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A PLEA FOR THE IMAGINATIVE ELEMENT IN TECHNICAL EDUCATION

There is strong reason for the belief held, with few exceptions, by our ablest university presidents that an institute of technology should be essentially a graduate school, in the same rank with schools of law and of medicine. For many years the best law schools have recruited their students from the graduates of colleges, and some of the leading medical schools have adopted the same principle. It has been felt that no amount of purely technical knowledge can replace the advantages of a broader culture and the better understanding of the affairs of the world which its possession implies. We need not pause to discuss here the relative educational value of science and the humanities, though this subject is touched upon in a later paragraph. Such weighing of one subject against another is not now relevant: we are concerned merely with the fact that students who have spent time enough to acquire a large amount of information of broad range are certain to have the advantage of those who have spent less time in acquiring less information of narrow range.

It is probable that the average member of a technological school is in more danger of a narrow outlook than any other class of students. In a large percentage of cases he has rejoiced from boyhood in a mechanical turn of mind, which has concentrated his attention on engines and machinery and the splendid achievements of modern engineering. Happy is the boy whose career is thus plainly foreshadowed. For him life is sure to be worth living, and the dangers of idleness may be ignored. But this very interest, in direct proportion to its intensity, is almost certain to lead to a neglect of other opportunities. The absorbing beauties of machine construction and design so completely occupy the boy's mind that they hinder a view of the greater world. He cannot be expected to perceive that a knowledge of the details of his chosen profession should not suffice to satisfy his ambition. He does not yet know that to become a great engineer he should cultivate not merely his acquaintance with the details of construction, but in no less degree his breadth of view and the highest powers of his imagination.

The greatest advances, whether in engineering, in pure science, in art, or in any other field, arise as mental pictures, at first uncertain as to details, but subsequently clear and distinct, requiring only an application of text-book methods to give them tangible form. It is in the conception of the picture, and not simply in the execution of the project it embodies, that the truly great engineer must excel. The mere dreamer never succeeds in bringing the confused and nebulous image to a sharp and definite focus. Lacking a substantial basis of knowledge, or otherwise failing to possess those subtle qualities which the realization of a splendid dream implies, he never gives walls or foundations to his castles in Spain. But practical ability to execute the design can never replace the design itself. The picture must be conceived and made visible to others before the work of construction can begin. Once the design has been transferred to paper and its fundamental principles made clear, an army of artisans, possessed of the skill required for its execution, can easily be found. It should be the purpose of the Institute to contribute to the world the largest possible proportion of men capable of conceiving great projects and the smallest possible proportion of men whose ambition can be completely satisfied by the work of executing them; and the means adopted to accomplish this end should be such as to improve the work of every graduate, including those who may be unfitted by nature for the greater tasks to which I have referred.

Perhaps it should be remarked at this point that what is ordinarily called invention, as applying particularly to machinery, is not alone considered here. A great engineer is not necessarily a great inventor, in this limited sense of the word. He may depend upon others to furnish the materials, whether perfected machinery or the simple brick or stone, copper or glass, with which he builds. It is for him to group them in such a way as to accomplish an advance, by securing greater economy in the industrial arts, by raising an architectural structure that shall benefit every occupant or casual observer, by facilitating transportation to such a degree as to revolutionize the conditions of daily life.

It would thus seem to be evident that a technological school can by no means afford to underestimate the need of broadening the view and cultivating the imagination of its students. What agencies, we may then ask, would best contribute to this end? It goes without saying that technical education must be the principal work of the school. Is it possible, in view of the heavy demands brought about by the rapid development of engineering, to give all necessary instruction in technical subjects, and also to extend the student's outlook upon the world and to develop his imaginative power?

I believe that three means contributing toward the accomplishment of this result should be considered:—

1. As a probable development of the future, the requirement of at least two years of general college work for entrance.

2. As a partial alternative under existing conditions, the allotment of as much time as can be spared to general studies in the Institute's curriculum, and the creation of new opportunities, outside of the regular work, for developing the social and cultural sides of the student.

3. As essential needs under all circumstances:

(*a*) Insistence upon the paramount importance of fundamental principles, as distinguished from specific facts and technical details.

(*b*) The fullest possible recognition and use of the educational value of science, both in its cultural aspects and in the means it affords of developing the reasoning powers and the constructive imagination.

