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TRENDS IN ENGINEERING EDUCATION

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YOUR presence here this evening indicates that you are interested in engineering education. Many of you, however, are not directly associated with engineering education and have not had the opportunity to read the many reports that have been written or the articles that have been published over the past number of years. It may be of help to us this evening as we explore this topic to review the evaluation studies that have been conducted over past years and I shall attempt to do this with a minimum of statistics.

The organization founded in 1893 as the Society for the Promotion of Engineering Education, but now known as the American Society for Engineering Education, has since its founding conducted many studies of engineering curricula. These studies dealt mainly with the content of various programs and the distribution of time among the major divisions of the work. For your information, and for the historical value, it is necessary to go back to the early studies made in 1923 known as the Mann Report. From this early study came the report known as the Wickenden Report which study was made from 1923 to 1929. The Wickenden Report is such a basic report and has been fundamental to many of the reports made since that time that I should like to quote a few parts of this report:

> "The multiplication of trunk and branch curricula based on technical specialization has gone fully as far as can be justified. Further differentiation in courses for undergraduates is much more likely to proceed on functional lines."

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"The most serious deficiency in engineering education is not so much in matter taught or matter omitted in college as in allowing the orderly process of education to stop, where it so often does, at graduation."

The Wickenden Report was then followed in 1940 by Ames and Scope of Engineering Curricula and in 1944 by Engineering Education After the War, both reports being known as the Hammond Reports. Both of these studies renewed the interest that had been generated by the Wickenden Report in the "general academic subjects." The two reports placed strong emphasis on the division of each curriculum into two parts; one, to be the scientific-technological stem, and the second to be the humanistic-social stem. The Hammond reports recommended that about 20% of the total program should be in the humanities and social studies. Both reports recognized also that engineering graduates enter into many kinds of varied activities upon graduation, therefore there should be a differentiation in the type of program taken in the undergraduate years. The reports recognized these varied activities as follows: "In order to provide for the satisfaction of the needs incident to these trends, the 1944 committee suggests, for consideration, a plan of curricula differentiation in the fourth year, through which three options would be offered within each major professional curriculum: (1) continuation of the present type of the four-year program essentially as a terminal program but with modification advocated by the committee, for a majority of the students. (2) an alternative fourth year emphasizing subjects dealing with the management of construction and production enterprises. (3) a fourth year intended to prepare for additional years of advance study by strengthening the student's command and extending his knowledge of basic sciences and mathematics, and by introducing him to the methods of advanced study."

In 1939, D. C. Jackson's Present Status and Trends of Engineering Education in the United States was published, and is considered a supplement to the Wickenden Report. A committee for evaluation of engineering education of the American Society for Engineering Education was appointed in 1952. A preliminary report on evaluation of engineering education was issued by this committee in October 1953; an interim report was published in June, 1954; and the final report on evaluation of engineering education was published in June, 1955. This report shall be referred to as the Evaluation Report or the Grinter Report.

This committee on evaluation included in its studies such topics as: (1) objectives of engineering education and their implementation; (2) the selection and development of an engineering faculty; (3) special factors that influence undergraduate educational achievement; (4) graduate study in engineering. The main part of the report was devoted to curriculum content as related to the objectives of engineering education. The objectives established for engineering education seemed to be in two factors: (1) that the engineering education program of the future should be based upon the obligations of the engineering profession to society and (2) the program should be based upon the importance of developing the student as an individual. The first part of this objective indicates that an engineering curriculum should never remain static. The increasing amount of knowledge of basic science and the vast quantities of material that are included in the engineering sciences, compel us to revaluate our curricula at frequent intervals.

The second objective encourages the development of a social goal in a program of engineering education. This objective leads to the development of leadership, may possibly help in developing some professional ethics, but it should, above all, tend to make the engineering graduate a better citizen and a person better qualified to take his place in society.

To accomplish these objectives the Grinter Report has designated that a curriculum should contain four basic areas: (1) the basic sciences including mathematics, physics, and chemistry; (2) engineering sciences including six sectors, (*a*) mechanics of solids (statics, dynamics, and strength of materials), (*b*) fluid mechanics, (*c*) thermodynamics, (*d*) transfer and rate mechanism (heat, mass, and momentum transfer), (*e*) electrical theory (fields, circuits, and electronics) and (*f*) nature and properties of materials (relating particle and aggregate structure to properties); (3) the humanity and social study area; and (4) engineering analysis and design.

