Report of the Committee

for the study of

Engineering Education at Yale University

Submitted to the President of the University

New Haven, Connecticut 23 October 1961

YALE UNIVERSITY
SCHOOL OF ENGINEERING

OFFICE OF THE DEAN

SHEFFIELD HALL
NEW HAVEN, CONNECTICUT

23 October 1961

President A. Whitney Griswold,
Woodbridge Hall.

Dear Mr. President:

I have the honor to transmit herewith the report of the Committee which you appointed approximately one year ago, to study engineering education at Yale and make recommendations. We have taken cognizance of your charge to us that the Committee explore the whole field of engineering at Yale anew and that it range freely in its thinking and not feel unduly restricted by present administrative arrangements or by other limiting features of the current situation. You emphasized that our task was to determine whether the present structure and philosophy of the School of Engineering represents the most effective contribution that Yale can make to engineering education.

It is our sincere hope that this document will be favorably received by you and by the Corporation and that it will be communicated without delay to the faculty of the School who must bear the responsibility of implementing it. It has the unanimous and enthusiastic endorsement of all members of the Committee. We believe that it provides a sound basis for the future development of engineering education at this University.

Sincerely yours,

Barnett F. Dodge

Barnett F. Dodge
Chairman

Introductory Statement

Before enumerating its conclusions and recommendations the Committee would like to set forth some of the assumptions and philosophy from which they were derived.

The foremost assumption is that, as was strongly implied by the President in his charge to the Committee, Engineering is an important part of Yale education, not only for its own sake but for its influence on the rest of the University. The increasing importance of technology in determining the structure of our society and the nature of our institutions, the continued infusion of techniques from engineering, science, and mathematics into the social sciences and even the humanities, and the importance of engineering or engineering viewpoints to the solutions of many of the most pressing problems of our civilization make a strong engineering school in the context of a great university peculiarly important and relevant.

The most important new fact facing technical education of all kinds is that the useful life of technical information has become so much shorter than the professional lifetime of an individual. Thus most of what an individual will use in his profession must be learned after the completion of his formal education, and it becomes the task of education to provide him with the tools for learning in contrast to the tools for earning a living. The problem of adjustment to this new situation has been much more complex for engineering education than for education in the basic sciences. The intelligent student has not failed to notice that, in the professional world, it has been much easier for the scientist to convert himself into an engineer than for the trained engineer to master the new science required for a dynamic technology. Thus, to an increasing degree, pure science and mathematics have appeared to the most intelligent students as better preparation for a technical career of any kind than

what has been offered in the engineering curricula of most universities and institutes of technology. In consequence, there has been a shift of students away from engineering into science and mathematics at the undergraduate level despite relatively thriving graduate programs in engineering.

It is easy to conclude from this that engineering is in process of transition to a purely graduate profession like medicine or law. In one sense this is true. The four-year bachelor program in engineering cannot produce a true professional, and the proportion of practicing engineers having at least one graduate degree is certain to increase rapidly. Thus the four-year curriculum seems destined to become increasingly oriented toward preparation for graduate work, or at least for further on-the-job training. On the other hand, engineering is distinct from science, and this fact must not be obscured by the frequent similarity of basic subject matter. We believe that, unless the prospective engineer has some exposure to the approach and attitude of engineering during his undergraduate experience, he will never be properly motivated for his later training and professional career.

What distinguishes the engineer from the scientist? Clearly it is the end product of his work. The engineer seeks a socially useful device or process; he is trying, with scientific techniques, to solve a problem which is initially presented to him in terms of a social objective. The scientist, on the other hand, is interested in knowledge *per se,* and knowledge which is ultimately expressed in the most compact and aesthetically satisfying way. The ultimate goal of the engineer is a specific accomplishment, while that of the scientist is a contribution to general understanding. The scientist is interested in specific information and results only insofar as they help him to verify, illustrate, or clarify general principles. By contrast the engineer is interested in general principles to enable him to encapsulate or codify a very large body of specific information for use in design. Thus both the scientist and the engineer must have similar and equally

thorough training in basic principles, but their attitudes toward them will be quite different. The engineer can and indeed often must be satisfied with less complete understanding than the scientist; he must be able to judge when his understanding is sufficient for the problem at hand.