Let us consider these points in the above order:—

1. It may be taken for granted that the progress of engineering will cause more and more difficulty in providing suitable technical instruction in a four years' course. Although I believe this difficulty can be partly met by giving less time to the mere acquirement of knowledge and more to practice in the solution of new problems, it is evidently no simple matter to reconstruct the curriculum on this basis. The development of the turbine engine, for example, must be recognized in the course of instruction. Its adequate treatment, however, demands time, which can be had only by eliminating other instruction. So with the theory of alternating current machinery, the phenomena of radioactivity, and many other subjects of recent development. All must find place in the curriculum, which accordingly becomes more and more difficult and condensed. The increasing entrance requirements tend to shift the more elemen-

tary mathematical courses from the Institute to the preparatory school, and the same may be said of other subjects. The inevitable tendency is, therefore, for the purely technical courses to crowd out other work. At Sibley College this process has eliminated even modern languages from the curriculum. At the Institute political economy, English literature and composition, history, modern languages, and business law are retained, and successful efforts have been made to provide for much general reading through the adoption of requirements for summer work.

It may be expected, then, that the future will see the best of the technological schools requiring part, at least, of an ordinary college course for entrance. Such a result is earnestly to be desired, in view of the better and broader education rendered possible by such means. The technological schools may then devote themselves to professional studies, though pure science should always play a very important part in their work, and every effort should be made to realize and develop the more truly educational possibilities of the instruction. The rapid increase in the number of college graduates at the Institute, and the establishment of a three years' course for them, leading to an M.S. degree, are significant signs of the times.

2. We are told, however, that the average student is not in a position to spend six or eight years, after leaving the preparatory school, in obtaining an education. Without attempting to question the truth of this assertion, the analogous case of the medical schools seems to indicate that room might now be found for one or two technological schools requiring two years of college work for entrance. Nevertheless, I do not favor the immediate adoption of such a policy by the Institute. Further experience will show whether so radical a departure is essential. For the present

we may consider the ordinary course limited to four years, and inquire whether it is possible to improve it in any considerable degree.

It may be hoped that the successful efforts made by the Faculty to retain a considerable number of general studies will be followed by an attempt to extend the scope of this work. The Institute graduate is in no less need than the Harvard graduate of a knowledge of history, literature, language, and art. The fact that the one may engage in engineering, while the other devotes himself to some other business, should draw no line of distinction between them. The engineer should know the accomplishments, the thoughts, and the ways of the world no less thoroughly than they are known by the broker, the banker, or the dealer in real estate. His work, as we have said, is not confined to the application of certain formulæ to the solution of engineering problems. It occupies, or should occupy, a broader field, in which an understanding of the impelling motives and the probable actions, under given conditions, of other men is one of the first essentials of success.

The time will inevitably come when the mass of engineering knowledge which must be taught in some form in a four years' course will be double or treble what it is to-day. What can be done then? Will it not be possible, through the elimination of the less important details and greater concentration of attention on fundamental principles, to overcome the difficulty? If so, it seems reasonable to suppose that something of the sort could be accomplished now, leaving time for the inclusion of more general studies in the curriculum and for more practice in the solution of problems new to the student, by which his creative and reasoning faculties would be developed.

3. The saving of time should not be the only result of

such reconstruction. There is reason to believe that the average student, at the present day, may often fail "to see the wood for the trees." His mind is not able to distinguish with sufficient clearness between fact and principle. A fact may be capable of attractive and forcible illustration, easily appealing to the mind. It may perhaps afford a most striking example of a general law, but the uninviting aspect of the latter, when reduced to a formula, may repel rather than attract. The law is soon forgotten, while the illustration of its application to a particular case is kept in mind.

But how, it may be asked, are we to escape the difficulty into which we have fallen? It is held, on the one hand, that double advantage may result from even greater attention than is now given to fundamental principles. It is admitted, on the other, that such principles must, in the nature of things, be taught and rendered attractive through just such illustrations as are now so effectively employed. Standing between the horns of this dilemma, we can only appeal for assistance to those who have demonstrated their ability in building up the Institute courses. In asking of them whether the last word has been said on this subject, we may confidently expect a negative reply, for the frequent revision to which the courses are subjected demonstrates a determination to keep abreast of the times. It may be hoped that this reference to the question will not be taken as a trivial attempt at criticism, since in their review of the year's work the members of the Faculty would probably have in mind the query here proposed.