The report of the Task Committee to the American Society of Civil Engineers, which appeared in Civil Engineering February, 1958, disclosed some interesting facts about civil engineering education. I shall not attempt to list them all, but the following are pertinent to the subject of the evening: (1) the quality and quantity of students in civil engineering are not keeping pace with other branches of engineering; (2) there is a definite lack of importance and prestige given civil engineering by the general public; (3) the feeling held by many civil engineers and civil engineering administrators that civil engineering is not a wise choice; and (4) there is an increasing difficulty to attract students to civil engineering. It is very evident that engineering enrollments are decreasing and that civil engineering is losing ground both in numbers and quality of students. These trends may be reversed in the next few years because of the responsibility and task before the civil engineer. It is also evident that civil engineering as a profession has lost ground, as compared to other branches of engineering, in terms of relative importance. This can be reversed if we in civil engineering can achieve a more realistic program of professional education and of public relations. Engineering education must assume the responsibility for the preparation of the young engineer, and must provide an adequate training for the young graduate so that he may find his place in a rapidly changing technology. It is the responsibility of the practicing or professional engineer to advance the prestige of the profession, to keep the house clean and in order, and foster those principles that not only lead to a learned profession but to an ethical profession.

One of our obligations as professional engineers should be to sell engineering education to young secondary school students and especially, as members of a civil engineering society, to sell civil engineering education. To convince them that it is not just a means to a living, but that civil engineering is the branch of engineering most directly concerned with man's environment and the fulfillment of human needs. Not only does the civil engineer plan, conceive, design and construct large projects that alter the face of the earth, but that when these projects are completed he has provided a means for better living, better working, and better recreation. The basic needs of our civilization are transportation, construction, water supply, sanitation and city planning; these are the responsibility of the civil engineer.

The many reports that have been published, including the report of the Task Committee, have for obvious reasons created a great deal of concern for civil engineering and civil engineering education. Many questions and topics have been raised by both engineering educators and professional engineers and in turn these questions have not only been a source of much debate, but of open "warfare."

It is impossible for me to list all of the leading questions of topics that have been raised, but I would like to mention those that I have considered to be some of the important ones so that you may understand the basic thinking that is taking place. (1) What is civil engineering? (2) What should civil engineering education achieve? (3) Should we call a specialist a civil engineer? (4) What sequence of subject matter should be included in a curriculum and how many years should it take? (5) Should we do away with the undergraduate civil engineering program and leave all professional education for a fifth and/or possibly a sixth year? This question could also be raised not only for civil engineering but for all branches of engineering. (6) Should the undergraduate program be extended to five or more years?

It was these questions and others that led the Cooper Union to take the initiative to organize a conference on civil engineering education. With the cooperation and the backing of the American Society of Civil Engineers and the American Society for Engineering Education and a grant of money from the National Science Foundation, planning sessions were conducted preliminary to a general conference on July 6, 7 and 8, 1960 at the University of Michigan. I shall refer hereafter to the report from this conference as the Michigan Report. The planning sessions presented the following resolution to the conference: "Therefore, be it resolved that this conference favors the growth in universities and colleges of a pre-engineering, undergraduate, degree eligible program for all engineers, emphasizing humanistic social studies, mathematics, basic and engineering sciences with at least three quarters of the program interchangeable among the various engineering curricula; to be followed by a professional or graduate civil engineering curriculum based on the pre-engineering program and leading to the first engineering degree, with a civil engineering degree awarded only at the completion of the professional or graduate curriculum."

So much then for a quick look at the important studies and reports that have influenced engineering education for approximately fifty years. These have, of necessity, been presented briefly, but I believe you now have some knowledge of the history of engineering education and what has been the background to our present situation.

Probably the greatest influence on engineering education is the major role played by ASEE. Of all the reports that have been published and the studies that have been made, the Grinter Report has made the greatest impact. This report has served as a guide to the Engineers Council for Professional Development, (ECPD), in establishing criteria for the accreditation of curricula. I commend the reading of this report to all who are interested in engineering education.

As to the trends in engineering education, I can only give you my personal impressions. These impressions are based upon progress reports that have been released in the past few years, conversation with engineering educators of other institutions, personal observations of what is taking place at educational institutions throughout the country, and the very definite changes in curricula that are appearing in current engineering bulletins.

