Engineering Education*

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I am going to ask your attention to some thoughts of mine which seem to centre pretty well about the topic—The proper scope of engineering education: in particular, the proper scope of electrical engineering education. All education, or certainly such branches as are at all familiar to any of us here present, may be broadly divided into two sorts; general education and professional education.

General education includes two sorts of subjects, these are:

(a) Those which are studies for the requirements of every day life, but without any especial object in view. Included in this class will be subjects like arithmetic, reading, writing.

(b) Those which are studied for the sake of the culture which they give to the persons who pursue them. In this class belong literature, history, language, and related subjects; in some cases mathematics and science are culture subjects.

Professional education is distinctly different. It includes subjects, a knowledge of which is essential to the carrying out of the duties of a given profession. It includes not only subjects which present the practice of a profession, but those which set forth the principles and theory underlying the practice; those which form the foundation stones upon which the professional career is to be built.

Engineering education is of this latter sort. Part of it is obtained in technical schools, or universities. Another part can only be obtained in that school everyone of us still attends—the school of experience.

Narrowing our thought to include for the most part the professional knowledge which is found in books, and which is best obtained under instruction, it needs no demonstra-

tion that in the earlier part there must be included such fundamental subjects as mathematics, physics, chemistry, etc. That the various branches known as engineering subjects must be included, goes without saying; a considerable amount of time being spent upon expositions of *why* things in nature are as they are—the laws of the subject—the theory if you choose, always illuminating this carefully with practice. And the scope must be such that in later life supplementary and advanced study *alone* is necessary to give an engineer the proper grasp of a subject he needs in order to solve any problems which present themselves. The work done on subjects which are the fundamentals of engineering knowledge must be so well and completely done that the superstructure, no matter just what its character, can be reared successfully without need of consideration for the foundations. They must have been laid strong and wide and secure.

And just here let me call attention to the fact that I am speaking of an education for an engineer. I therefore have no thought of trade school courses, elementary technical courses, and the like; which, if given with honesty of purpose, are only intended to fit men for the less important positions in the wide field of engineering applications, (those in manufacturing, operating, and the like).

What I have so far said would probably be said by anyone connected with engineering education. But how far shall the education go? How comprehensive shall it be made? There is no school where engineering is taught but it would be easy to lengthen the course and make it extend over more time. There is no one who comes to the end of his course, but he feels, if he understands at all what engineering is, that his professional education has not more than just begun.

Before a man starts on an engineering education, he has decided what

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he proposes to make of his life; not only has he considered what his inclinations and abilities are, but what sort of career he may expect. Hence the expenditure of time and money upon a course of study (in many cases this means not only a direct expenditure of money, but a sacrifice of earning capacity as well), is an investment which is made, as is any investment in any business venture, with a view to the returns which are to be expected.

Now depending upon his age, his position in life, and his earning capacity, there is a time for each man when any gain he is making in education is over-balanced by the cost of it to him; and so the time has come when he ought to stop paying tuition, and under an entirely different environment, partly in the school of experience and partly by reading and study alone or in some special way, continue his education.

In making this statement it will be clear that certain things have not been taken into account. A student cannot stop a course at some particular point of its length, for example, three quarters the way through and realize three quarters of the benefit of what the course had in it for him. Nor can he select such subjects as he pleases to put into the three quarters that he takes, for reasons obvious to anyone who has had experience in educational matters. I believe that a man who enters a given course of study ought by all means to follow it through and graduate from it. But in order to give some support to the opinions I have expressed, I want to ask you to listen to some ideas in reference to the arrangement of an engineering course.

I do not believe there is one standard plan, requiring a fixed number of years to accomplish the amount of education which properly belongs in an engineering course. I have stated earlier in this paper that it is vitally important to have the foundations properly laid. But it is possible, on the

other hand, so to arrange things in a long course, that at the end of any given period, a definite kind and scope of engineering study has been accomplished. I mean to contrast this with the plan, too often found in engineering, as in other professional courses, where everything is planned to be preparatory to, or to lead up to, the final year of work.

By a suitable arrangement of subjects of instruction, such as I have suggested, even the man who is stopped in a course because of inadequate mental endowment to pursue it further, leaves the institution where he has been under instruction with an equipment of engineering knowledge complete in itself, so far as it goes, even if he never attempt on his own account to extend it further. Somehow, in my experience, I find many men who have fine engineering qualities—particularly in the direction of being able to do things and do them well—who have tremendous difficulty in mastering higher mathematics and pure science; subjects usually placed early in their courses. Failure to pass them often forces them out before real engineering education has been begun.

