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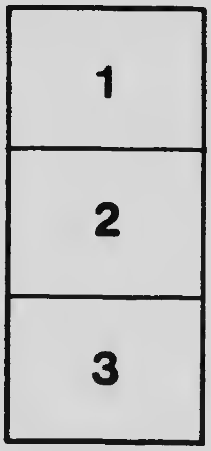

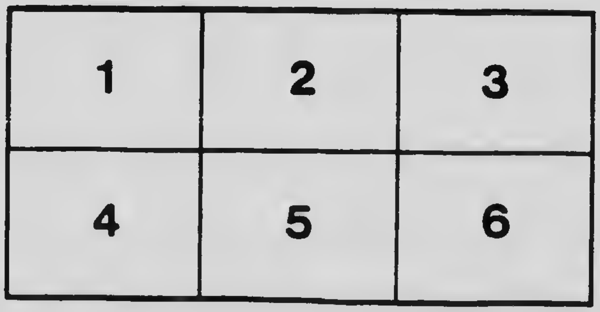

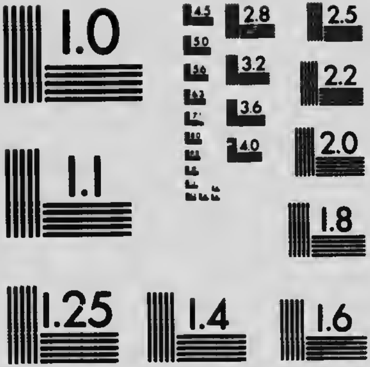

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THE FUNCTION OF THE SCHOOL OF APPLIED SCIENCE IN THE EDUCATION OF THE ENGINEER

BY

PRINCIPAL GALBRAITH

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The following is the text of Principal Galbraith's address at the banquet given in his honour December 21st, by the students and graduates of the School of Practical Science:—

1466.

The Function of the School of Applied Science in the Education of the Engineer.

Mr. Chairman and Gentlemen—

NO words of mine can do justice to the magnificent reception tendered me this evening by the graduates and students of the School of Practical Science. It falls to the lot of few to receive such an ovation and I know that you will forgive me if I fail to express in measured phrase, the feelings which overpower me.

In casting about for a theme on which to address you this evening it seemed to me that it would be appropriate to the occasion to give you my views on the subject of engineering education formed as they have been largely on my experience of the last twenty-one years in the School of Practical Science, and on my knowledge of the success of our graduates.

The fact that our course is in a measure unique, differing as it does in some important respects from the usual four years' course in the great universities of the continent, may add some interest to the subject.

When the school was remodelled and removed to its present site in 1878, by the late Hon. Adam Crooks, Minister of Education, the faculty consisted of the late Professor Croft Chairman, Professors Chapman, Loudon, Ramsay Wright, Dr. Ellis and myself. On Professor Croft's resignation he was succeeded in the Chair of Chemistry by Dr. Pike, and the late Sir Daniel Wilson President of University College, became the Chairman of the Board. Professor Baker was shortly afterwards added to the staff. In its early days the school could be considered only in the light of an experiment. It became evident that it ought to serve the necessities of the Province rather than those of the municipality like its predecessor the College of Technology. Each member of the board of 1878 gave the question of the function of the new school close study and earnest thought, and I hope that I am not making an invidious distinction in mentioning more particularly in this connection the services of President Loudon, who from the early seventies to the present time, has been a thoughtful and clear-sighted student of the various developments of technical education. About the year 1888, the present Premier, the Hon. G. W. Ross, then Minister of Education, recognized that the time had come for putting the School on a broader basis and for introducing the practical or laboratory method of teaching into all departments. To provide against the possibility of serious mistakes he decided to make a personal inspection of the more important institutions in the Eastern States engaged in the same class of work as the School of Practical Science, and arranged that I should accompany him. We visited Cornell, Lehigh, Columbia, the Stevens Institute and the Massachusetts Institute of Technology. As a result of that visit the present building was erected and equipped. The Department of Engineering was divided into Civil Engineering and Mechanical and Electrical Engineering and a Department of Architecture was added. Later on the Department of Mining Engineering was established and the Department of Analytical and Applied Chemistry remodelled. With the progress of time many additions and alterations have been made both in the equipment and in the methods and subject matter of the teaching.

