SCIENCE

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FUNCTIONS OF TECHNICAL SCIENCE IN EDUCATION FOR BUSINESS AND THE PROFESSIONS.[*]

" * * to write now the reforming of education * * * one of the greatest and noblest designs that can be thought on, and for the want whereof this nation perishes. * * *"*—Milton, 'Tractate.'

THE most remarkable and impressive movement of a period which has been well named the 'wonderful century' was one which, from early and feeble beginnings, had been for generations slowly developing, and in rate of motion accelerating, until we to-day see it, in tremendous magnitude and power, affecting every department of human life. This movement causes progressive and cumulative changes in the methods and the products of the labors of the scholar and of the unskilled laborer, of the professional and of the mechanic, of the agriculturist and of the merchant; it changes the views and the studies of the historian, of the philosopher and the psychologist, of the business man and of the educator. It is the advance of the scientific spirit and method into all the fields of human learning and exertion. Scientific method is now dominant in all branches of human life.

This great change commenced with the earliest endeavors of thoughtful men to acquire knowledge by direct appeal to nature and experience. It acquired impetus as the experimental method and the spirit of research began sensibly to enrich our stores of learning and to yield their fine returns in the natural sciences. It assumed its firm grasp upon men's thought and controlled their work when invention and discovery and the upbuilding of new sciences impressed upon the minds of all sorts and conditions of men the fact that its methods were the only direct and sure

[*] An address at the dedication of 'Engineering Hall,' Iowa State College, May 22, 1903.

ways to achievement. Those methods are simple and even axiomatic in principle.

Science, *scientia,* is knowledge, and its significance became evident immediately it was seen that such an idea is the opposite of speculation, that the determination of a fact and its exact identification by suitable methods was the first step to further and exact knowledge of phenomena, and that this process and its result, the discovery of the laws governing facts in sequence, are the antipodes of the ancient method of primary appeal to the imagination, with later endeavor to find evidence sustaining the fairy tale thus evoked from the inner consciousness.

Wherever work is to be accomplished, the fact is the first requirement preliminary to action, and the controlling law is next to be discovered, in order that it, and every other agency of nature as well as of art, may be directed to the furtherance of the purpose held in view. The scientific method is as fundamental in education as in any other system of application of energy to useful result. A scientific training is an essential, a fundamental, element of all professional education, and systematic training, scientific training, is the direct way toward profitable acquisition and most prompt and complete success.

The scientific method is not restricted to the work of the distinctively so-called man of science. There is a scientific method in history, in the teaching of languages, in theology or in philosophy, quite as definite as in mathematics, chemistry or physics. There is a scientific method of education and of pedagogy. In all cases it simply means the coordination of the two essentials, knowledge, exact and definite, and sound reasoning, the exact acquaintance of the teacher with the fact to be taught, a distinct recognition and formulation of the principles and laws behind the system of facts and phenomena, and systematization of all contemporary knowledge of the subject in such manner as to permit the presentation of all in concise form, in logical order and in perfect symmetry. There is even a 'scientific method of advancement of science';* as of every other department of human knowledge, even of the spiritual in humanity itself.

The mission of science, therefore, in the broadest sense, is the promotion of all human knowledge and, through the extension of learning and of culture, to give wisdom and to offer opportunity for its exercise.† Its direct product is material advance in the industrial system, providing increasing comfort and leisure for the people and, through this improvement in the lives of men, giving opportunity for the development of the intellect, the affections and the soul. But its highest task, though not a more essential element of progress, is the promotion of the efficiency of all our methods of preparing our youth for the 'future of their lives,' as Paley says, 'to perform justly, skilfully and magnanimously, all the offices, both private and public, of peace and war,' as Milton puts it in his specifications for a 'complete and generous education.' In every department such an education teaches first the facts, then the principles and formulated law, and next the system, and finally all practicable applications and illustrations and, where physical manipulations are involved, as in the laboratories, in the gymnasium, in the military academy or in the applications of science in the industrial arts, the utilization by the practitioner of the sys-

* 'The Scientific Method of Science Advancement,' vice-president's address, American Association for the Advancement of Science, St. Louis meeting, 1878, R. H. Thurston.

† 'The Mission of Science,' vice-president's address, American Association for the Advancement of Science, Philadelphia meeting, 1884, R. H. Thurston.

tem thus established. In abstract learning, the principles and the methods of science, as of philosophy, of history, grammar and of philology, are practically applied in the acquirement of further knowledge by the educator and the investigator, and in securing and in maintaining full possession of that learning by the scholar.*

A 'technical education' must be defined before it can be intelligently discussed, and in this discussion it will be understood that by a technical education is meant one that will most effectively prepare the individual to become competent, after experience has had its ripening effect, 'to perform justly, skilfully and magnanimously, all the offices' appertaining to his vocation. His business in life may be commerce or a profession, trade or transportation, education or theology; in each and all, there is a certain essential foundation of exact knowledge, a certain system of principles assuring stability and characteristic form, and another desirable but less absolutely essential quantity of accessory and incidental information and general education and 'culture,' which is needed to give the man that finish and perfection of fitting for the intercourse of man with man which, while not vocational or professional, is none the less an element of real and highest success.