It is undoubtedly true that no amount of general study and no method of teaching science can replace the advantages of personal experience. On the other hand, it must be admitted that, by adopting the best means to acquaint the student with the broader aspects of science, results may be accomplished which might otherwise be long delayed. The catalogue of the Institute rightly states, in opening its discussion of the courses of instruction, that the "fundamental elements in the curriculum of the school are mathematics, chemistry, and physics." It adds, further, "Instruction in technical methods is subordinated to the question of principles, and these principles are studied with the predominant purpose of exercising the powers and training the faculties." It would be difficult to prepare a more admirable statement of the purposes of the school, and this may seem to render any recommendations in this direction superfluous. As in the case of general studies, however, where these remarks may do no more than second the efforts already made by the Faculty, I may be permitted to emphasize the importance of extending the application of a principle already recognized and of adopting any practicable means of widening the outlook of the student.

In remarking upon the desirability of cultivating the scientific imagination and of developing that breadth of view which is most effectively acquired through reflection and experience, I have had in mind the fact that the most fertile and inspiring of all scientific theories has never, it would appear, received adequate recognition in the curriculum of educational institutions. I refer to the theory of evolution which, when rightly appreciated in its broadest scope, is perhaps better competent to awaken the imaginative powers and to develop an understanding of the greatest aims of science than any other single conception. Many institutions, the Institute among them, give a limited number of undergraduates courses involving the study of evolution in one or more of its innumerable phases. The opportunity remains, however, to present a general course of lectures dealing with evolution as applied to the various branches of science, and to require that it be attended by all students. Such a course, if accompanied by collateral reading and illustrated by a small museum of carefully selected objects, would do more, in my opinion, to accomplish the purpose in mind than any other single agency.

The natural tendency of the student, from which few escape, is to regard science as partitioned off into compartments, each more or less sufficient unto itself. Every effort should be made to break down this tendency, in order that it may become clear that science should be considered as a whole, particularly if its fullest educational value is to be realized. The theory of evolution, on account of its endless range and its importance in almost every branch of science, may serve as the best means of illustrating the arbitrary nature of the boundary lines that have been drawn. Even in the conception of evolution itself there is a natural but undesirable inclination to distinguish, for example, between organic and inorganic evolution, and to confine general courses of lectures to one or the other branch. What the student needs, if this view of the subject be correct, is some such picture of the general operation of the evolutional principle as Spencer has outlined, but so modified as to deal with the advances of recent years, and illustrated by the best and most striking examples that can be brought together.

Such a course of lectures should be arranged on a chronological basis, and would therefore open with a popular account of recent investigations on the origin and development of the heavenly bodies. The remarkable results of recent astronomical photography afford the richest of illustrative material for such lectures as these. Nothing could be more suggestive than the magnificent whirlpools of the great spiral nebulæ, which are now considered as the source from which solar and stellar systems are developed. After seeing for himself the forms of these star sources, the student would listen with interest to an account of Laplace's nebular hypothesis and the more recent views which promise to supersede it. Then would follow a description of the sun as a typical star, and a sketch of stellar growth and development based upon modern inquiries. Here the intimate relationship between this field of astronomical research and the laboratory studies of the physicist and chemist would become apparent. For it is possible to solve physical and chemical problems through observations of the stars, as well as to solve solar and stellar problems through experiments in the laboratory. It would be easy, therefore, to introduce at this point such a sketch of modern physical and chemical conceptions as would bring home to the student the fundamental character of these branches of science, their relationship to other branches, and their remarkable development in recent years.

The transition to the next phase of the evolutional subject would be so natural as to be imperceptible. The formation and development of the earth and of its surface phenomena, which it is the function of the geophysicist and the geologist to study, involve another application of physical and chemical principles. At the present time the processes by which the rocks of the earth's crust were formed are being imitated in the laboratory, just as solar and stellar conditions are being reproduced, in minor degree, by laboratory experiments designed for the interpretation of astronomical observations. The picture of geological phenomena would be no less striking. What better mode of developing the scientific imagination could be found than that afforded by the conception of the early history of the earth? The rise and fall of mountains and continents; the changing area of the sea and the story of sedimentary deposits revealed in the stratified rocks;