The engineer is, in a sense, the middleman between the sciences and society, and as such he must, to an increasing degree, know both science and society. He operates within a different framework of values, even though he may often be dealing with much the same subject matter as the pure scientist.

The conventional response to the crisis in engineering education has been to introduce what is known as "applied science" into engineering departments. The term "applied science" would be better understood if it were called "applicable science," for that is what it really is. There are many areas of science which are of increasing importance to engineering, but are no longer fashionable in basic science departments. These areas are usually referred to as applied science, and it is in this sense that the term is used in this report.

We do not believe there is anything basically wrong with the trend toward applied science, but it does have pitfalls if carried too far. Many major engineering undertakings today are carried out by engineers teamed with scientists. Indeed, much of what is known as engineering analysis employed in the design process is applied science. Thus sophisticated applied science should form an important part of engineering education, and a first-class engineering faculty should include many men who are applied scientists rather than engineers, and indeed who do not even carry the term engineering in their academic titles. There are two dangers in this trend. One is the failure to recognize that applied science in the above sense is not *all* of engineering, and the other is the tendency to equate applied science with diluted science. We believe it to be vital that Yale have in its en-

gineering faculty a number of men who are distinguished as scientists rather than engineers, but who work in areas which are more congenial to an engineering department than to the basic science departments. A way of insuring this is to make a number of joint appointments between science and engineering which are fully endorsed by both faculties. But if Yale built up only its applied science effort, it would be merely following an already long procession. The special feature of the plan which we are proposing is that it involves not only a strengthening of applied science but also a more distinctive professional engineering program with its own professional degrees.

It should be recognized that the engineer is the middleman between science and society. Yet few engineering schools are in a position to give sufficient emphasis to the "society" aspect of this function. This requires more than a selection of courses in the humanities and social sciences for engineering undergraduates. A faculty and graduate student research effort concerned with some aspect of the interaction between technology and society would be an important element in strengthening the social and economic aspects of engineering and in exploiting the unique advantages of an engineering school in a university environment. Yale has an unusual opportunity in this regard because of the existence of strong and growing graduate programs in the relevant social sciences. A joint research effort drawing strongly on the Graduate School and Yale College faculties would ultimately contribute to the development of a better integrated humanities and social sciences program for undergraduate engineering students.

With this general background, we proceed to the discussion of our specific recommendations:

Recommendations

A. General

1. In order to offer the strongest possible undergraduate and graduate programs in engineering, we recommend the creation of a Department of Engineering and Applied Science. This department would be in the Faculty of Arts and Sciences and would correspond to the other academic departments of the University, which offer degrees in Yale College and in the Graduate School. Within this department there should be created divisions corresponding to, but not limited to, the existing engineering departments.

We believe that such an organization could strengthen the position of engineering at Yale, and could also provide the desirable features of administration inherent in a single department within Yale College and the Graduate School, especially in the preparation and presentation of consolidated engineering programs and budgets.

2. We recommend that the faculty of the new department include a number of scientists whose titles would carry designations such as "applied mathematics" or "applied physics" rather than "engineering." The department might thus include a number of new divisions labeled with applied science designations and having no counterpart in the present engineering departments. The possibility also exists that within the engineering department some divisions might correspond to combinations of several of the present departments of the Engineering School.

3. We recommend continuation of the School of Engineering, which would evolve ultimately into the administrative division responsible only for students enrolled in programs leading to the professional graduate engineering degrees (the M.Eng. and D.Eng. as described under C, 1 below). The School of Engineering would be under the direction of a Dean, who would be the same individual as the Chairman of the Department of Engineering and Applied

Science. The faculty of the School would consist mainly of those individuals most directly concerned with the development and execution of the programs leading to the professional engineering degrees. In general, it would be expected that those members of the faculty whose main interest was in applied science would be members of Yale College or the Graduate School faculty, but would not necessarily belong to the faculty of the School of Engineering.

4. The Committee recommends that every possible measure be taken to strengthen the office of Dean and Chairman, which is obviously a key to all the recommendations here presented. Many such measures can be envisaged. The creation of a single Department of Engineering and Applied Science will obviously be important in this connection. The Dean should be empowered to assemble *ad hoc* committees to pass on all tenure appointments, and should be encouraged to recommend appointments which cut across boundaries between present engineering departments. The authority of the Dean should be upheld and advanced in all areas, including appointments policy, educational policy, and budgets.