Proceeding to consider the circumstances which determine the form and extent of the technical education of the citizen, the relation of such education to the whole system of preparation by special training for life's special work, it is first necessary to agree upon a definition of the terms technics, technical, technological. The Greek, from which the terms originally come, in the primary and the broadest sense regards these terms as relating to the arts, both esthetic and industrial, and the technique of the artist, of the musician, of the watchmaker and of the steam-engine builder, in each case, infers special talent or special acts appropriate particularly to the art. Technical education, therefore, is a system of instruction devoted to the development of a knowledge of an art, as, for example, taught in a school of music, of law or medicine, of engineering, of theology, or of any industrial department.

Huxley says: Technical education 'means that sort of education which is specially adapted to the needs of men whose business in life it is to pursue some kind of handicraft'; but this definition is obviously narrow. Technical education is admitted to include engineering, for example, which demands a most extensive and most intense preparation, and involves as large an amount of learning, especially in both pure and applied science, as any other vocation —as much as is demanded in the other schools of the 'learned professions,' once distinctively so called. The technical educations include all the educations which fit the man for 'the sequel of his life,' as a member of a working community. But any business career is chosen as a means to an end, and that end should always be the attainment of a competence to insure comfort in old age, and meantime a comfortable life from youth to age, and the privilege of seizing all opportunities for moral and intellectual growth and for becoming of some use in the world. The business education must, therefore, be accompanied by a general education such as will do most to fit the scholar for his place in the social world, and to take advantage of those opportunities which come to all energetic men and women in a country such as ours.

Fortunately, these requirements do not usually conflict or result in inefficiency of

* 'The Miltonian Teaching.' An address delivered at Pratt Institute, Brooklyn, December 11, 1894.

either branch of work. The opportunities which are opened to the average citizen, or to genius, even, in this country, apart from those of the vocation, may be usually seized by any one having the requisite intelligence, ambition and vigor, if possessed of a good common-school education. If such a person needs more, his common-school training will have set him at the beginning of the path, at least, and will have fitted him to move forward, not as easily and rapidly as if under expert instruction, but, as experience has shown in many cases, so as to attain the object of the ambition of the moment. Fortunately, also, whatever the ultimate aim, the beginnings of education must be those which supply the tools with which to construct a career. The education of the primary, and, in large part, of the secondary, school is a preparation for the whole sequence of life, whatever that sequence may become. The arts of reading, writing and computation underlie all arts and all vocations and professions. The languages are the entrance ways to all the literatures. All persons, whatever their aims, must begin by learning the curriculum of the primary school and must usually go on through that of the secondary school. This is, necessarily, all of the nature of education, as distinguished from technical training. Technical science can not be taught effectively, even where essential to the plans and the future of the individual, until a considerable amount of general knowledge has been acquired and the beginnings, at least, of a liberal education supplied. The beginnings being thus acquired, the ambitious man or woman will find ways of supplementing it; the unambitious will forget what has been already gained.

The place for the beginnings in the teaching of technical science, applied science, science in its applications to business, is evidently at the point where the scholar commences his formal preparation for a business life. Yet it is generally the fact that something should be done in this direction in advance of the actual beginning of the business-school work. There is a certain amount of scientific instruction and something of technical, or applied, science needed by all, whether the future is to be a life of scholarly leisure or one of strenuous endeavor in whatever department of industry. Such sciences are, for example, physics and chemistry. These should be taught in the general course, irrespective of the plans of the scholar for the future of his life. Certain sciences, also—botany, for example—have interest for all and are essential parts of the education of the man whose vocation is to be that of the scholar, as well as of the technical training of the naturalist. These classes of subjects are, or should be, taught as electives when the curriculum becomes easy of enlargement in that manner, after the pressure for necessary primary instruction has been relieved. Thus, through all the earlier stages of the education of the citizen, the curriculum is mainly a fixed one, given form by necessity. Time must be devoted to those studies which the child first and most needs as preliminary to all the later education and life. As these are acquired, opportunity gradually reveals itself for the introduction of special and elective courses to be distributed to the pupils in compliance with the demands of their prospective business lives.