When one considers the wonderful variety of work covered by the engineering and allied professions, it seems almost incredible that any useful field should be found for an institution professing to prepare candidates for them all. The construction of railways, canals and harbours, water and sewerage works; exploring, surveying and mapping, heating, plumbing and ventilation, architecture, the manufacture of engines and boilers, machine tools, dynamos, transformers, the erection of machine shops, factories and power houses, the transmission of power in all its forms, the sinking and operation of mines, the reduction and preparation of ores for the market, the manufacture of iron and steel, of colours, acids and alkalies, of sugar, paper and leather, etc.—such are the industries which absorb the graduates of the technical schools. It is plainly impossible within the short space of three or four years, and under academic conditions, to turn out an engineer, architect or chemist, fit for the full responsibilities of his profession.

On the other hand, experience shows that a school can furnish its students with such advantages in the race for success that it well becomes worth their while to spend time and money in acquiring them. The sciences underlying the professional work outlined above are few in number, and may be roughly classified under the heads of mathematics, physics, chemistry, geology and biology. Each of these sciences at the present day covers such an immense field that no one man can become familiar with all its parts. Their main principles, however, fortunately for the student, are few in number, and faithful study for three or four years will give him a sufficient grasp of them and of their applications to enable him to make practical use of them in his profession.

It may be said that the chief object of a school of applied science is to train its graduates in such a way that they are able to read. Man acquires his knowledge from two sources: his own experience and the experience of others. If he cannot absorb knowledge from books he is cut off in great measure from the experience of others, and is like a one-armed workman. At the present day a large amount of engineering literature consists of examples of the applications of science to practice, and as the years go on this kind of literature is ever augmenting in volume. It is only by the generalizing of experience into the principles of science that it is reduced to manageable compass; otherwise man would struggle helplessly with the ever increasing mass of accumulated facts, and an end come to human advancement.

While obtaining his knowledge of science in the school the student acquires skill of hand, eye and ear by work in the laboratory, drafting-room and field, and it is upon this skill that his chances of employment immediately after graduation largely depend. As he advances in his profession the mental training received in the school tells more and more upon his work, and the necessity for skill of hand gradually disappears.

The practical knowledge and training of the engineer can be acquired only when engaged on professional work, as they are dependent far more largely on his own experience than on the experience of others. Until this practical knowledge has been in some measure obtained the young engineer should be placed in subordinate positions, not entailing more responsibility than he is fit to bear.

By the practical knowledge of the engineer I do not mean the practical knowledge of the mechanic and tradesman, and yet they overlap to some extent. The civil engineer requires some knowledge of the trades of the excavator, the carpenter, the blacksmith, the mason, the concrete mixer, the stonecutter, the pipe-layer; the architect, of some of these, and also of the trades of the painter, the plumber, the glazier, the plasterer, the roofer, etc.; the mechanical engineer, of the trades of the pattern-maker, the moulder, the machinist, the boiler-maker, the pipe-fitter, the blacksmith, the tinsmith, etc., and so might be [illegible] the trades under the eye of the electrical engineer, the mining [illegible] the chemical engineer and the metallurgist.

The commonest weakness of the young engineer is insufficient knowledge of the trades, and this ignorance brings upon him, and properly so, the distrust and scorn of the practical man. No one—not even the practical man—will find fault with the engineer because he may not have the manual skill of the tradesman, but if he is deficient in the practical knowledge of the engineer, if he does not know when work is good and when it is bad, if he does not understand how it should be conducted, if he does not recognize the material he has specified when he sees it, if he is ignorant of the properties which affect its usefulness, the chances are that he will soon meet with disaster. This knowledge comes only from personal experience. Practical knowledge of the trades can be gained only on the works.

If the young graduate neglects to keep his eyes and ears open, and to make plentiful use of his note-book, if he does not absorb practical knowledge as a dry sponge absorbs water, he ought to go into some other profession; he will never become an engineer, even though he be a graduate of the School of Practical Science. The old saying is true

> "Books, gowns, degrees will leave a fool, a fool,
> But wit is best when wit has been to school."

