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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

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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?

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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.