At the beginning of this latter period, the place of technical education and of the teaching of technical science comes into view. As the pupil becomes older and his plans for life more definite, the extent and character of the technical science to be taught him become more obvious and more completely known. But the desirable

course is now to transfer him to the school of his trade, or to that which most nearly supplies its place, where expert instruction in every department may contribute with maximum efficiency to the proposed end. If the 'business' to be pursued is commercial, it would seem that the youth should remain in the academic schools just as long as time and money and natural capacity permit, and then he should take up the work of the business or the commercial school. The sciences taught, meantime, in the academic public schools should evidently usually be those which may fairly be assigned to a general course, as being valuable to all citizens. Specialization implied by technical science should be deferred as long as practicable.

When the vocation or the profession is finally chosen, the pupil will demand preparation for the technical or the professional school and, where the demand is sufficiently large to justify it, special arrangements, if necessary, should be made for meeting its requirements. This may mean the establishment of electives for pupils preparing for the academic college, the law-school or the school of engineering. It may mean some substitution of scientific for the usual educational courses where the latter may be safely thus displaced. Those requirements determine the nature and extent of the scientific and of the technical instruction to be introduced. Where the pupil is to go directly into business and his precise line of work is not settled, or where it is evident that he is of that class, large in this country, liable to pass from one vocation to another, the technical sciences of the curriculum should be, in general, the mathematics and the sciences of physics and, particularly, of chemistry. The constant endeavor of our school boards and committees to crowd the whole pantology of an extensive liberal education into a common-school system can never succeed, and the attempt only embarrasses and renders inefficient the work actually squeezed in. If the school is large enough, as often in the cities, it may be practicable to arrange a system of electives, as is done in the colleges, wherever it appears that a sufficient number may be classed together to compensate the specialist to be employed as teacher. In smaller schools this course is usually impracticable.

Education for a vocation being the leading object of any school, its curriculum properly involves mainly those subjects which contribute especially and directly to, and are essential to, its purpose. General education has no place, as such, here, and the student should clearly understand that his education, in the ordinary sense of the term, should be obtained, and as fully and liberally as practicable, elsewhere, and usually previously to taking up the scholastic apprenticeship. The curriculum of the school should include the essential studies, the sciences and the technical information regarding materials and products, processes and apparatus, which contribute to accurate and efficient work and to economical production. There is always a certain sequence which is entirely logical and which settles all questions of order in taking up the various subjects, and this problem is usually non-existent in the technical school. Thus the mathematics must be taken in a fixed order; the applied science must follow the study of the pure science; and physical and chemical and mechanical work must be given after the mathematics have been more or less completely mastered; for, in the technical school, these sciences are quantitative and involve mathematical processes. In this assignment there is no question of the place of these sciences in the work, as the object to be attained fixes all requirements.

The sciences are all, ultimately and necessarily, taught as applied sciences. There is no time, and no needless expenditure can be made, for the acquisition of abstract knowledge when so much is to be learned which is to be utilized directly. It is thus essential to complete success that the teacher be entirely familiar, as an expert, with the applied science. Experience shows that, in the engineering colleges and schools, thoroughly satisfactory work in the sciences is best insured by the selection, as teachers, of talented and interested scientific men who have given sufficient time to the business for which it is proposed to fit the student to become practically familiar with it and with its applications of his science. The pure sciences are as necessarily also best taught by experts, and this means those who have specialized in the sciences commonly taught in the academic departments of our schools and colleges. In fact, the rule that teaching should not be permitted to amateurs, in any branch, least of all in technical departments, should be made universal.

The curriculum should be as obviously constructed by experts in the business to which the school acts as feeder. Only the expert in the business can say what branches of instruction properly constitute the technical plan of instruction. The determination of the character and extent of the technical work in turn settles the question, What sciences and what general instruction must be supplied as a basis for the technical work? The form of the whole scheme of instruction being thus completely fixed, the details should be assigned to specialists, so far as practicable; each to be familiar as an expert with the work demanded of him.

Every business, even purely commercial, involves some connection with the producing industries, and the commercial man should evidently, in each case, have sufficient familiarity with the industry to be able to buy and sell intelligently and to discuss details involving financial interests with his correspondent.

It would seem that, in the individual case, only the student himself can say precisely what kind and approximately what extent of scientific and technical instruction is required by him. The technical school should be prepared to meet the demands of as large a variety of business interests as practicable, after sufficient experience has been had to permit decision. Probably some knowledge of mathematics, chemistry and physics will prove useful to all. Those intending to go into lines of business connected with the iron and steel industries will demand some instruction in the chemistry of metallurgy; those expecting to deal in products of the machine-making arts will need instruction in applied mechanics and machine-design; those about to enter upon commercial work relating to transportation will need some knowledge of the principles of conduct of shipment and construction of invoices.

