

a body of ideas and conceptions which operates for perception, and (b) a mathematical structure, which, in many cases, but by no means in all, supervenes and leads easily to an elaborate conclusion. These two complexes do indeed constitute a new engine which helps the mind as tools help the hand, and if the first (the perceptive phase of physical science) were insisted upon in our technical schools with approximately the same emphasis as pure mathematics, our students would not be so ridiculously perverted by mathematical superventions as to calculate that a two-horse-power steam engine would be required to drive a *willing* mule. But such is the earlier stage of technical education as it is to-day!

PHYSICS TEACHING AT FAULT

The fault, however, seems to me not to lie to any great extent with our teachers of mathematics. Their mode of presenting their subject is, I believe, in a general way correct, but I am firmly convinced that our mathematical courses at present include a great many topics which might well be omitted, and a thorough drill in descriptive geometry should certainly be included. I believe that too much time is devoted to the study of pure mathematics in our technical schools and too little time to the study of elementary physics and chemistry. It is certainly a fact, however, that a large number of our college and university teachers of physics are anything but enthusiastic as teachers, and the subject matter which they place before their students is certainly not up to the requirements of modern technical education. A real fault, as it seems to me, may be charged against our teachers of physics.

In the discussion of engineering education before the American Institute of Electrical Engineers on January 24, 1908, a great deal was said concerning the place of mathematics in technical education; and the exacting character of technical education, which is associated in most men's minds with the teaching of mathematics, was emphasized as important. In the old days mathematics was indeed the only scientific study which could be made

definite and exacting. Nowadays, however, nearly every technical subject which is taught in the engineering school can be made as exacting as mathematics and, above all, the elementary sciences of physics and chemistry have been reduced to a basis which enables these sciences to be presented in a way which, in my opinion, must soon entirely revolutionize technical education. I believe that our engineers and many of our engineering professors fail to realize the change which has taken place in the teaching possibilities of elementary physics in the last ten or fifteen years, and therefore we find these men still expecting our teachers of mathematics to lift themselves and a large superstructure by pulling on their boot straps, these faithful teachers being held responsible for the most serious faults which underlie technical education. Let the heads of our technical schools look rather to their teachers of physics, demanding of them the best that modern science teaching can give, and allowing them the necessary time to accomplish what is desired.

ELEMENTARY PHYSICS TEACHING NECESSARY

I do not think we can look to our teachers of mathematics to establish the simple logical structure of physical science.

Nothing is more completely established in psychology nowadays than that ideas can not be formed out of the clear sky, as it were. They must be built of stuff, and *the rational study of the physical sciences especially in its earlier stages is the transformation of simple intimate knowledge into general ideas*. All elemental knowledge, such as the knowing how to throw a ball, how to ride a bicycle, how to swim, or how to use a tool, is locked in the marginal region of the mind (the region of reflexes) as a very substantial but very highly specialized kind of intuition, and the problem of the teaching of elementary physical science is the problem of how, by verbal and concrete suggestion, to drag this material into the field of consciousness, where it may be transformed into a generalized logical structure having traffic relations with every department of the mind. *An abstract treatment of the principles of elementary physics tends, more than anything else, to inhibit the influx of this elemental knowledge from the marginal regions into the field of consciousness and results in the building up of a*