What are some of these observations which have been made in regard to the changes in engineering curriculum which have resulted from the Grinter Report? I believe one important trend has been the breaking down of departmental barriers. Not only have science and engineering grown together, but the distinctions that have existed between the old branches of engineering are disappearing, and modern engineering education is finding it necessary to alter its viewpoint rather drastically if it is to maintain its position. Any discussion of engineering education will result in many viewpoints. Some educators will advocate a curriculum that leads to a learned profession, some will favor a broad general form of engineering education, and still others will desire a program of specialization. The types of curricula that would be recommended to accomplish these various aims would also be numerous. Many would suggest, for excellent reasons, the conventional departmental program in existence now with the common freshman year. Others would suggest the five-year program, three in liberal arts and two in engineering. Still others would argue for a common three-year engineering program for all engineers.

Many institutions have already made the move and have introduced drastically new programs of study in the undergraduate years. I believe we will see in the next few years, more and more colleges of engineering introducing an undergraduate program built around basic science, engineering science and the humanities and social studies. The professional or applied engineering science courses will be moved into a fifth year of study and shall be the basis of the first degree in a major area.

Another important trend is the change or shift from the teaching of the more fundamental and general concepts. We are beginning to recognize that engineering education for all branches of engineering encompasses broad classes of basic concepts, theories and engineering systems. If the engineer of the future is to be trained and qualified to handle the engineering problems of the future, he must have his background based on the fundamental and general rather than on the specific. With this type of training he would then be able to handle many types of engineering systems not only as to the techniques of the engineering art, but as to the methodology of approach to the problem.

The young engineering student that we have graduated from our institutions has always been able to make things work. The educational system in which he was trained was primarily concerned with producing an engineer who would be able to take his place in an established economy. From his endeavors and his genius would come some new products and new processes and as a result engineering education had to be steadily, but not rapidly, improved and changed to accommodate these changes. The Evaluation Report, however, was quite emphatic and made it very clear that engineering education could no longer be guided by that which is in existence, but should educate the engineer for that which is not foreseen. The rapid change in our technology could mean that the illustration we use today may be obsolete by the time the young engineer would choose to use this specific knowledge.

We see, therefore, that an education that teaches the specific and develops those skills necessary to take a place in present society, must give way to a form of education in which one acquires an understanding of the general method and approach of engineering problems that at this time are wholly unanticipated. Many educators and professional engineers feel that it is far more important today to be familiar with the most fundamental and far-reaching technological and scientific resources than to be able to do the many specific detailing operations. To provide an educational background to take care of this change in emphasis the engineering curricula have introduced those courses now referred to as engineering sciences. The Evaluation Report defines engineering science as, and I quote, "An engineering science is defined as a subject that involves largely the study of basic scientific principles as related to, and as related through, engineering problems and situations." The report on the engineering sciences based on a study made from 1956 to 1958 says, and I quote: "Engineering science has its root in basic science, but carries knowledge further toward applicability. It delves into the more practical situations, illuminates these with logical reasoning based upon the fundamental laws and generic principles of basic science, and leads into the statement in method of solutions of problems fundamental in engineering analysis, design and synthesis. Engineering science, therefore, stems from two basic areas: mechanical phenomena of solids, liquids, and gases; and electrical phenomena."

Simultaneously with the introduction of the engineering science courses, there has been a considerable decrease in the emphasis placed on techniques and skills. It is no longer necessary for the civil engineer to be an accomplished surveyor. In the same way the engineer who may be concerned with production need not be a skilled machinist. The use of graphical representation has always been an essential means of communication, especially in our field between the architect, the engineer and the contractor. However important it may be, there seems to be no longer a need for an engineer to be trained as a skilled draftsman.

The role of the laboratory has changed a great deal. Recall with me the type of laboratory work we performed 20 or 25 years ago. Much of the time spent was on repetition work, or cookbook type of experiment. It was easy on the instructor, and one found out only if the student could read, and secondly if he could follow directions.

The laboratory should be as effective in teaching as the classroom. It is the place where the student has the opportunity to test theories, to note any contradictions, and expand his knowledge by experimenting. Laboratory time should be spent wisely and should be used when essential data is necessary or some result needs to be interpreted. The use of routine or stereotyped experiments is questionable. A student would profit a great deal more if he were able, under effective guidance, to develop his own tests and draw his own conclusions.

