SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

REPORT OF COMMITTEE ON AIMS AND SCOPE OF ENGINEERING CURRICULA*

The appointment of this committee was authorized at a joint meeting of the Council and institutional delegates held during the annual convention of June, 1939. The occasion for its appointment was the discussion, which had been active for some time, of the need of extending the period of undergraduate curricula to five or six years. There was active discussion also of the desirability of a preliminary period of study in schools of liberal arts before admission to the engineering school. A bill had recently been introduced in the Legislature of the State of New York intended to promote this practice by giving credit for such educational experience to those applying for professional licensure.

The committee was instructed to examine the various aspects of this matter and to present a report at an informal meeting of members of the Society to be held at Washington during November. A preliminary report was therefore prepared for discussion by those present at the meeting. Other members of the Society, engineers in practice, and educational leaders were invited to submit criticisms and suggestions, and copies of the report were sent to presidents and deans of institutions offering engineering curricula. The present report has been prepared, therefore, as a result not only of the deliberations of the committee but in the light of expressions of the views of many others.

In directing its attention to the matter of the length of the curriculum, the committee has naturally and of necessity considered the broader aspects of engineering education which bear upon the specific problem and presents its report as one dealing in general with the aims and scope of engineering curricula.

The committee has held two meetings, one of three days duration. A sub-committee has also held several meetings to edit drafts of the report prepared at general meetings of the committee. These drafts have then been circulated and re-edited. During the concluding stages of this process the committee has enlisted the cooperation of Mr. J. R. Killian, Jr., of the Massachusetts Institute of Technology.

* Copies of this report may be secured from the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.

The committee comprises the following members:

J. W. Barker
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E. S. Burdell
G. M. Butler
I. C. Crawford
R. E. Doherty
H. J. Gilkey
W. O. Hotchkiss
E. L. Moreland
W. E. Wickenden
H. E. Wessman
H. P. Hammond, *Chairman*

While approving much of the material in the report, Dean Butler dissents from the view that a satisfactory professional engineering curriculum can be provided in four undergraduate years.

I

Current Problems

From its very nature, engineering education operates under changing conditions which constantly challenge its processes and test its results. Its recent history has therefore been one of continuing appraisal and adaptation to changing needs.

Continuation of this process of self-examination seems now to be called for by new conditions, trends, and attitudes that will be readily recognized:

(*a*) The thoughtful public has become aware in recent years of the technological nature of our civilization and of the part that engineers must play in the solution of many of its problems. There is therefore a widespread insistence that the technological professions should be competent to evaluate the social problems with which they deal and to recognize the social forces which they create.

(*b*) Within the engineering fraternity there is a concerted effort toward a clearer definition of professional status and function coupled with higher qualifying standards and more adequate safeguards for both the practitioner and the public. Among some engineers there is also a desire to reduce the numbers of those preparing for engineering careers.

(*c*) Others would seek, rather, to secure further recognition of the engineer's vital function, both technical and administrative, in industry and government.

(*d*) Many leaders in education are supporting a movement to make education beyond the secondary school more widely available and to postpone entry upon specialized study until a preliminary period of general study in college has been completed. Particular aspects of this movement are the establishment of many junior colleges in urban and regional centers and the setting up of "general colleges" or junior divisions within universities.

(*e*) Engineering education finds itself confronted also by the rapid and constant advance of science and by the swift changes in technology. New knowledge, new techniques, and new fields of application are pressing for adequate attention in our curricula and the limitations of time imposed by a four-year course of study make the resulting problems acute.

(*f*) This elaboration of knowledge and the resulting specialization in college faculties tend to place emphasis on particular items of knowledge at the expense of fundamental relationships. Many engineering educators are therefore seeking ways of increasing thoroughness and breadth of instruction in fundamental matters and of stimulating among students initiative, resourcefulness, and originality.

In the light of these conditions and attitudes we believe that the engineering colleges will desire at this time to examine anew their functions as institutions of higher education, to reconsider the selection and grouping of their materials of instruction, and to weigh without prejudice the duration and character of the formal training needed to prepare engineers for their careers, whether in more highly professional capacities or in other technical and administrative service of industry and government.

