promotion of scientific research upon the other, I ask your hearty cooperation and assistance. An institution, like an individual, must grow in its experience, in its appreciation of truth, in comprehension of the meaning of art and of science and of life, if it is to minister to a growing civilization. The inspiration which shall stand back of this growth must rest, in large measure, upon your zeal and your effort.

Alumni of the Institute: To each of you has been mailed an invitation to this gathering. These missives have gone to every country and to every climate. Some are at this moment being borne on the backs of men or in snow-sledges to the interior of Alaska, to be read months hence amid the winter snows. Some will be read in the tropics, under the glare of a summer sun.

Your alma mater would gladly have welcomed each one of you this day to her fireside, though the fare be frugal and the feast modest. Since this cannot be, let her invitation carry at least this suggestion: How farsoever from her halls your path may lead, it can never take you beyond the circle of her affection.

The institute is proud of the men it has sent forth, and she counts upon their loyalty and their devotion. She invites your counsel, your suggestion, your friendly criticism, your help. And while she listens with willing ear to every voice which rings true, she asks you to remember that no greeting so thrills her as that which comes up from one of her own children who is doing a man's work in the world.

Students of the Institute: In a more real sense than any other body you are the Institute of Technology. As such I salute you to-day, and assure you not only of my earnest wish for your advancement and your success, but also of my wish for your friendship and for your help. I prefer to think of such an institution as that in which we work together, not as an empire governed by the few, but as a republic in which faculty and students alike are charged with the government of the whole body.

I congratulate you on taking up the study of engineering, using that term in the broadest sense. There was never a more opportune time to enter such work; nor was there ever a period in the history of our country when the trained engineer had open before him so attractive a field.

This is the day of the trained man, and to him the responsibilities and the rewards will go. To the American engineer a whole series of new problems of the highest interest have in recent years been presented. Railways are to be built, canals are to be cut, a whole empire of desert land is to blossom under his hand. The Pacific Ocean and the countries which border upon it are to be the theater of an enormous development.

Cables will be laid, cities will be developed, the tropics will be subdued. In all this development the engineer, the trained engineer, is to play a rôle that he has never yet played since civilization began. The next quarter-century is to belong preeminently to him, and in all these world problems and world enterprises you are to share.

May I hope that in your preparation you may bear in mind as your ideal of an engineer, not only one who works in steel and brick and timber, but one who by the quality of his manliness works also in the hearts of men; one who is great enough to appreciate his duty to his profession, but, likewise, and in a larger and deeper sense, his duty to a common country and to a common civilization. H. S. Pritchett.

*ENGINEERING EDUCATION IN THE UNITED STATES AT THE END OF THE CENTURY.**

There is no reason apart from custom why any special significance should be at-

* Address of the President of the Society for the Promotion of Engineering Education.

tached to the arbitrary measure of time that we call a century. The main course of history is not much affected by the arbitrary transition from one century to another. But custom has established the turn of the century as an appropriate time to record the past and forecast the future. Since to this Society is entrusted more than to any other agency the future of engineering education in this country, and since we as a nation have risen out of the Monroe doctrine and our isolation, and have taken our first steps to become one of the number of great powers that assume to direct the course of civilization and decide the destiny of the rest of the world, and since this nation largely through the work of the engineer is making rapid progress toward the commercial conquest of the world—the present seems an auspicious occasion on which to study briefly the progress of engineering education.

The century just closing has witnessed a marvelous development in all matters relating to education. Probably the most remarkable feature of the educational history of the century is the extension of the opportunities of an education to the common people as a right. To-day there is nothing in this country so free as education, and the United States is far in the lead of foreign countries in school attendance, about one-fourth of the school population of the world being Americans.

At the beginning of the century there were thirty colleges in the United States with about 3,000 students, while to-day there are 472 collegiate institutions with 155,000 students. But the mere increase in numbers is not the most significant feature. The colleges then were of a lower grade than most academies to-day. This is the explanation of the frequent mention in the biographies of men of that time that they graduated at the age of 15 or younger. The remarkable improvements in the methods of instruction have been both a cause and an effect of the popularization of education.

