengths of the chemical engineer has been a balance of business judgment, knowledge of scientific principles, and technical problem-solving ability which has made him valuable to industrial management. Certainly, in fundamental research there is a need for the individual well versed in theory in depth. But, should the purpose of chemical engineering education be to make all schools of this type? Should not certain schools concentrate in certain areas of specific competence? Should a school with outstanding reputation in a certain area (e.g. chemical process engineering) abandon that area to start turning out carbon copies of the latest image of an engineering scientist? Is there sound engineering education thinking behind the move--if made--or is it immediate prestige seeking?

Don't misunderstand me. From the Company's point of view, if you have a super-superior chemical engineering scientist finishing his Ph.D. this summer--industry oriented--then sell him on my Company and send him c.o.d. to us! We can use him, but we still shall have need for many Production, Technical Service and Development, and Sales oriented engineers to make the profit after taxes to pay his salary.

Remarks By Harold S. Mickley

Despite the pessimistic views held by some, we are not here to attend a wake or to discuss the best way to bury engineering. Rather, we are here to explore ways to capitalize on our past accomplishments in order to ensure greater ones in the future. My optimistic attitude is borne out by hard economic facts.

The June 10, 1963 edition of "Chemical and Engineering News" reports starting salaries for college graduates. Technically trained people continue in high demand and of these, Chemical Engineers are among the best paid. The median starting salaries for Chemical Engineers are greater than those for chemists:

Degree	Median Starting Salary	
	Chemist	Chemical Engineer
B.S.	500	560
M.S.	578	645
Ph.D.	825	875

On the other hand, engineering is not without its problems. The report of the President's Science Advisory Committee: ("Meeting Manpower Needs in Science and Technology", Report No. 1, Graduate Training in Engineering, Mathematics, and Physical Sciences, Dec. 12, 1962, Washington, D.C.) states that we have no lack of engineers but we are critically short of engineering leaders. Unstated but certainly implied is dissatisfaction with the technician type work now done by a large fraction of our engineering graduates. In my opinion this minimal skill employment is responsible for the growth of unionism in engineering; a growth, which if unchecked, will dissipate the professional status of the engineer. The advisory committee advocates greatly increasing the number of engineers who go on to graduate work. It points out that engineers are far behind the scientist in the fraction that go on for advanced work:

Discipline	% Ph.D.
Biology	33
Chemistry	25
Physics	17
Mathematics	8
All Engineering	3.5
Chemical Engineering	11

Chemistry alone produces more Ph.D.'s than all of engineering.

It is safe to say that the universities will soon receive Federal support for graduate training in engineering on a scale undreamed of five years ago. Our job is to capitalize on this support.

What is our principal task? I believe it is to nurture Chemical Engineering as a true profession. Our product, the chemical engineer, must satisfy the following criteria of a true professional.

1. He must recognize that he forms one of the bridges between science and the fulfillment of human aspirations.
2. He must assume the responsibility for recognizing and solving a complete problem. Handling the purely technical aspects is not enough; he must take on the political, economic, and social headaches as well.
3. He must have a technical area in which he excels and must be prepared to maintain this excellence by continued self-education throughout his career.

An adequate discussion of possible means to achieve these requisites is not feasible in the limited time available. Consequently, I shall focus on item 3.

The technical area of the chemical engineer is the optimization of composition change. It is a vital, exciting, and growing area. Our position in this area is challenged from two sides by the scientist, principally the chemist, on one hand and by sister engineering disciplines on the other.

The Challenge of the Scientist

The main challenge which the scientist poses is: "Is a University education devoted exclusively to science a superior training for a man who intends to function as an engineer?" The key words are function as an engineer for there is no cause for alarm if he functions as a scientist. There should be no gnashing of teeth if an industrial scientist makes a basic discovery, as engineers we should cheer since this is the wheat from which we fashion our bread. When, however, the scientists by education show signs, as they now do, of carrying a basic discovery into the production stage more rapidly and more effectively than the engineer by education it is time to sound the alarm.

I think that the rapid evolution of new technology of increasing complexity has created a situation where the scientist now has some definite advantages. These advantages principally reside in the ability to size up a new situation faster and explore it in more depth. They are derived from

1.) A better grasp of basic laws and phenomena.
2.) A greater familiarity and experience with prediction methods.

There are some important disadvantages which show up when a scientist starts to practice engineering.

1.) He avoids incompletely understood techniques.
2.) He tends to carry analysis and research past the economic optimum.
3.) He is not accustomed to thinking in terms of synthesis of the whole in contrast to analysis of individual segments.

It is perhaps trite to say that we should seek to incorporate the advantages of scientific training into engineering education without adding its disadvantages but I think we can do a better job than at present.