II

Controlling Factors

The institutions in which engineering is taught include universities of complex organization, land-grant colleges, privately endowed and publicly supported institutes of technology, colleges with associated curricula in liberal arts and in engineering, and junior colleges which offer the first two years of engineering. Despite this diversity in organization, there is among engineering colleges a basic uniformity of aims, ideals, methods, and standards of undergraduate instruction. This homogeneity is not the result of any imposed standardization; it is derived from a strong sense of solidarity among the different institutions and from the common ends they serve. In these circumstances there is ample opportunity for well-considered variations in curricula and for educational experimentation.

Within the broad realm of technology are functions which are highly diverse and exist on many levels of responsibility. Some of them are in a high degree professional, others are sub-professional or non-professional in nature; some are scarcely to be distinguished from pure research, while others verge on commerce or finance. Diversity is, in fact, one of the basic characteristics of engineering services.

While the activities of engineers have a common denominator in the engineering method, they are too numerous and varied to fall within any definition of a profession that could be legally defended and applied. These responsibilities include the entire range of technical and executive direction involved in the production of fuels and industrial materials, the planning and erection of structures, the design and fabrication of industrial products, the planning and operation of utility services, the ordering of industrial plants and processes, the sale of technical products and their adaptation to special uses, and the administration of technical enterprises, both private and public. The education of men for all these activities lies within the responsibility of the engineering college.

Since the *engineering profession* clearly cannot isolate itself from this complex of men and functions as a well-defined caste, it may be said to exist as a vaguely bounded nucleus within a much larger enveloping group which we may call the *engineering fraternity*. While progress is being made in defining the boundaries and standards of this professional nucleus and in giving it legal status through state registration, diversity of practice and fluidity of organization still remain distinguishing characteristics of engineering groups.

In the conduct of engineering education the colleges are associated with an important group of professional societies, some primarily technical and some concerned mainly with professional status. They are associated also with state licensing boards, with industrial interests, and with agencies of government concerned not only with education but also with social welfare, scientific research, the regulation of industry, and the direction of public works.

These many-sided relationships and the diverse activities of engineers have had a determining influence on engineering colleges and their programs. These institutions should not be considered as professional schools in the exclusive sense, as are the schools of law, medicine, and theology. Rather, they constitute one of the major functional branches of the national system of higher education; the technological branch as distinct from agriculture, commerce, journalism, education, and the like. For the most part engineering colleges have given their students a sound, general education distinctive in type and useful in a wide range of occupations. They have emphasized professional responsibilities and ideals more than other colleges of a general functional type, and this emphasis has contributed to the coherence of their work, but few have made preparation for strictly professional practice their predominating objective.

The varied activities and responsibilities demanded of engineers have had another important result. For many years engineering schools devoted themselves almost wholly to instruction on an undergraduate level, but in recent years a large number of them have extended their teaching and research to include the entire range of undergraduate and postgraduate activity.

Students served by engineering colleges for the most part are young men who have been drawn at a relatively early age by the appeal of applied science. Some of them have been influenced by the favorable placement of engineering graduates or by the fact that they can be prepared for self-support in four years. Many of these students are the unsifted products of the secondary schools except as early fixation of interest and the distinctive entrance requirements of some engineering schools serve as selective influences. Because of the popular appeal of the college degree and the unfortunate lack of recognition of excellent types of institutions other than the degree-granting college many students enter engineering colleges who would have better prospects of success in institutions offering a briefer and more practical type of program.

Among those who are well qualified for college, the motivation of practical interest is usually strong, but a definitely intellectual interest often needs to be awakened and nourished in college if it is to survive after graduation. The purpose to follow a career in the more highly technical aspects of engineering or to seek one in the commercial or executive ranks of industry usually remains only partly formed until graduation approaches. A substantial and increasing proportion of those who decide upon a career in technical engineering continue as advanced students, although often on a part-time basis and not infrequently through training programs offered by industry.