Another important element in the development of education in America has been the munificent contributions of individuals and of governments to the cause of education. The movement in this direction, during the closing years of the century, has been at a rapidly accelerated rate, and is therefore an element of great promise for the future.

Technical education, the application of the sciences to the needs of man, is a growth entirely of this century. Apparently the first technical school in the world was the École Polytechnique in France, established in 1794 to train men for the artillery and engineering corps of the army. The U. S. Military Academy was founded in 1802, and for more than thirty years thereafter was the only organized agency for engineering education in America. For three-quarters of a century a surprising proportion of the graduates of this institution practiced engineering in civil life, not because the education there given was what would now be called engineering instruction, but because it was the best preparation for engineering practice that could then be obtained. Apparently this fact has been overlooked alike by friendly and unfriendly critics of this noted institution. In 1825 at Troy, N. Y., was organized the first institution in the world for giving instruction in engineering not military. Apparently at the time of the founding of this institution the term civil engineering had not been coined, the word engineering being synonomous with military engineering.

For thirty years after the establishment of the engineering school at Troy, *i. e.*, from 1825 to the close of the civil war, only four engineering schools were founded, of which only two were really entitled to the name engineering. During this time the engineering schools gave but little technical instruction; most of the so-called engineering part of the course consisted of mathematics and elementary science.

In 1862 Congress passed an act giving to the several states public lands for the benefit of 'instruction in the arts and sciences relating to agriculture and the mechanical arts.' Shortly after the close of the civil war many of our engineering schools were organized under this act. Never was there a movement more timely or more successful than this, since it has resulted in the establishment of sixty-four technical colleges—at least one in each state and territory. Fifty of them give instruction in one or more branches of engineering.

The number of institutions at present giving instruction in engineering is shown in Table I. The institutions are classified

TABLE I.

Number of Institutions giving Instruction in Different Branches of Engineering in 1898–99.

Institutions.		Number Offering Courses in						
Grade.	No.	C. E.	M. E.	E. E.	Min. E.	Arch.	Nav. A.	E.
Class A	30	27	21	21	5	8	2	2
Class B	27	24	17	14	10	6		
Class C	20	12	12	7	5	1		
Class D	9	1	9	5				
Class E	3	3	2	2	1			
Total	89	67	61	49	21	15	2	2

with reference to their requirements for admission according to the scheme presented by the Committee on Entrance Requirements—see the annual report of the Society for 1896, pages 103–4. The report of the Committee includes 110 institutions, but the writer concludes from a careful study of their catalogues that at least twelve of these have no engineering course. The writer has received no report from seven of the United States institutions listed by the Committee, nor from the two Canadian engineering schools.

Table II. shows the number of students in the several branches of engineering for the year 1898–99; and Table III. the number of graduates for the year 1899. These data were collected from the institutions for this purpose. A few schools were not heard from, but in each case they were small ones having few, if any, engineering students, which fact probably accounts, in some cases at least, for their failure to report. Therefore, Tables II. and III. may be considered as representing the total number of

TABLE II.

Number of Students in Different Branches of Engineering in 1898–99.

Institutions.	Number Offering Courses in							
	C. E.	M. E.	E. E.	Min. E.	Arch.	Nav. A.	S. E.	Total.
Class A	1359	1579	1405	245	366	54	19	5027
Class B	794	435	510	313	20			2072
Class C	463	919	299	298	3			1902
Class D	10	337	156					503
Class E	41	23	27	4				95
Total	2667	3293	2397	860	389	54	19	9679

engineering students and graduates for the year 1898–99. During the decade 1889–99 the number of students increased from 3,043 to 9,659, or 317 per cent.; and the graduates increased from 483 to 1,413, or 242 per cent. However, in this connection averages are misleading, since the rate of growth for the different courses vary greatly. For

TABLE III.

Number of Engineering Graduates in 1899.