Hence, I am in favor of an arrangement of subjects which does not follow "standard" lines. Some subjects must take precedence of others, but physics and trigonometry can be studied together; physics need not be completed before engineering subjects are begun; analytical geometry can be rather better taught with calculus than preceding it; mechanics of materials and alternating currents can be taught side by side with the study of calculus; and all these things can be done without the sacrifice of any valuable principles in any of the subjects. In fact, the close association of subjects like those just mentioned is of great advantage. Students are thus enabled to see the application of what seems like an abstract principle even while studying it. How many of us would have been delighted to know,

when we were being introduced to such symbolism as $\frac{dx}{dy}$ or $\int_a^b y dx$ that

these things embodied ideas of vital consequence in many lines of engineering. How much our interest would have been awakened in subjects we thought were abstract and uninteresting, but which we had to wade through because they were in the course, if their intimate relation to other subjects in which we *had* a lively interest could at the time have been made plain to us. According to the method I am setting forth, even if at times mathematical knowledge lags behind the requirement of another subject, it seems to me that in all engineering work a physical conception of phenomena is far more important than a mathematical conception. Thus in an alternating current circuit it is much better to know that the electromotive force of inductance lags behind the current there flowing by one-quarter period, as a simple and direct consequence of Lenz' law of electromagnetic induction, than to base this wholly on the differentiation with respect to time of the instantaneous value of the current expressed as a sine curve in a mathematical equation. The first method makes it real; helps it to live in a student's thought and memory. The other invariably seems abstract. Both together are properly supplementary and it is best, of course, to understand both.

Once more, a few words in reference to the subjects which are properly included in an engineering course—one of professional study. Culture work is not properly included in it. The study of foreign languages is wholly a culture study. Some foreign language used to be thought necessary as a means of looking up engineering information. There never was a time when there was as little need for a knowledge of foreign language with this in view, as at the present time. No one, even if he devotes a large part

of his time to it, can keep up with the literature and periodical information in his *own* language; not even in a single narrow line of engineering. English language and literature study is being eliminated from many college courses in engineering; a sort of culture work far more important, it seems to me, than the other. But there is another sort of culture study harder to eliminate from engineering courses. The subjects of mathematics, chemistry, physics, and even drawing, can be and often are taught as culture subjects. The higher mathematics, if taught by a mathematician, becomes largely a sort of mental gymnastics; valuable no doubt for mental culture, but to most students a subject apart from, and having little connection with, the engineering studies in which it is made use of. In the hands of an engineer, mathematics is a means to an end; a tool to be used as a means of digging out solutions to practical problems. To a mathematician, mathematics is not practical and should not be considered except as an abstract subject of knowledge. Physics, whose relation to engineering is so vital that the man who cannot compass its principles is unlikely to gain any real understanding of engineering problems, can easily be made a pure science subject, so pure that its connection with engineering becomes almost, if not wholly, lost. Drawing may partake so much of art, that those vital purposes on account of which it is made a necessary part of an engineering education would never be revealed.

And yet there is a culture which, it seems to me, ought to be made an important part of an engineering course. Engineering has a history and a literature of its own to which every student should gradually, in the course of his study, be introduced, and with which he ought to come to feel very well acquainted. There are many lives of engineers which are as much an inspiration to high ideals, to honest working, to benefit their fellow men,

as any to be found in literature. There are many achievements in engineering, a knowledge of which is as much a matter of culture as anything to be learned from a history of nations, especially if the latter includes the study of conquest and of political intrigue.

Last, of all, a word in reference to the scope of electrical engineering education. Electrical engineering education is an outgrowth from physics and mechanical engineering. All of us can remember how, fifteen years ago, it was often said that electrical engineering was nine-tenths mechanical engineering and one tenth Ohm's law. That time has long passed. An electrical engineering course must indeed include mechanical engineering subjects as surely as does a civil engineering course; but it is not hard to find courses where thermodynamics and steam engine occupy as important a place as electrical subjects. There are a large number of positions in electrical engineering, probably a majority of places, where no knowledge of steam is required at all; where the knowledge of thermodynamics and heat in physics and in electrical study more than covers all requirements. I believe thoroughly in a strictly and distinctively electrical course for electrical engineers. And above all, I believe in having all the subjects of a course in engineering taught by engineers who are working together to one common end.

A Summer in the General Electric Test*

To start at the beginning of things, it was one morning in June this last summer when I first formally reported at the General Electric works in Schenectady. First impressions were not as marked in my case as in most cases, because two weeks before I had visited the works while on the annual inspection trip of the senior electricians.

In the waiting room I met several of the college graduates about to start in. After having been presented to the electrical superintendent, Mr. Rohrer, we were sent down to one of his assistants for final instructions. As we were seated in the last mentioned office, awaiting our turn, the thing which occupied our attention most was a Red Cross case, which suggested accidents to come. This thought was more forcibly brought to mind by the assistant asking, among other things, our religion. I do not know the true reason for asking that question, but the only one that has been suggested is, to know what kind of a divine to call in case of serious accident.

The questions through with, we were then assigned to places in the machine shops. This was rather unexpected, for hitherto college graduates had been placed in the testing department immediately. Some of the men were placed on purely mechanical work, such as helping on large boring-mills, on drill-presses, lathes, etc. Others were placed in the commutator department, with the winders of induction motors and also direct-current motors, with assemblers of regulators, transformers, motors, etc. I chanced to be among those assigned to induction motor assembling.

As I have said, we were the first set of college graduates to be placed in the machine shops, and undoubtedly many changes in methods of placing and shifting men have since been inaugurated which will serve to give the man starting in a more comprehensive idea of the manufacture of a machine from start to finish. However, as it was, most of the men heartily endorsed this scheme of a month or two of preliminary machine-shop work.

In my own case, the work was interesting, involving as it did the assembling of field-spiders, armatures, shields, bearings, oil-rings, oil-gauges, etc., of induction motors ranging from five horse power to five hundred horse

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