Guiding their students in a progressive choice of career aims is one of the major responsibilities of an engineering college. While it would be to their great advantage to divert many applicants to other types of institutions and to select their students with greater discrimination, proposals which might lead to a break in the continuity of the guidance process in the college period ought to be examined with critical care.

III

General Policy

In considering the trends and attitudes outlined in Section I and the conditions affecting the conduct of engineering education described in Section II it seems clear that the problems of the engi-

neering colleges might be simplified by restricting their function to the training of men for the higher professional levels. It must be borne in mind, however, that at present engineering colleges constitute almost the sole agency for preparing young men for technological pursuits. For the common good, therefore, technological education must be kept widely available, its admission requirements should correspond to present needs and interests of young men, and its terminal points should conform to the varied needs of industry and the public service as well as to the standards of admission to the engineering profession. Until other types of institutions are established in sufficient numbers to assume a significant part of the burden, satisfaction of these needs must continue to be the duty of the engineering colleges. Moreover, it is an obligation clearly to be recognized in the constitution of many of our institutions, including the large group of land-grant colleges which were established to diffuse scientific knowledge among the industrial classes rather than to canalize it in strictly professional channels.

In view of their broad function and their complex relationships, we consider it neither feasible nor socially desirable for the present group of engineering colleges to limit their aim to the preparation of young men for professional registration and practice. Neither do we see any reasonable means of dividing these colleges into two groups, one to include only professional schools in a strict sense and the other to comprise more general schools of industrial technology.

In addition to providing the elements of a widely useful general education the engineering colleges should specifically provide: (1) a professional discipline in the several branches of engineering, and (2) preparation for numerous executive, commercial, and service functions in technical industries and public agencies which are not strictly professional in character, although of comparable responsibility. These two fields require nearly identical foundation training with a broad scientific and social base and adequate grounding in engineering methods of analysis and application. The higher and more specialized forms of technical training are essential only in professional activity, and cannot be provided adequately in undergraduate curricula alone.

We are encouraged by recent evolutionary trends, which include a broadening of undergraduate curricula and a pronounced increase in graduate work, to believe that the ends suggested in Section I can be obtained by further changes in the selection and grouping of studies and improvements in methods of instruction, by better selective processes of admission, and by further development of graduate work where more specialized or advanced training is desirable. Furthermore, we believe that constantly chang-

ing needs can be better met within the present framework of undergraduate and postgraduate studies in the colleges and of advanced training programs provided by industry than they can through a program uniformly extended for all engineering students.

While we believe that the broad aims which have characterized engineering education should be preserved, a clearer definition of its scope seems highly desirable. Engineering education rests on a foundation of science, of humanities, and of social relationships rather than on the practical techniques of particular occupations or industries. Training in such practical techniques should require less than four years. Moreover, occupational demands which might be served by training of this type are potentially much larger than those requiring an engineering degree. Since few schools of this kind now exist above the secondary level their number should be greatly increased in order to broaden the opportunity for technical education. Greater recognition, furthermore, should be given to these institutions in order that their importance in our educational structure may be appreciated and understood. A highly desirable result of such a development would be to open new paths of success and placement to many young men of good abilities, but with practical rather than scientific interests, who now enter the engineering colleges with a resulting disadvantage to themselves and to the colleges.

Considering only those young people to whom the education given by an engineering college is well adapted, we believe that their needs cannot properly be met by a program of uniform length, although we are convinced that the course leading to the bachelor's degree conforms well to the interest and career requirements of a large proportion of these students. For many of this group graduation represents a genuine limit of time and of means available for formal education; for many it represents also a scholastic attainment satisfying their tastes and native endowments. Moreover, this level of attainment conforms well to the personnel requirements of many service functions in industry, in engineering organizations, and in government agencies. We believe the imposition of a longer college program on all engineering students through a prescribed five- or six-year course would be inconsistent with the financial resources, career needs, and abilities of many of this large group.