Institutions.	Number of Graduates in							
	C. E.	M. E.	E. E.	Min. E.	Arch.	Nav. A.	S. E.	Total.
Class A	210	299	252	43	54	9	1	868
Class B	143	52	77	14	2			288
Class C	56	89	27	21				193
Class D	5	37	11					53
Class E	5	3	3					11
Total	419	480	370	78	56	9	1	1413

example, from 1889 to 1899 the increase of civil engineering graduates was 56 per cent., and of mechanical 117 per cent.; while the entire growth in electrical engineering is practically a matter of the past decade.

Table IV. presents some interesting statistics as to engineering education in comparison with the so-called three learned professions—theology, medicine and law. The data for the first three columns of Table IV. were compiled from Bulletins 7, 8 and 9—'Professional Education in the United States'—published by the University of the State of New York.

The data in Table IV. concerning the length of high school course required for admission to engineering schools must be regarded as only roughly approximate. It is difficult for one not acquainted with all the facts to determine from the catalogue just what the requirements are; and the need of these data was not foreseen when those in the preceding tables were asked for. Farther, the value of a year of high-school study varies greatly even within the limits of a single State, which adds materially to the difficulty of making a correct general statement as to the conditions for admission.

There are several matters in these tables that invite discussion. For example: 1. Why do so few institutions offer instruction in architecture?—see Table I. Why so few students in architecture?—see Table II. 2. The significance of the fact that more than half of the engineering students are receiving their education in Class A institutions, *i. e.*, those having the highest requirements for admission—see Table II. 3. Are the number of graduates more or less than required to fill the ranks of the profession? 4. Is the number of engineering graduates greater or less, in proportion to the demands of the profession, than law and med-

TABLE IV.

PROFESSIONAL EDUCATION IN THE UNITED STATES. DATA FOR 1898–99.

Item.	Theology.	Law.	Medicine.*	Engineering.
Number of Schools,	165	86	156	89
Growth since 1878,	32%	144%	82%	21%
Number of Instructors,	1070	970	6416	
Number of Students,	8099	11833	26088	9659
Growth since 1878,	87%	294	142%	516%
Number of Graduates,	1193	3110	5725	1413
Requirements for Admission,				
College Degree,	43%	2.3% Re-		
Completion of Junior Year,	2	quire Col-	0.7%	1.1%
Completion of Freshman Year,	11	lege work.		
4-yr. High School Course,		3.5%	8%	4.1
3-yr. " " "	11	14	2	24
2-yr. " " "	4	13	3	51
1-yr. " " "	1	9	62	17
Common " "	11	30	19	
None or Indefinite,	17	28	1	4
Total Reported,	100%	100%	100%	100%
Length of Course,				
4-yr. Course,	24%		91%	98%
3-yr. Course,	70	51%	6	1
Less than 3-yr.,	4	43	3	1
Total Reported,	98%	94%	100%	100%
Average Length of Yearly Session,	8 mo.	7¼ mo.	7 mo.	8.7 mo.

*Does not include Dentistry, Pharmacy and Veterinary.

icine? 5. Do the data in Table IV. justify the usual classification of schools of law and medicine as post-graduate and engineering as under-graduate? In this connection the fact must not be overlooked that some of the students in law and medicine have more or less college training before entering upon their professional course, and the same is true in engineering but to a much less extent. Time forbids a consideration of these questions here.

But statistics can not represent the most important developments in engineering education in the last third of the closing century. Immense strides have been taken in both the methods and the scope of instruction. At the close of the civil war there were nominally only six institutions giving any grade of instruction in engineering; and for ten or fifteen years thereafter, the engineering instruction offered by the best institutions is hardly deserving the name in comparison with that offered by many institutions at the present time. During this period some of the engineering instruction was practical and not scientific, and some was scientific and not practical; but none of it consisted of the principles of scientific engineering, nor of the relations of the sciences to engineering problems. Text-books were few and poor. The equipment of the schools was inadequate. Then the student went to college to learn details of practice and to fill his notebook with formulas; he was reluctant to give his best efforts to the acquisition of fundamental principles and to the development of the ability to see straight and to reason correctly. Happily now all that is changed, and the schools of America are now offering unexcelled facilities for the acquisition of the fundamentals of an engineering education, and the students are laboring heroically to ground themselves in the principles of scientific engineering.