The whole case, so far as relates to curriculum building, may be put in a few words, thus: The practitioner in the vocation, professional or other, for which educational apprenticeship is to be provided, should decide what sort and how much technical instruction is needed at entrance into that branch of industry. This schedule of required work should be assigned to experts in each of its divisions, to those who have practical and expert knowledge of the business. The requirements being thus ascertained, the next step is to provide for such studies and such tuition as are needed to prepare the student for beginning the prescribed studies. These being introduced, the next lower stratum of subjects is laid out as introductory to the

preceding, and this process is continued until a curriculum is constructed which, leading up out of the common schools, terminates at its superior limit at that point at which the diploma of the technical school or college becomes a sufficient guarantee of satisfactory preparation to enter the business and to perfect the professional education by the regular practice of the vocation chosen.

The final form and extent of this curriculum must necessarily be determined by experience, and the preliminary outline must be accepted as provisional. The curriculum will be subject to constant change, amplification and improvement in detail, as time and the forward progress of the profession or the business permits or compels, and thus the adjustment of the work to the requirements becomes more and more perfect. Ultimately, the practitioner will find that the institution is doing all that can be fairly asked of it, and the novice entering into business will find himself as well outfitted as is possible in the time and at the expense permissible, and the youth proposing to take up the line of work in view will find his progress out of the common school, into the business school or college, and out of the latter into business, a smooth and continuous and clearly defined movement. Once in business, thus prepared, his success will depend upon his own talent, industry, tact and judgment.

This development of our system of general education is the great work of our day and generation. The wisdom of our statesmen as well as of our educators is to be tested, and is being measured by the promptness and effectiveness with which they adapt their own ideas, and fit the educational system, to the requirements of a modern industrial organization. When they stolidly follow the ways of the ancients, modern life flows past them. Modern educations illustrate the wisdom, the learning, the knowledge and the culture of later centuries. The wonderful gains of the nineteenth century, particularly, are being supplemented by those who have the wisdom of great statesmen, the learning of modern times, the knowledge which science supplies and the culture which comes of a symmetrical education in all the arts, the sciences, the literatures and the philosophies of our own time, so far as it has been permitted to incorporate them into school and college curriculums. The extraordinary work of the German empire had its origin, in fact, with statesmen who, without being themselves familiar with the scientific curriculum, were wise enough to understand its fundamental importance and to know its place in the modern educations and the social system.

The nineteenth century has been called the wonderful century; but the world has, since the commencement of the seventeenth century, at least, been progressing with swift acceleration, and each century has been wonderful and each more wonderful than the last, to the contemporary looker-on. The twentieth century is probably to be more wonderful than the nineteenth, not perhaps in the fact of its seeing the inauguration of a new era in science and the arts, that is a wonder, unique and probably without precedent or later rival; but it will no doubt bring its share of new wonders and of new achievement, opening new realms of nature, utilizing new forces and energies, and availing itself of the old in new and unanticipated and marvelous ways. New elements and new compounds are to be discovered having more remarkable and more useful properties than the old; new methods of manifestation of that protean power which we call energy will be observed and utilized in forwarding the tasks of the engineer and strange and mys-

terious phenomena now puzzling all philosophers, 'natural' or other, will find interpretation and application to good works for the benefit of mankind.

In all this the young men now coming into their opportunities, and their successors of the next generations, will have their part and find their opportunity. The progress of the world is still an acceleration, and the gain and the opportunity acquire magnitude as a rapidly increasing function of the elapsing time. The work of the educator assumes constantly higher value and greater importance and commands more respect and larger distinction. The place of the engineer in the world, lofty as it has been in earlier days, when Archimedes and Leonardo and Watt and Fulton and Morse pointed the way to advancement through the union of the sciences and the arts, and high as it is to-day, when its apprentices are coming forward with the learning of the centuries at their command and the skill of the modern mechanic and inventor and the productive power of all modern machinery at their will; it must grow with the advances of the new industrial world until it shall become one which old-world, old-time, kings may well, and in vain, aspire to hold. The engineer must be the general of the industrial army and in his hands be held the fortunes of nations. Those who to-day witness the foundation or the dedication of a noble structure, appropriated to the work of contributing to the education and the professional training and apprenticeship of the young engineer, are witnesses of an event contributing to the highest welfare of the race. Those so fortunate as to be of the generation entering upon this work with the commencement of the new century have the splendid privilege of taking just as large a part in the growing opportunity of the engineer and his army as their wisdom, talent, ambition and energy may permit them to assume. The man, to-day, who has the wit to recognize opportunity and the skill and ability to take advantage of it may fairly expect to go as far and to rise as high as he may choose—always provided he maintains himself in a condition of mental and moral and physical efficiency. For he must make himself a part of the great machine and keep time with its march, and maintain what I am accustomed to call 'maximum commercial efficiency.'