Preparation for the higher technical levels of engineering is unquestionably a duty of the engineering colleges. Such preparation clearly requires more than a four-year period and should extend beyond the baccalaureate degree. Provision for postgraduate education is necessary, furthermore, if adequate time is to be allowed in the undergraduate period for thorough grounding in

the basic sciences, for laying the foundations of a social philosophy, for developing powers of effective expression, and for cultivating reflective and critical habits of thought. If the undergraduate period is concentrated chiefly on these objectives, and if, at the same time, an adequate introduction is given to engineering methods of applying science to actual problems, the value of the four-year program, we believe, will be enhanced. To attain these objectives will require the transfer of some of the more advanced subject matter to the postbaccalaureate period where it may be pursued with a rigor consistent with adequate preparation for engineering specialization.

The individual's need of this advanced training is not always evident to him before graduation; frequently it cannot be discovered and defined until the individual has had some exploratory experience in practice. We believe a natural process of selection operating through individual experience in this transition from undergraduate to advanced study is a more desirable means of limiting the higher ranks of professional engineering than is the imposition of a uniformly lengthened program of studies.

We believe that the rearrangement of program and change of emphasis suggested above not only would make for thoroughness and breadth in fundamental studies, without sacrifice of the motivation which springs from youthful interest in applied science, but also would encourage greater resourcefulness, imagination, and self-development among engineering students.

We believe that there are advantages in the parallel development of the *scientific-technological* and the *humanistic-social* sequences of engineering education. When the elements of these sequences are compartmentalized and taught at different stages of the curriculum, they frequently remain unrelated and uncoördinated in the student's mind. Furthermore, a continuous development of the humanistic-social sequence prevents its complete relegation to the less mature stages of the student's career when it cannot be so effectively presented and when the student has an inadequate understanding of its importance and its bearing upon his scientific-technological studies.

We favor an integrated program of study extending through the entire undergraduate period rather than a division into separate stages. This program should be so planned, furthermore, that it may be articulated with specialized postgraduate programs.

For a minority of the students with time and money available for a period of undergraduate education extending over five years or more, we recognize that there may be advantages in a program of study in a college of liberal arts followed by work in a college of engineering. The chief advantage to be gained from this combined

program is often intangible, and resides in the experience of life and work in two diverse types of institutions quite as much as it does in any wider range of instruction.

The engineering colleges in some circumstances must coördinate their programs with those of detached junior colleges or of general colleges covering the first two years of undergraduate study in universities. This arrangement usually necessitates more than four years of study for a degree in engineering. It also involves a sacrifice in the coördination of scientific, technological, humanistic, and social studies present in well-planned four-year engineering college curricula. This observation does not apply with equal force, of course, to students who transfer from those junior colleges which duplicate the engineering curriculum of the first two years of the senior institutions.

IV

Objectives of the Proposed Policies

Certain phases of the general policy here outlined, especially those dealing directly with undergraduate curricula, require further definition and emphasis. The committee wishes to make clear that it cannot envisage at this time all the detailed measures which may be necessary to put its recommendations into effect. It is able to indicate them only in outline and without the weight of specific proposals.

First, broadening of the base of engineering education, now in process, should be continued. Its roots should extend more deeply into the social sciences and humanities as well as into the physical sciences in order to sustain a rounded educational growth which will continue into professional life. Two stems are thus implied in the undergraduate curriculum which we have designated as the scientific-technological and the humanistic-social. Each of these should be organized in an articulated sequence of subject matter and disciplines designed to lead to definite educational objectives.

The scientific-technological studies should be directed toward:

1. Mastery of the fundamental scientific principles and a command of basic knowledge underlying the branch of engineering which the student is pursuing. This implies:
   (*a*) grasp of the meaning of physical and mathematical laws, and knowledge of how they were evolved and of the limitations in their use;
   (*b*) knowledge of materials, machines, and structures.
2. Thorough understanding of the engineering method and elementary competence in its application. This requires:

(*a*) comprehension of the interacting elements in situations which are to be analyzed;
(*b*) ability to think straight in the application of fundamental principles to new problems;
(*c*) reasonable skill in making approximations, and in choosing the type of approach in the light of the accuracy required and the time available for solution—in sum, a foundation for engineering judgment;
(*d*) resourcefulness and originality in devising means to an end;
(*e*) understanding of the element of cost in engineering and the ability to deal with this factor just as competently as with technological factors.