Twenty-five years ago practitioners had doubt as to the value of a technical training for young engineers, and distrusted the engineering graduate; but now general managers and chief engineers prefer technical graduates, since they have been trained in scientific methods of working, and have a knowledge of the fundamental principles underlying all engineering practice, and look out upon the world of truth from the view-point of a man of science. The national engineering societies now give credit for training in the engineering school toward the requirements for admission to membership. The most cordial relations now exist between practitioners and the schools of engineering. Within recent years, largely if not mainly through the influence of the technical schools, engineering has ceased to be traditional and has become scientific.

The technical school met with no welcome from the older colleges and universities. In the beginning the devotee of the non-technical subjects was not willing to admit the study of engineering as being upon the same high plane as that of literature, history and philosophy. Now all who know the facts are ready to admit that the engineering student secures greater advancement during his college career than any other undergraduate. This result is due to the definiteness of the aim of the engineering student, to the stimulus of professional preparation and to the nature of the study.

One of the most important advances in engineering education has been the introduction of the laboratory method of instruction. Now all the better institutions have extensive and well-equipped laboratories fitted up especially for experimental work, in which the student receives instruction of the very highest value. In this respect our American schools are unrivaled in the world. In Europe, particularly in Germany, are some notable and well-equipped engineering laboratories which have done much to advance engineering science, but which are used by experts in research and commercial work and not for purposes of instruction. Although our engineering laboratories are maintained primarily for purposes of instruction, a considerable amount of research work is performed in them.

The curriculum of the engineering college at present consists of about 10 per cent. of English or modern foreign language, usually the latter; 30 to 40 per cent. of indirect technical studies, as mathematics, physics and drawing; and 50 to 60 per cent. of technical work. The tendency is to make the engineering courses as completely professional as are courses in law and medicine. Experience has shown that it is impracticable to teach culture subjects in a course with strongly marked technical tendencies, since the student devotes all his time to the latter and neglects the former. Very recently there has been a tendency to force some of the indirect technical subjects, as advanced algebra and trigonometry, into the preparatory school to get more time in the engineering college for directly technical subjects. The effect of this is still further to curtail the culture studies of the engineering students by eliminating these subjects from the preparatory course.

A number of institutions offer post-graduate instruction in engineering; but the number doing post-graduate work in engineering is less than that in science or literature. In 1898–99 at twenty-three leading institutions the average per cent. of graduate to undergraduate students in non-engineering departments was 9.94; in the engineering departments, 2.3; or, in other words, the per cent. doing graduate work in non-engineering courses is more than four times greater than in engineering courses. In the above computations graduates doing undergraduate work are considered as undergraduate students. But few, if any, Americans now attend European engineering schools, for it is generally conceded that the American schools, in equipment, methods and scope of instruction, are superior to any European schools, at least for American engineers. There are at least three reasons for the relatively small number doing graduate work in engineering:

a. In many cases, if not in a majority, the chief object of post-graduate study is to secure the preparation necessary for teaching the subject. In many branches the whole range of study, both undergraduate and post-graduate, is purely academic and can be obtained in college environments better than anywhere else. But in engineering the prospective teacher must secure a personal acquaintance with the conditions of practice, which can be obtained only by engaging in actual engineering work. In short, the future teacher of engineering prefers to engage in practice after graduation rather than to return to college halls for further study.