Perhaps, in this day and generation, nothing can more effectively contribute to the weal of the nation than the institution of efficient means of promotion of the work of the engineer and of his profession. As chief of the industrial army of producers of permanent wealth, his wisdom, his knowledge, his culture and his professional efficiency, as derived by the application of talent and wisdom to the improvement of the apparatus and the methods of production, constitute the primary elements of material progress and, through material gain, of the advancement of the nation and of the race.

The progress of the state in all directions is largely influenced by the statesmanship of the people of the state, through the legislation of the representatives of the people in investing available capital in the cultivation of the applied sciences and the encouragement of the universality, the continuity and the efficiency of the industrial system. A people which is thus made in maximum degree industrious, skilful, fruitful, through the exercise of every talent in the most diversified employments, and capable of thus making the industries in highest degree effective in supplying all the needs of the most enlightened community, attains most promptly and completely the highest position in the scale of civilization.

This end can only be secured by systematic and thorough education, not only in the departments of culture, but also of economic production, including, it should be understood, apprenticeship in the professions and the trades. In no department is this more essential than in engineering, where the sciences of mathematics, of physics and chemistry and of construction find their most important uses, and where a perfected economic system must find its directing minds.

This is also quite as true where the interests of the agricultural classes are involved. This intimate relation of engineering and agriculture comes of two principal requirements. First: The energies and the skill and the talents of the people should be so applied in agriculture that the energy of that industry shall be in minimum proportion given to that form of production which directs its powers toward the provision of articles for necessary but, nevertheless, in an economic sense, wasteful expenditure. The products of agriculture are intended to be destroyed, and the less this production of ephemeral forms of product compels a diversion into the work of providing the needed food-products, the larger the proportion of the producing power of the nation to be directed toward the production of permanent forms of wealth. Secondly: The more efficient this thus increased proportion of the producing power of a people can be made, the larger the accumulation and the more rapid the growth of wealth in the community, in its most permanent forms.

Already agriculture is a branch of mechanical engineering.

The responsibility of the state arises out of its duty to promote the welfare of the people of the state. This duty as respects the common school, the free public school, has long been admitted; it is now coming to be seen that higher education to-day is quite as necessary to the highest interests of the state, and even to its industrial progress, as was secondary education when the latter was inaugurated as a fundamental purpose of statecraft, a primary object of legislation. Of these two divisions of this great task of the state, Germany exhibits the finest example of the higher, the United States, of all nations, the most admirable example of the lower. But the higher, and especially the technical, education of all competent to profit by it effectively, is now recognized as an essential which only the state can supply fully, continuously and without distinction of class of citizen.

The state, therefore, inaugurated this work with the enactment by the national legislature of the Land Grant Bill of Senator Morrill, although at the time the nation was engaged in a struggle for life and the civil war was in its most uncertain stage. The several states, following this initiative of the general government, have since assumed their duty, usually in a liberal and enterprising and patriotic spirit, sometimes with apparent reluctance and occasionally evading it largely. In this matter the western states have been usually more statesmanlike than the eastern and fine buildings and noble institutions of learning have marked their progress. In the older states there are larger numbers of colleges already established, often long established and firmly founded by private grants and individual generosity, and there has been less apparent necessity of action by the state, although the essential difference between higher education for the average citizen and that desired by the man of leisure or a member of a so-called 'learned' profession is coming to be seen

and provided for even amongst the most conservative of the older colleges.

In some states the work of the state is carried on by private contributions, in large part, directed, nevertheless, toward the education of the people for life. It is, however, well understood that the work is essential to the progress of the country, and that, on the whole, it is not safe or wise to leave it to the sporadic and fitful care of private benevolence; the duties of the state should never be entrusted to enterprises which are of necessity usually mendicant and unequal to their work as are the colleges generally. The latter are always poor and always more or less inefficient from that cause and they are always necessarily mendicant, receiving their accessions of income irregularly and commonly least freely when most in need. This work must ultimately be mainly carried on by the state to insure thorough efficiency and most rapid advancement of the industries and of the people. There will always be ample opportunity for private means to flow into this form of investment for special purposes; but the state must make it certain that the forward movement of civilization and the advancement of the nation is not permitted to halt because of any lack of provision for education of the coming captains of industry or any defect in efficiency of the means thereto. Every man of genius, whatever his circumstances, will be assured of the privilege of gaining that essential training and learning which only can make his genius of value to the world. It is the state which must provide these 'freaks of nature,' as Huxley called them, these Watts and Faradays and Davys, each genius, according to the great man of science, 'cheap at an hundred thousand pounds.' That nation will go furthest and fare best which produces and utilizes most fully the largest number of these 'freaks of nature.' Our country has, perhaps, produced most freely and utilized most fully; but the time has come when even the man of genius, whether in science or in industry, must, to make his talent effective, know what the world has acquired of learning, and must be trained usefully and effectively to apply that learning by means of the most perfect of all known apparatus and methods. That nation which fails thus to utilize its men of ability will inevitably fall behind, and its people taste of the bitter bread of poverty.