The case is to some extent different when we consider practical knowledge of materials as distinguished from that of work. It seems to me that a very large amount of useful knowledge, and what is of even more importance, of useful training, can be given to the student during his course in the school in the experimental determination of the properties of materials. This is done, of course, to some extent already in the testing laboratories. The usefulness of these laboratories might be greatly increased by adding to them part of the equipment of the ordinary school shop, viz., vise-benches and forges, an emery wheel and a small crucible furnace, for the purpose of training the students in making easy tests of the various grades of iron, steel and alloys. The difference between such work and shop work is that the attention of the student is fixed upon the properties of the metal he is testing and not upon methods of using tools. He would thus gain in a short time the knowledge indispensable to the engineer of a great variety of metals, whereas in shop work, with the other object in view, his experience must be confined to but few.

I have little faith in the value of so-called commercial work in a school of applied science. It lacks the main element which, in real commercial work, burns lessons into the brain, viz., the feeling of responsibility. The practical work of the school should for the most part be of a kind for which there is little or no opportunity in ordinary professional life. It should consist in experimenting with machines and materials, and in discovering the application to them of the principles of science rather than in using them for their ordinary industrial purposes. The capitalist who employs the engineer does not care to see his money spent in this way. The life work of the engineer is construction and production. His practical work in the school should be analysis and experiment. The child breaks open his toy to see the wheels go round, long before he carves out a boat or constructs a windmill. The time of the school should not be unduly taken up in teaching the tyro what he is bound to learn in any case if he sticks to the profession. Although these principles seem sound, there are many prominent men who would in great measure disagree with them. Only a few days ago a letter by a well-known engineer appeared, who seemed to think that a graduate of an engineering school should be worth at the start a salary of $100 to $125 per month. I should consider the school which succeeded in such an undertaking to be little less than a failure. I once saw another letter in an engineering journal complaining of the technical schools because their graduates could not immediately make the quick and accurate analyses necessary in commercial metallurgical work. I prefer to see the student taught chemistry rather than spend his most receptive years in some narrow lines of analysis. There is time enough for that after he gets into the steel works. Readiness will come with practice. So with all specializing in the schools. It may be true that one cannot make a success in life unless he specializes. It by no means follows that the specializing must be done in the school. On the contrary, the best basis for successful specializing is a sound general training.

I do not care to see the graduate specialize immediately after leaving the school. Let him first get a little experience and a knowledge of the world and its ways. In many cases the graduate finds employment in a different branch of engineering from that in which he graduated. The lesson to the school is that the training in each department should be sufficiently general to enable the graduate to train himself without difficulty for his new work. His time for school is past.

One of the great advantages of a course of study in a school of science is that the mind of the student is almost unconsciously trained in the classification of facts. He cannot attend the various classes for three or four years without knowing to what departments or sub-departments of science the facts of observation are to be referred ; and even if he has forgotten how to apply the sciences, he knows at least where and how to get the information he requires without loss of time. His course in the school has supplied him with a great catalogue of knowledge. This is true in a measure even in the case of students who fail to complete the course.

Another function of the engineering school besides the training of students for the professions is the training of men for research work connected with engineering. There cannot, from the nature of the case, be employment in the country for many such men. In general they, like the majority of scientific workers, must earn their living as teachers.

There seems to be more doubt and difference of opinion with regard to the proper training of the mechanical and the electrical engineer than in the case of the civil engineer and the architect. To spend time working as a tradesman is not the custom of the latter professions, and in the former we find men with all degrees of workmen's experience from zero to the maximum amount.

The architect and the civil engineer are the lineal descendants of the craftsmen of the ancient civilizations of Egypt, Greece and Rome, while their mechanical brother is the product of this modern age of steam. It may be that the differentiation between the tradesman and the engineer has not occurred to the same extent in the latter case as in the former, simply on account of insufficient lapse of time. It may, however, proceed at a far quicker pace. Division of function or division of labour, as it is commonly termed, is the first necessity of this age of combinations of capital and labour. Roughly speaking, mechanical engineering, like all Gaul, is divided into three parts, of which one is occupied by the designing and consulting engineer, who in his functions most resembles the civil engineer and the architect, and who generally enters the profession by the drafting room door. Another part is occupied by the works manager in manufacturing establishments who corresponds in a measure to the contractor of the civil engineer and the architect, and who enters by the shop door. To the third part belongs the engineer in charge of engines and boilers, pumps and dynamos. He enters by the engine room door. Manual experience, as it may be called, is more or less necessary in the case of the last two classes, while it is not in the case of the first. On the other hand, the practical knowledge which can be gained only by familiarity with manufacturing operations and with the operation of power plants, is an absolute necessity for the three classes. This practical knowledge cannot be obtained in the engineering school.

