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*

theoretical structure which can have no effectual traffic with any mental field beyond its own narrow boundaries. Such a state of mind is nothing but a kind of idiocy, and to call it a knowledge of elementary science is weak scholasticism. . . . A large part of simple theoretical physics is constructed out of sensuous elements which are not habitually and fixedly associated with verbal forms of expression, and it is impossible to marshal these elements in any other way than by direct appeal, by sight of feeling, to the actual things which correspond to them.[1]

The equipment and methods of the physical laboratory are a necessity in the teaching of elementary physics. The point of view of many of those who are responsible for the arrangement of our technical courses is more or less confused in regard to elementary science instruction and it may be accurately characterized by a slight variation of a statement of Bacon's:

> Natural philosophy [in their minds] is not to be found unadulterated, but it is impure and corrupted by mathematics which ought rather to terminate natural philosophy than to generate or create it.

I have heard that near Nancratis, in Egypt, there was born one of the old gods, the one to whom the bird is sacred which they call the ibis; and this god's name was Teuth. And this god, or demigod, found out first, they say, arithmetic, and geometry, and logic, and gambling, and the art of writing. And there was then a king over all Egypt, in the great city which the Greeks called Thebes. And Teuth, going to Thebes, showed the king all the arts he had invented, and said they should be taught to the Egyptians. But the king said: "What is the good of them?" And Teuth telling him at length of each, the king blamed some things and praised others. But when they came to writing: "Now, this piece of learning, O king," says Teuth, "will make the Egyptians more wise and more remembering; for this is physic for the memory and for wisdom." But the king answered: "O most artful Teuth, it is one sort of person's business to invent arts, and quite another sort of person's business to know what mischief or good is in them. And you, the father of letters, are yet so simple-minded that you fancy their power just the contrary of what it really is; for this art of writing will bring forgetfulness into the souls of those who learn it, because, trusting to the external power of the *scripture* and *stamp* of other men's minds, and not themselves putting themselves in mind, within themselves; it is not medicine of divine memory, but a drug of memorandum that you have discovered, and you will only give the reputation and semblance of wisdom, not the truth of wisdom to the learners: for[2] becoming hearers of many things, yet without instruction, they will seem to have manifold opinions, but be in truth without any opinions; and the most of them incapable of living together in any good understanding; having become seeming-wise instead of wise."

I always think of this prognostication of the old Egyptian king concerning the influence of letters when I consider what may be the true path through the tremendously widened and at present greatly confused field of human endeavor which has come with the discovery of physical science. We are now, in regard to science, in the midst of something like the pandemonium which was imagined by Socrates as a possibility in the field of letters. We have, indeed, become hearers of many, many things, and we seem to have manifold opinions; and, although I believe we are not really without opinions, I certainly do believe that many of us do not take sufficient pains to make ourselves understood when we attempt to express what opinions we may truly have. (It may be justly said, I think, that the voluminous discussion of technical education which has taken place during recent years, especially that which has taken place before our engineering societies, is but slightly edifying.) Nor do I believe that we are *incapable* of living together in any good understanding. As to being seeming-wise instead of wise, we should in all humility admit that wisdom is a

[1] From a paper on "The Study of Science by Young People," by W. S. Franklin, *Proceedings of the Twelfth Annual Meeting of the New York State Science Teachers' Association*, pp. 65–94.

[2] This powerful story of the mythical discoverer of writing was quoted thirty-five years ago by a very severe writer, who inserted the following parenthesis at this point "now *do* listen to this, you cheap education mongers." I believe, however, that technical educators are as far removed as any from the cheap type, except only the one who knows of no other kind of precision but the precision of numbers.

truly wonderful state, not presuming to have reached it in its perfection.

But let me return to the question of the perceptive phase of the physical sciences. A splendid example of almost pure perception is the recent work of Rutherford and others on radio-activity which is based on what would seem to be an absurdly slender group of observable effects. No one can overestimate the power of men who do such work as this. My chief business, however, is the *teaching* of physics; as a teacher I am concerned with average men; and every year I am more and more amazed to see the feebleness with which men hold things in the mind, and more and more impressed with the tremendous power with which men hold things in the hand, a power which, as Plato says, encompasses with eternal security an ancient polity and ancient divisions of rank founded on possession, but which also, alas! as Ruskin says, too often takes the name of Christ in vain and leagues itself with his chief enemy covetousness, which is idolatry.

W. S. Franklin

What can be done to enhance the value of the work of the Bureau of Standards to the chemical industries?

The greater part of the scientific work done in the United States is accomplished through two agencies, the universities and technical schools on one hand and the bureaus of the government on the other. As regards the latter, the principle that the government should undertake, in the main, only such work as can not efficiently be handled by unofficial enterprise, is generally accepted as sound and has, with some exceptions, been adopted as a policy by the bureaus. It must be admitted that it would not be well to draw such a distinction, or any distinction, too sharply or rigidly. To attempt this would certainly impair the usefulness of the work of the governmental departments. But, broadly speaking, it is not impracticable to avoid needless competition with scientific research carried on by other instrumentalities.

It is an indubitable fact that some lines of scientific research lie farther away from practical applications than do others. Those can be and are well cared for by educational institutions. On the other hand, experience has shown that scientific investigations which bear more directly upon the industries can not be so satisfactorily undertaken without government aid and are more or less seriously neglected when left wholly to private enterprize. Such technical researches are by their nature (costliness, necessity of continuity, direct bearing on legislation, etc.) appropriate subjects for governmental treatment. The success and value of the official work of the United States authorities on road building, on the testing of materials of construction and of foods and drugs, and on standards of measurement, are approved and appreciated alike by scientific men and by the general public, and scarcely require special emphasis here.

It is fortunate that popular recognition is accorded to this branch of governmental work, not only in a liberal degree, but also in a way that harmonizes with the principle enunciated above. So long as the bureaus concentrate their labors on the solution of problems of practical interest, so long will they enjoy the approval and support of the public. Just in the measure that they allow themselves to be diverted to the study of scientific questions lying far afield from practical industrial applications, will the public interest cool and the necessary appropriations become increasingly more difficult to obtain, and this quite apart from the intrinsic interest or importance of the work done. As an example of the sort of scientific questions referred to, determinations of the atomic weights of the elements may be cited as typical. If the considerations advanced here have any validity, such determinations had better be left for other institutions and remain untouched by the government. We are free to admire the excellence of the work as much as we like, and to extoll its importance, and we may still without inconsistency take the stand that such work is not within the proper scope of governmental departments, because, (1) it can be and is well taken care of by other agencies, (2) it is not of direct industrial or so-called "practical" application, (3) it is not calculated to com-