b. Probably many students pursue an engineering course chiefly because it promises an early means of securing a livelihood, and not unnaturally feel that they can ill afford the means required for post-graduate study. Others who are financially able to continue collegiate work beyond graduation are more anxious to have a part in the activities of the outside world than to pursue post-graduate study. At present the demand for engineering graduates is such that in both of these classes, at least those that are really deserving, find little or no difficulty in obtaining remunerative positions in practical engineering work. The engineering college is attempting to give a professional training to its graduates, and it is not surprising that they are anxious to apply in practice that which they have been studying in college. A few years ago many engineering students were unable to resist the seductive offers of positions in actual practice, and left college before graduation. Recently the demand has been almost exclusively for graduates, and now a much larger proportion than formerly stay to graduate. When the competition of young engineers for positions becomes greater, as it doubtless will, probably a greater proportion will be willing to engage in post-graduate study. But this element may not become very effective in increasing the number of engineering students seeking advanced collegiate work, for some of them may prefer to serve for a time after graduation as apprentices at comparatively low salaries. Already there are evidences of a considerable tendency in this direction.

c. The third reason for the less number of post-graduate engineering students is by far the most important. Ordinarily post-graduate study is primarily intended for independent research work; and this is properly so, for after a young person has been under the direction of tutors for fifteen or twenty years, it is time that he should attempt to blaze a road for himself. If this research work is really original, it will inspire the highest ambition of the student, and will secure his utmost efforts. This class of work will always attract. But departments of study differ greatly in the opportunities for original research. The less fully developed branches of study doubtless have many unsolved problems waiting for investigation, and some of these are such that a recent graduate may reasonably be expected to solve them, or at least to collect part of the data required for a subsequent solution. Engineering post-graduate study offers fewer opportunities for this class of work than many other departments of collegiate work, because of the more fully developed state of most branches of engineering knowledge. Again, the nature of the investigations in many departments is such that they thrive better in a college atmosphere than anywhere else. This is not true, in general, of engineering investigations. Finally, and most important of all, original research in most departments of study is carried on only because of the enthusiasm of the investigator or by public or private benevolence; while in engineering most of the research work is done in connection with practical work at the expense of individuals or corporations or municipalities having a direct financial interest in the result. Many engineers devote a large part of their time to original research work, and nearly all practicing engineers have more or less of such work. The life of an engineering student before and after graduation is much more nearly continuous than that of a student in most other departments. The ambitious engineering student knows that, shortly, if not immediately, after graduation, he can secure actual engineering practice of high educational value, and many choose positions chiefly with reference to the value of the experience to be obtained. The salary, the educational value of practical experience, the possibility of promotion—all draw the engineering student away from post-graduate study. In other words, the study of engineering is essentially graduate work, and there will probably never be any considerable number who will pursue engineering studies beyond the present four-year course. But there are sufficient reasons why adequate provisions should be made for the competent and ambitious few who seek truly graduate instruction in engineering.

All the preceding is intended to show in rough outline the present state of engineering education, and particularly the rapid growth. The present phenomenal rate of progress promises still larger things for the future, and lays upon this Society important responsibilities in directing the future development of engineering education in America. In this connection there are several matters which invite the careful attention of individual members of this Society, and possibly are worthy of official action by the Society itself.

1. Is any general movement for increasing the requirements for admission desirable? The standard has been rising quite rapidly within the past five years, particularly in mathematics, English and foreign languages; but even now comparatively few of the engineering departments of the universities have as high requirements for admission as the literary departments. Is this justifiable?

2. Is it wise to require advanced algebra and trigonometry for admission to the engineering courses? Is it wise to require prospective students to take these subjects in secondary schools to the exclusion of subjects in science, literature or history? Will the forcing of these subjects into the curricula of the secondary schools handicap them in discharging their just obligations toward students who are not seeking an engineering education? Which subject can the preparatory school teach the better? Which school will teach the mathematics the better?

3. At some institutions a considerable number of engineering students have had previous collegiate training. Can anything be done to increase their number?