In order to strengthen the office further, the Dean should be provided with a first-class administrative assistant in order that he himself should be able to devote his major attention to long-range planning and to recruitment of faculty, which the Committee considers to be of critical importance to the future of the School.

B. The Undergraduate Curriculum

1. Undergraduate engineering at Yale is important and should be preserved and continued as a four-year program, which can be terminal. In our opinion, a four-year program cannot be truly professional and still provide the foundation for future learning which is so essential to the education of today's engineer. Professional accreditation is not necessarily

inconsistent with this position. However, it is quite possible that educational policy may dictate curricula which are not appropriate for accreditation at the baccalaureate degree level. The program should aim mainly at laying a solid foundation for future learning whether in further graduate work, formal on-the-job training, or self-instruction.

2. The various engineering curricula should be designated as majors in Yale College. We believe that the present organization tends to isolate engineering students and faculty from the rest of the University. This recommendation would bring the faculty into closer association with colleagues in other disciplines in the day-to-day planning of policies and curricula. It would have the further advantage of promoting better integration among the individual engineering programs.

3. The engineering and applied science curricula should be essentially the same for all first-year students. Beyond this, maximum flexibility should be sought, with the proviso that undergraduates should not be permitted to confine themselves to highly specialized technical subjects until a minimum number of basic courses has been completed. The basic course offerings could be numerous enough to allow considerable choice and to permit courses to be taken across divisional and departmental lines, especially during the last two years.

Curricula following traditional divisional lines will still be in order, but the high proportion of electives should make possible stronger concentrations in applied science than has been possible in the past. It should be possible, in this setting, to develop new interdisciplinary programs of interest and utility.

4. Considerable progress was made two years ago in the liberalizing of the Yale engineering curricula through the reorganization of course sequences. This excellent effort should now be extended to encompass the examination of the content of technical courses, possibly with the aid of

outside consultants, with a view to developing more generalized approaches to many topics.

5. The Committee recommends a similar continuing study relative to the structuring of studies in the humanities and social sciences in the requirements of the engineering majors in Yale College.

Despite the fact that Yale has been a leader in increasing the proportion of the curriculum devoted to courses in the humanities and social sciences, we believe that the time now allotted could be used to better advantage if, in designing a student's program, more thought were given to the course content and course sequence in terms of their relevance to the social role of the engineer.

6. In general, the Committee wishes to avoid making detailed recommendations regarding curricula. We have two suggestions, however, which we believe to be worthy of further study, even though they may be quite difficult to implement in a practical way.

a. The Committee recommends development of a course, probably to be taken in the first or second year, which will serve to introduce the student to the nature of engineering. Several methods, for example, historical case studies in depth, might be suitable for such a course, but great care and thought would have to be devoted to avoid superficiality or a merely anecdotal approach.

b. The Committee also recommends that steps be taken to introduce undergraduates to numerical analysis and the use of high-speed digital computers at an early stage in their careers. We believe this can be done without extensive prior preparation in mathematics and that, indeed, for the particular interests of engineering students, such a course might provide the best foundation and the best motivation for later, more advanced work in applied mathematics.

C. The Graduate Program

1. The Committee recommends two parallel paths to graduate degrees in engineering, one emphasizing research in engineering science or applied science, the other placing primary emphasis on problem solving, system analysis, or design, leading toward the professional practice of engineering.

Thus the long-range goal would be four degrees: Master of Science and Doctor of Philosophy, administered by the Graduate School, and Master of Engineering and Doctor of Engineering, administered by the School of Engineering. The degree designations are unchanged, but, in contrast to the present situation, there would be a very clear distinction in content and spirit between the studies leading to the professional and the research degrees.

The Master of Engineering would be a two-year degree. The first year would be an intensive advanced program in engineering science with emphasis on applied mathematics. The second year would put major emphasis on design and would probably be organized about a series of design problems or case studies. Since the Master of Engineering program is aimed at preparing men for the practice of engineering, it is entirely appropriate that this program should meet whatever accreditation standards may evolve.