That state which most and best avails itself of the opportunity to establish institutions of higher learning for the promotion, particularly, of the industries, through education for their leading positions of those men of ability, who will invariably seek their opportunities, will find its investment a handsomely paying one. One such man recently saved to the state of New York a million dollars by a single scientific investigation, and every young man leaving the engineering school has his value doubled at the start, and often multiplied many times later, by the training thus provided by the state. The investment is one which pays the state better than any possible purely commercial one can, and the future is far more advantaged than the present and the public at large is profited many-fold by the ability, natural genius trained by scientific method, which is thus gained for its industrial system.

It is not sufficient, however, that the education offered shall be the best possible of its kind; it is essential for its full utilization, that it shall be given by those who are experts, each in his own branch, and, still further, that each of these experts shall be in constant and intimate touch with all the contemporary, and especially the local, industries of the state. Highest

efficiency can not be attained and most prosperous conditions reached by the state unless all the industries are closely and helpfully knit together, and unless every individual in each promotes to the best of his ability the work of each and every other. The state college or university has for its particular opportunity and its especial duty this promotion of the mutual helpfulness of the various departments of industry. Its representation at conventions, its provision of valuable information and its keeping the leaders in the industries well informed of the progress of science and of the arts in directions having interest and importance to them; its scientific researches and attempted discoveries, or its revelations of facts and phenomena having importance in the industries; its finding of the right men for special and important places in which peculiar talent and special training are needed; perhaps more than all, its introduction of new arts and industries and new methods of utilization of natural resources: each and all may advance the best interests of the state inconceivably, and all costs become insignificant in comparison with the benefits derived. This has been true in the past; it will be still more impressively true in the future. It is only the state, however, which can properly carry on this great work and do full justice to the people and to the opportunity.

As between the state and the state college, the obligation is mutual; the college, as the creature of the state, owes to the people composing the state its highest and best work, and always primarily in the interests of the mass of the people and the fundamental industries of the state. The state, on the other hand, owes a duty to the college and, through it, to the people, again: this is the maintenance of the college constantly at the highest possible state of efficiency and fruitfulness by providing it with men and material and suitable accommodations of every sort in such manner that no one member of the staff shall find his usefulness decreased by reason of deficient space, equipment or opportunity to do good work for the state and for the learner.

In meeting these mutual obligations, experience would seem to indicate that it is the state rather than the college which fails of either interest, ambition, earnestness or conscientious compliance with duty. It is oftenest the state which fails to see the opportunity to promote the best interests of the people and to take advantage of that opportunity.

In the hundred or more engineering schools of the United States are about fifteen thousand students, of whom about fifteen hundred pass out into business each year. The growth of these schools has been five hundred per cent. in the last generation, although comparatively few of the splendid private contributions to education of these years have been placed here, where most needed. A few large schools send out the greater part of these young engineers; one third sending out half and more.

A list of one thousand has been prepared for me, tabulated. The average period since 'graduation' is about seven years. Of these, so far as reported, one third are holding positions of independent responsibility; one eighth are managers and superintendents of works; ten per cent. are teaching in the professional schools, and twice or thrice as many are wanted. Ten per cent. are designing engineers, planning the machinery of the workshops, the manufacturing establishments, the railroads, and the fleets of the country. Several are editors; one fourth are manufacturers; many are presidents

and vice-presidents of corporations; others are treasurers, and the balance are distributed throughout the whole system of industries of the country. One half of these men are not above an average of 25 or 28 years of age, and ninety-five per cent. are not above 35 or 37. Practically all retain their connection with their profession. They commonly realize and fully appreciate their advantages, educationally.

One writes, for example, 'The great value of the training given me and especially by the college is brought home to me forcibly many times every day and I prize that training more than all the wealth of the land.'

The severe pruning out of men unsuited to the profession has given these professional schools of engineering the reputation of producing the best-trained of all professional men.