3. Ability to select the significant results of an engineering study and to present them clearly and concisely by verbal and graphic means.
4. Stimulation of a continuing interest in further professional development.

The humanistic-social studies should be directed toward:

1. Understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development.
2. Ability to recognize and to make a critical analysis of a problem involving social and economic elements, to arrive at an intelligent opinion about it, and to read with discrimination and purpose toward these ends.
3. Ability to organize thoughts logically and to express them lucidly and convincingly in oral and written English.
4. Acquaintance with some of the great masterpieces of literature and an understanding of their setting in and influence upon civilization.
5. Development of moral, ethical, and social concepts essential to a satisfying personal philosophy, to a career consistent with the public welfare, and to a sound professional attitude.
6. Attainment of an interest and pleasure in these pursuits and thus of an inspiration to continued study.

Second, to attain the ends indicated by the foregoing general policy requires high efficiency in use of the limited time available to the student. Attainment of this efficiency means further reduction of the total content of required subject matter and concentration on fewer courses pursued simultaneously; it means minimizing purely descriptive material and repetitive tasks; it means the abandonment of effort to develop the specialized skills that are

now emphasized. It means, in brief, a process of pruning to the essentials of a sound educational content in the interest of the mastery of those essentials.

Such a process of pruning, however, does not mean the weakening but rather the strengthening of the undergraduate program as a preparation for subsequent professional development. Greater concentration of effect upon the mastery of fundamental concepts and the cultivation of intellectual powers required in the more advanced use of the engineering method would provide a more effective base for advanced scientific study, render the graduate more sensitive to the lessons of practical experience, and thus prepare him effectively for subsequent professional development.

To weaken the educational base of professional study would, of course, defeat our entire purpose. The fact must always be held in view that, while we regard the humanistic-social element as fundamental and vital to the engineering curriculum and feel that its importance must be more adequately recognized and its aims more clearly defined than they usually are at present, engineering science and method constitute, by definition, the dominant interest in the curriculum and so must be accorded the dominant portion of time. Otherwise the curriculum would no longer be within the scope of engineering education.

And finally, we reaffirm the belief that under the diverse conditions that surround and permeate engineering education no single plan as to length and nature of the curriculum applicable alike to all institutions, is either practicable or desirable. On the contrary we believe that the variety of conditions that will always pertain to science and technology require diversity rather than enforced uniformity in the educational process; and we believe especially that there should be freedom for experimentation and change in education just as there is in the world which it serves.

Summary of Conclusions and Recommendations

Engineering colleges serve diverse functions and prepare men for a wide range of technical, administrative, and executive responsibilities. Technological education should, therefore, be kept widely available, and engineering colleges must continue to serve a correspondingly wide variety of purposes. They should not limit their aim to preparing young men for professional registration and practice.

The present flexible arrangement of four-year undergraduate curricula followed by postgraduate work will better meet the needs served by engineering education than will longer undergraduate curricula of uniformly prescribed duration.

Engineering colleges could operate more effectively if briefer and more directly practical forms of technological education were provided by other types of institutions.

Advanced training for the higher technical levels of engineering should be included in the general program of engineering education but should not become its dominating aim.

Undergraduate curricula should be made broader and more fundamental through increased emphasis on basic sciences and humanistic and social studies. This will require greater efficiency in the use of the student's time to be gained by pruning to the essentials of a sound educational program.

Some of the advanced technical subject matter now included in undergraduate curricula should be transferred to the postgraduate period where it may be pursued with a rigor consistent with preparation for engineering specialization.

There are advantages in the parallel development of the scientific-technological and the humanistic-social sequences of engineering curricula. The present integrated type of program extending throughout the entire undergraduate period should therefore be preserved.

No measures taken with respect to engineering education should limit the freedom that now exists for experimentation and change.