The Doctor of Engineering is envisaged as a very high level degree awarded for creative work of a design or system study character. In many, if not all, cases, candidates admitted for this degree would have had several years of professional experience, and might return to Yale to pursue some design problem, arising out of their work, in much greater depth than was possible or justified in their professional post. However, the degree should be awarded only for work done largely in residence at Yale.

2. In order to carry out the above recommendation, the faculty of the School of Engineering might well include

a number of part-time professors who spend the remainder of their professional life in engineering practice.

3. The Committee has not spelled out the programs for the two professional degrees because such programs would be quite novel and their formulation will require care, thought, and experience applied over a considerable time. In the meantime, existing graduate programs will presumably continue. Nevertheless, we feel the effort is so important that an appropriate team should be assembled and given time free of other teaching duties to undertake the task of developing such a program. This effort may require funding from outside the University, and should probably include both Yale faculty and professional engineers from industry and government. The task will be formidable, and the program will have to be experimental for several years; but we believe that its successful accomplishment would represent a major step forward in engineering education.

D. Research

The nature and scope of the research activity carried on by the faculty and graduate students of the School and Department of Engineering will play the largest part in determining the future character and evolution of engineering and applied science at Yale. The following points seem worthy of mention in connection with the development of the research program:

1. One of the important responsibilities of the Dean will be the encouragement and development of a research program. Although the initiative for research projects must come largely from individual faculty members, the Dean can, by persuasion and encouragement, and especially by taking a personal interest in the research programs, help the faculty to evolve a coherent program with emphasis on interdisciplinary collaboration and on collaboration with the scientific departments.

2. Although most sponsored research would be, as at present, under the direction of a single "principal investigator," there are funds increasingly available, both from government and industry, to support groups of faculty members to work on programs of common interest. These group programs have the advantage that they permit the establishment of broader facilities and bigger instrumentation than could be justified by individual faculty projects.

3. We recommend the University consider the appointment of a joint committee representing engineering and science with a specific mandate to explore possibilities for interdisciplinary research projects. However, these projects should not be started just because they are interdisciplinary, but because they result from natural common interests. Very often these common interests can go unrecognized for long periods in the faculty, and the purpose of the committee would be to identify and foster the natural tendencies toward interdisciplinary collaboration which are already latent in the existing interests of the faculty. Such a committee could be of great assistance to the Dean in identifying opportunities for future appointments, particularly those lying in the area we have termed "applied science."

In considering the development of the research program, the term "research" must be interpreted broadly. It is true that much of the research will be science oriented and will thus be research in the conventional sense. However, some research should be concerned with design, e.g., the systemization and eventual mechanization of design procedures; and some should be concerned with the identification or formulation of social needs in engineering terms, and the study of engineering systems to meet these needs. It is in this area that collaboration between the engineering faculty and the faculties in some of the social sciences would be most important and productive.

E. A Science and Engineering Center at Yale

The Committee was impressed with the potential advantages of a science and engineering campus at Yale to include the present basic science departments, the present engineering departments, and any applied science groups that might be developed under this program. Indeed, we were so impressed with this idea that we could not forego a recommendation that serious thought be given to the possible creation of such a center.

We strongly urge that the group at Yale concerned with planning building locations give serious attention to bringing the scientific and engineering disciplines into as close physical proximity as is practicable. While physical proximity is far from a guarantee against intellectual isolation, it is a tremendous spur to collaboration.

F. Costs

The financial needs of the program we have outlined are substantial. We have not been able to give them thorough consideration. However, engineering and applied science at Yale may, over time, require the annual equivalent of an additional several hundred thousand dollars a year, represented in part by income from new endowment, in part by the flow of government and foundation grants, and continuous private individual and corporate support.

Conclusion

We count it a privilege to have engaged in this study and in the preparation of this report, and we hope that its recommendations are reasonable, relevant to the Yale situation, and can be implemented. If many of the recommendations seem very general and lacking in specific examples, it is because we believe the progress of engineering at Yale should be evolutionary rather than revolutionary, and many

of the suggestions will have to be studied in considerable depth with the faculty in order to translate them into an operational curriculum and organization.

Respectfully submitted,

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