In most engineering schools shops are established for the purpose of familiarizing the students with the use of tools and with practical processes. The expediency of taking up the time of the student with this work has always appeared to me to be questionable. The time spent in the shops is not long enough to make the student a finished workman, and consequently a judge of good work. As far as materials are concerned, a useful knowledge of them may be obtained as I have already indicated by methods much more economical of time. All that the engineer can get from the school shop that will be of use to him he is bound to get from his life work, whether he enters his profession through the drafting room or through the shop door. For these reasons I advised the Government in 1888 not to establish shop instruction in the School of Practical Science, and have as yet seen no reason to change my mind, although I have since that time examined the working of many school shops.

Our regulation that the students in mechanical and electrical engineering must put in their shop work outside has at least the advantage of saving the time of the session for what we consider more appropriate work. It also gives them a valuable opportunity for using their eyes and their note-books, and studying the methods of actual life.

The practical training of the mechanic, the foreman and the engineer in charge of small power plants must, it seems to me, continue to be obtained in the ordinary shops. For scientific instruction they must depend largely on the evening technical schools and on the correspondence schools. Young men who have the ambition to become managers of works and large power plants ought to make up their minds to attend the higher technical schools and also to go through the hard manual work necessary to enable them to become fairly competent mechanics. They will be fortunate if they have been brought up in the shops from boyhood and have at the same time acquired habits of study.

In this description of the aims and methods of a school of applied science for engineers I have had in view the practicable rather than the ideal. If it were possible within the limited time at the disposal of the student to give him a competent knowledge of the engineering trades, of engineering law, of engineering business methods and of engineering economics in addition to that of science no doubt it should be done, as he would then be so much further on when he begins his life work. It must not be forgotten, however, that the capacity of the student is limited as well as his time. The difference between one engineering school and another consists not in the total quantity of information carried away by the graduate, but rather in the distribution of his knowledge over the various subjects, theoretical and practical, and above all in the methods used for stimulating and strengthening the imagination and the powers of reasoning and observation.

Turning once more to our own institution I feel that its success is largely due to the harmony which has always existed between the members of the staff, and their loyalty to its ideals. The same spirit prevails among the students and graduates and it would be hard to find, the world over, a body of men more united and faithful to their *Alma Mater*. Above all, the School has been fortunate in commending itself to the public and to the Government. I do not know that there has ever been serious opposition in Parliament to its modest estimates for maintenance. The Premier, to whose foresight as Minister of Education the enlargement and improvement of the School is due, has no reason to be ashamed of his work. There is now a similar task to that which he undertook in 1888, awaiting his successor, the present Minister of Education. New building accommodation, equipment, and additions to the staff are required, as the School has reached and passed the bounds laid down for it twelve years ago.

It must not be forgotten that the success of our technical schools depends almost altogether upon the prosperity of the country and that the prosperity of the country depends only partially on the success of the technical schools. There is too great a tendency at the present time to consider technical education a panacea for the troubles in the world of production. This is not only unfair to the schools but is a dangerous doctrine for the country.

I shall now close by making an announcement which will be a source of congratulation to all friends of the School and of the University of Toronto. A week ago the Senate of the University passed a statute which provides that the School of Practical Science, its teaching staff, examiners and students, together with the examiners for the degrees in Applied Science and Engineering, shall *ex officio* constitute the Faculty of Applied Science of the University of Toronto. By this statute the powers of the Senate with reference to the degrees and those of the School with reference to the curriculum and work of instruction as also the statute respecting affiliation, remain unaltered.

The result is that the University gains without expense a fully equipped Faculty of Applied Science and in this respect puts itself on an equality with the other great universities of the continent: while on the other hand the School gains public recognition of the fact that its work is of equal rank and dignity with that of the ancient faculties of Arts, Medicine and Law.

This action of the Senate forms a fitting close to the history of the School in the nineteenth century. And now, gentlemen, let me in taking my seat thank you one and all for the great honour you have done me, and more especially the members of the committee who have this evening brought their arduous labours to such a successful close.

Professor Chapman was a better prophet than he knew when in designing the crest of the School he selected as its motto—

"Scite et Strenue."