More perhaps than in any other profession is it true that the practitioner, to be successful—which means to be in highest degree useful to the state—must possess a peculiar mental and intellectual make-up. He must unite—at least this is coming to be true very generally if not universally—he must unite that strength of character which every leader must possess, with good sense, such as all men commanding the respect of their neighbors must exhibit, with integrity such as no man can advance without, with thorough professional education and training such as is always essential to professional success. It is further true that the intellectual training of the engineer, for example, furnishes as large opportunity and as great capacity for purely intellectual enjoyment as can possibly any ordinary purely 'cultural' education. Nevertheless, the preparation of the engineer for greatest fulness of life demands cultural study and an extent of learning far broader and deeper than the solely professional. He, like all other men, must for highest results make himself a liberally educated man and must attain wisdom as well as culture, learning as well as technical knowledge, if he is to meet men on a common and lofty ground. It is not enough that he shall make of himself a most efficient machine; he must make of himself a gentleman and a scholar as well as a professional.

The outlook for the young man going out into business of whatever sort from a course of study which has comprehended the elements of a good, sound, English education, college courses which have given him some familiarity with the contemporary literatures and access to the languages in which the thoughts of the masters in his field are immortalized and the practice of his art is exemplified, and from a technical training, a professional apprenticeship, which has built up for him foundations, firm and stable, upon which to raise the structure of his later professional career: the outlook for such a man, if himself well fitted by talent, character and experience to profit by his advantages and opportunities, is now more promising than ever before in the history of the world. The tremendous aggregations of industrial enterprises now coming into form can only be handled by men of more than ordinary capacity, wisdom and experience and only the complete union of the learning of the schools, the judgment gained by experience and the intimate knowledge of the business acquired by the practice of the profession or the vocation, all conspiring with perfect union of the science with the art, will hereafter give highest efficiency in positions of responsibility. The army of industry is now organized and must be officered. Its grades are coming to be as distinctly recognized and established as those of the military or the naval organization, and the

kind of man needed for each grade is as distinctly defined. Every competent man will gravitate to his place; for the head of the army and the chiefs of staff are eagerly looking for that rare and precious character for each position as vacated by the falling out of the incumbent of the moment by retirement or death.

Of the calls which I have received for such men from the 'captains of industry,' 45 per cent. are for positions worth $750 to $1,000, 15 per cent. at $1,200, 20 per cent. at $1,500, 15 per cent. at $2,000, 5 per cent. at $2,500, and in many cases from two to ten men are sought. The needs are greatest in the highest positions and where men capable of carrying large responsibility and having exceptional executive capacity find their place. One man who did not take his diploma for some years after a business call had withdrawn him from his earlier studies is now a vice-president of one of the largest corporations in the United States; another, only about ten years out of college, has become the president of several important corporations aggregating several millions in capital and as a whole extraordinarily profitable, mainly through his ability, good judgment and business efficiency.

One of the best gauges of the value of these men when well suited to their professions is found in the fact that, when these alumni of the engineering college are asked if they desire to change their present positions, they almost invariably reply that they are well satisfied. Asked at what salary a change would be considered, ten per cent. of these giving definite figures proposed $1,000, 30 per cent. $1,500, 30 per cent. $2,000, 10 per cent. $2,500, and 5 per cent. in each grade $4,000, $5,000 and $6,000. The ablest men in highest positions usually declined to consider a change of employers or of employment.

The young engineer, just from college, if he has profited by his opportunities usually gets on slowly at first and very rapidly later. The man who refused $1,500 a year to accept fifty cents a day, where his opportunities were greater for learning his business, now receives—six years out of college—$3,500; the usual figures are $60 to $75 a month when employed rather than taught in the great manufacturing organizations. Salaries a little later range from $1,000 to $3,000 and sometimes $5,000 and $6,000. The average asked by men willing to change their fields of work as reported a year or two ago was about $2,000 for men seven years out of college. One young man dropped out of college to secure an opportunity to become familiar with an important industry, the chance coming unexpectedly. He returned to take his degree, three or four years later, with a contract for four years, at $6,500 a year, in his pocket.

Many become inventors in their chosen fields and accumulate fortunes rapidly. Others enter great enterprises and build up the cotton manufactures of the south; direct the great departments of the electrical industries; revolutionize the methods of production of pig iron; produce a tool-steel capable of multiplying the work of machine tools; invent a steam-engine governor and take in royalties of thousands a month; systematize a gas industry, gaining a fortune while financially benefiting the stockholders and the gas-consuming public; multiply the rate of transmission of intelligence across the ocean, beneath or above its surface; utilize the electrical energies in light and power transmission by new methods; organize new systems and new industrial establishments. All who

thus contribute to the welfare of the people are very sure to secure a handsome commission and scores of these men of the new generation are thus helping others while helping themselves. The conduct of the industries of the country is constantly more and more falling into the hands of the systematically trained and technically learned man.