4. Engineering courses have become so highly specialized that frequently students of one course receive no instruction in the fundamental technical subjects of a closely allied branch of engineering. This practice is burdensome upon the school and is probably not of the highest advantage to the student. But the colleges are not likely to retrace their steps, and therefore the highly specialized course is a condition to be reckoned with. Should anything be done to prevent further specialization? Some students correct the defects due to high specialization by remaining a fifth year and pursuing the allied course. Can anything be done to increase the number who do this?

5. The engineering course of to-day is so loaded with required technical and scientific work that the student has little or no time to cultivate those subjects, indefinitely, but not inappropriately, called the humanities. Engineering students, more perhaps than any others, need training in such subjects. Those who follow the other learned professions deal constantly in their technical work with the relationships of their fellow men, while the engineer in his professional work deals mainly with the inanimate world. The engineer has little opportunity to come into intimate relations with men either through the study of history, economics and sociology, or through personal contact. The engineer usually possesses strong character, sound judgment, thorough knowledge of his business; but frequently because of a lack of that knowledge which other men consider essential in a liberal education, he is ranked as a relatively uncultivated man, and therefore is unable to exercise the influence his training justifies, and fails to secure the reward his abilities merit. Can the instructors in engineering create in the mind of the engineering student such a hungering for a knowledge of the humanities that he will secure it after graduation by private study and personal intercourse?

Such, then, are the conditions and the problems of engineering education as we step into the twentieth century. The present conditions have been determined largely by the engineering colleges themselves in advance of the demands of the engineering profession and of the general public, and often in opposition to such demands. Chiefly through the influence of the engineering college the engineering profession has developed during the past third of a century into a truly learned profession. There was never a time in the history of the world when the questions of general education were more carefully considered than at the present; and there was never a time when this country was more concerned with the work of the engineer than now. The nation, just awakening to a consciousness of its power and responsibility, is taking its place among the nations of the earth, and is seeking to decide the destiny of the peoples of the earth. We are now sending our manufactured products to all parts of the world, and if we are to have part in the commercial conquest of the earth, it will be because of the ability, the foresight, the wisdom of our own engineers. The only agency seeking to prepare engineers for their work is the engineering college. Their work in molding and directing the engineering education of the future will be no less important than in the past. They enjoy the respect and confidence of the public, and a still wider field of influence and responsibility lies open before them. May the deliberations of this Society continue to be a source of strength and inspiration to the engineering colleges. May the engineer of the twentieth century have better technical training, broader culture and nobler aspirations. May the profession of engineering come to occupy a still higher position in the esteem and respect of the public.

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PROGRESS IN IRRIGATION INVESTIGATIONS.

THE organization and objects of the irrigation inquiries of the U. S. Department of Agriculture have been partly explained in an earlier number of this JOURNAL.* Congress at its last session increased the appropriation for this work from $35,000 to $50,000.

It was realized at the outset of these investigations that a basis of settlement of the controversies over rights to water for irrigation purposes, which are very frequent and acute in the arid region, where the supply of water is limited, must be reached before it would be wise to attempt to greatly increase the use of water for irrigation. The uncertainty of water rights and ignorance as to the amounts actually needed for successful agriculture led irrigators to claim more water than they could possibly use, frequently more than the natural supply yielded, and encouraged extravagant rather than economical use of water. It was for this reason that the Department directed attention first to the collation and publication of information regarding the laws and institutions of the irrigated region in their relation to agriculture, and a number of bulletins dealing with this phase of the subject, as well as with general irrigation practice, have been published. At the same time it was realized that an exact knowledge of the water requirements of cultivated plants at different stages of growth and under varying conditions of soil, climate, etc., is fundamental to an economical, rational practice of irrigation. It was therefore determined that one of the two main lines of work undertaken should be the collation and publication of information regarding the use of irrigation waters in agriculture as shown by actual experience of farmers and by experimental investigations. It was decided, however, that the strictly scientific studies provided for in this plan could be more intelligently pursued after the actual practice as regards irrigation in the various localities where it is already engaged in had been ascertained. Inquiries having the latter object in view were planned and put into operation on a comprehensive scale. The results of the

*SCIENCE, 11 (1899), p. 798.