One of the strong recommendations of the Evaluation Report involved an increase in the emphasis on teaching humanities and social studies. The professional engineer can no longer be satisfied in having only technical knowledge and skill, but since he meets with and works with people from all walks of life and in all professions, it has become necessary for him to have some acquaintance with the subject matter of these other fields. It is the aim of this area in the engineering program to provide a foundation upon which the young engineer may build a career. The fields of humanities and social studies from which he might select his courses would include history, economics, and government, which might make him a more competent citizen: or in the fields of literature, sociology, philosophy, psychology, and fine arts that provide a means for broadening his outlook. Through a limited number of courses in his program it is hoped that he would learn a respect for education in all its forms, that he might become aware of what others think and feel.

Another area in which the Evaluation Report gave new emphasis was in the area of engineering analysis and design. There has been an increased tendency on the part of engineering schools to eliminate those courses which were based on standard procedures or could be described as being merely descriptive courses. It is in this area that institutions are doing a great deal of study, or experimenting with various types of design and analysis courses, and although much has been done there still remains a great deal of confusion. To many engineering educators it is evident that this area of our former engineering curricula has been weakened, even though the attempt was being made to strengthen the program. In certain fields courses in design have been eliminated and finally only those courses involving engineering analysis may be found. Constant effort is being made to develop new ways, new approaches, new techniques, to teach analysis and design effectively.

It becomes quite evident when one considers that an engineering curriculum must include basic science, including sufficient mathematics, physics, and chemistry; a reasonable amount of humanities and social studies to permit a student to build upon the foundation gained in his undergraduate days; sufficient courses in the engineering sciences to provide the necessary fundamental background for an engineer to work effectively for a period of about 40 years, and to provide a sufficient number of courses in analysis and design, that it becomes impossible to educate a student with sufficient depth as well as breadth in a period of four years. I do not believe we are still able to train a professional engineer in four years. We should, therefore, decide what we do plan to do in the undergraduate program.

Technical information changes rapidly. It does not last a professional lifetime, its useful life is very short. This would seem to indicate that the knowledge and information an individual will use in a profession will be learned after he has completed his formal education. It, therefore, is the task of engineering education to equip the student with the necessary tools for learning, and we should no longer attempt to provide him the tools to make a living.

A foundation in mathematics and science provides the foundation to make the necessary adjustments in engineering and provides a better background to keep pace with a rapidly changing technology. It is easier, I believe, for the student trained in mathematics and science to step over into the field of engineering, than it is for one trained in engineering to move into the area of science. This may account for the fact that engineering enrollments are decreasing, while those in science are increasing.

Engineering is undergoing a transition, and to what extent this may develop is difficult to say. I believe we should recognize that it is impossible to produce a true professional in four years. It is impossible in four years to provide the necessary foundation for future learning, if we are also responsible to produce engineers for professional practice. I believe that the undergraduate four year program shall become a program of study oriented to the preparation of graduate study, self-education, or in training education. Thus the number of graduate degrees should increase.

We should be careful at the same time how far we move in the direction of an engineering science curriculum. There is a difference between a scientist and an engineer and as long as the end product of the engineer is a useful device or process, we should include in our curriculum some course work that applies mathematics and science to the solution of engineering problems. We are still faced with the age-old problem of how much of our vital human resources remain untapped when we continue to graduate highly trained specialists who have no interest in areas beyond their specialty. On the other hand, we graduate less highly trained students who seem capable of making a living, but are not qualified or are incapable of using their spare time in community service. Both of these educational situations are related; the education has been incomplete.

References

Report on Evaluation of Engineering Education—American Society for Engineering Education, 1955.

Accreditation of Professional—General and Professional—Scientific Engineering Curricula—Committee on Evaluation of Engineering Education, 1953.

Civil Engineering Education, 1959-60—American Society of Civil Engineers and American Society of Engineering Education.

Report of the Task Committee on Professional Education—American Society of Civil Engineers, 1958.

Report on the Engineering Sciences—American Society for Engineering Education, 1958.
"Where Are We Headed in Civil Engineering?" by subcommittee of Committee 1: Educational Policy, Civil Engineering Division, ASEE: Presented June 7, 1957, at the Annual Meeting of the Society at Cornell.
"A Survey of Current Changes That Are Modernizing Engineering Education" by L. E. Grinter, 1959.
"The Applied Civil Engineering Courses in the Light of the Evaluation Report" by Dean F. Peterson, Jr.