Young men, such as our best professional schools of engineering are now turning out, are greatly needed and the need is recognized by employers. The demand has been for some years past greater than the supply. A generation ago it was next to impossible to induce the average manager of an industrial establishment to admit the college man within his doors. To-day the same class of men is sought by all, and the larger and the more important the interests involved, the more anxious are the officers of the organization to find men trained in the professional school, combining science with practical knowledge, and prepared to face and to solve the tremendous problems now constantly arising. I have a deep file of letters calling for such men; there is practically none unemployed, unless on the sick-list. All the professional engineering schools are thus situated. Turning out a thousand or more annually, the whole output is absorbed by the great industries and immediately upon leaving the doors of the college. If suited to the profession, success is assured; otherwise, failure is just as certain.

The prizes to be won, like those in all other professions, are large; there is always room at the top; the earnings at first are usually small in cash, large in valuable experience; opportunities come in increasing number if the man is the right man for the higher place; more men are needed than can be found to take the higher positions of responsibility and of commensurate compensation. The wise young professional seeks opportunity for profitable experience without much regard to compensation. I have known a man to refuse a good salary and to accept fifty cents a day, where he saw an opportunity to secure practical experience and training such as, in his estimation, was what he most needed. His spirit was that of Agassiz, who, when asked why he refused an important and lucrative business position, is said to have replied: 'I can not afford to give my time to money-making.' Both had their rewards, each in his own way, in that form of professional success which was the highest ambition of each. Many young college men are to-day working for the great railroad companies, for the electrical companies and for industrial enterprises of all kinds, accepting insignificant pecuniary reward for the time, in order that, by securing that special experience and expert knowledge needed to supplement their special education, they may prepare themselves for positions of honor, of responsibility and of financial value. Here 'the last shall be first.'

It is of little consequence what line of work the young man enters, provided it be that for which he is individually well fitted by nature and training. In mechanical and electrical engineering, in shipbuilding and in the railway system, in mining or in public works, great opportunities are all the time, and more and more frequently, offering. It matters little what line the man selects, provided he is naturally fitted to do the work, by talent and by inclination, and that he acquires promptly the needed professional training and a later experience. If able and reliable and loyal to his employers, he is far more likely to be promoted faster than is desirable than to remain unrecognized in any important organization. His early years should be devoted to securing pro-

fessional knowledge and practical experience, efficiency in his business and ability to deal with other men. Opportunity, responsibility and financial returns will come later, once he reaches the age at which older men holding such positions begin to drop out. If suited to the work he will find his place.

Meantime, the work of the world is falling into the hands of these able, expert, experienced and efficient men of the new generation in rapidly increasing proportion, and the professionally trained engineer now finds himself wanted wherever learning, ability and experience are essential to the success of a great enterprise.

In this great work the student for whom all these sacrifices are made has his part, and his duty is quite as imperative in the utilization of these opportunities as is that of the state to provide them. His first privilege and duty is that of playing his part conscientiously and well. If unable to do the work well that is set before him he should retire to make place for a more competent candidate for opportunity; if found lacking in conscientiousness, he should be retired.

Stradivarius, whose violins to-day will fetch large sums, though they cost but little two centuries ago, in answer to a charge that he worked only for pelf, replied:

"Who draws a line and satisfies his soul,
Making it crooked where it should be straight?
An idiot with an oyster shell may draw
His lines along the sand, all wavering,
Fixing no point or pathway to a point,
An idiot one remove may choose his line,
Straggle and be content; but, God be praised,
Antonio Stradivari has an eye
That winces at false work and loves the true,
With hand and arm that play upon the tool,
As willingly as any singing bird
Sets him to sing his morning roundelay,
Because he likes to sing and likes the song."

The spirit of Stradivarius is that which underlies all success, and not only should the protégé of the state illustrate this spirit as justifying his adoption by the state; but he should understand that the interest and pride and ambition of Stradivarius are essentials of his own later advancement. Thoroughness in college work is no less essential and fundamental an element of success with the individual than is the success of the outgoing army of alumni vital to the progress of the country and the growth of the state in all that makes success for the people, or that makes life worth living for the dweller in their midst. Given this spirit of wholesome and cheerful ambition and the atmosphere which it engenders, and the world will be the better and the brighter each day.

Our own progress as a nation depends upon the wisdom and foresight, the patriotism and courage and persistence of our own educators and statesmen and industrial leaders. With wise statesmanship, our own nation may become the leader of the world and our country may always move onward in the van of modern progress. At the moment, what is most needed is the awakening of our legislative and executive officials to the duties and the opportunities of the times. It is the fossilized educator and the ignorant and unpatriotic politician, and the demagogue who aspires to lead 'labor,' and the educated man with his head in the clouds, who are the most serious obstacles to the progress of education, and to that of the nation toward higher and better things. These classes being either enlightened and purified, or extinguished, we may trust the American people to take full advantage of their opportunities and to hold a foremost place in the peaceful rivalry of the nations.

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