The Challenge of other Engineering Disciplines

Most other engineering disciplines are based on physics. They present a challenge because in some respects they are better qualified than chemical engineers to treat the problems of composition change.

The changes in physics-based engineering education directly reflect the changed directions taken by the technology which they take to be their special areas. This technology has emphasized the importance of attention to fundamentals and deflated the position of specialized knowhow. They have been frankly concerned with the skill with which the scientist has handled problems in their areas. The result has been a realignment of their educational philosophy with renewed attention to basic science. They are now doing what the chemical engineer has always felt to be essential, but using as a base physics rather than chemistry. The results are somewhat different however. In many ways physics is a tidier science than chemistry and the phenomena of interest to the engineer are more susceptible to analysis. Further, the mathematical description and analytical approach to apparently different phenomena turn out to be closely related and the results of intensive work in one area are readily applied to another. For example, the electrical engineer is well prepared to attack problems involving potential flow of any kind (fluid, heat, mass) and to carry on with fluctuating phenomena (i.e., turbulence) because of the effort which he has made to analyze and understand similar phenomena in electromagnetism.

The other engineering disciplines have begun to devote considerable effort to formalizing the synthesis of systems and have made considerable progress.

What significance do these changes in the educational approach of the other engineering disciplines have for chemical engineers? It seems to me that in certain overlapping activities we are currently being pushed hard; for example:

1. The other disciplines are attacking momentum, heat, and mass transfer in an intensive and fundamental manner.
2. In operations carried out under extreme conditions with or without interacting fields, the interests of the other disciplines in such things as plasma jets, extremely high speed flight, deformations under very high stress, etc. has led them to undertake work of an advanced character. Further, much of this work involves chemical reactions which they have taken in stride.
3. It is known that semi-conductors are closely related to chemical reaction catalysts. The solid-state work of the electrical engineer and metallurgist is carrying him further into the fundamentals of catalysis.
4. In systems synthesis, the pace is accelerating.

The above and similar circumstances represent challenges to the chemical engineer to look to his own laurels and to make certain that he is truly operating at maximum effectiveness.

It is with these opportunities and challenges to the profession of Chemical Engineering in mind that I suggest the following objectives for the technical part of his University Education. How this accomplishment is split between graduate and undergraduate years will vary from institution to institution.

1. A broad but penetrating exposure to the areas of both fundamental and applied technology. Much of what is traditional in Chemical Engineering education belongs in here but it needs redoing.

2. More depth in chemistry but with emphasis on understanding and application rather than on manipulative technique. Wet analytical chemistry is not our dish. Emphasis structure and synthesis approached from quantum ideas at the atomic scale; how does one tailor-make molecules? Formulate and use the connections between the molecular and continuum approaches to the behavior of matter. Give increased attention to interphase phenomena adsorption, liquid/liquid equilibria, etc. because their applications are so important. Investigate non-equilibrium phenomena: kinetics, interaction with electromagnetic and high energy particle fields, extreme temperatures.

The subjects which in combination provide this depth in chemistry will not all be given by the chemistry faculty. Physics and other engineering disciplines may well offer more suitable material; the chemical engineering faculties will need to develop programs of their own.

3. Depth in a field theory discipline: continuum mechanics (which includes fluid mechanics) or electromagnetic theory. A real understanding in depth in one of these areas is readily used as a springboard to real understanding in a related one. Everywhere we turn we find old and new applications of field phenomena.

4. A meaningful experience in synthesis and design. This is fundamental to engineering and very difficult to accomplish. We have not done well here. "Plant design" etc. is in the right direction but too artificial and contrived. We need a no-holds-barred experience which includes laboratory experiment, economics, politics, and technical theory. Industry can be of great help here and I think we should seek new ways of drawing on their ideas and experience. In my own institution I have seen the project oriented Instrumentation Laboratory (Guidance System) and Lincoln Laboratory (Radar Systems) used as superb training grounds for engineers. These laboratories operate at high levels of technical competence with real hardware to produce under pressure of deadline, budgets, contract negotiations, etc. Men trained in this way, on moving into industry, become project managers and ultimately top management people. We in Chemical Engineering ought to be able to do something like this if we really set our minds to it.

Finally, we should reassess our Ph.D. program. There is a real need for competence in areas outside of research and development. The present format of the Ph.D. degree, entailing several years effort on a single research problem, is borrowed from antiquity. Although well suited for training for a career in research, I have serious doubts as to its efficiency for training men for other jobs in engineering. A shortened research interval, perhaps oriented more toward a project-type problem, might be far better. The introduction of another educational path requires a break with tradition but to be an engineer one must pioneer.