# THE TEACHING OF SCIENCE

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# PREFACE

The addresses and papers collected in this volume were written for special occasions and delivered to various audiences during a period of more than twenty years. They all however bear upon one general theme, science teaching, and indicate a consistent trend of thought. In a measure, they constitute the history of a movement in education.

The title of the book requires a word of explanation. The addresses were, for the most part, delivered to teachers of physics and chemistry. Why then should not the title be The Teaching of Physical Science? Although the illustrations were of necessity chosen mostly from physical science, the addresses were a constant appeal to all science teachers to teach science rather than special sciences.

The addresses are arranged in chronological rather than logical order. Although the same theme is often repeated, the treatment is progressive as befits the history of the growth of certain ideas among teachers.

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# THE TEACHING OF SCIENCE

## I

## THE EDUCATIONAL VALUE OF NATURAL SCIENCE [1]

In this paper I have undertaken only to state the case; the limits of space will not permit the presentation of arguments to defend it. It will be understood that I have not attempted to state the value of science as it is now taught in the schools, but rather as it might be taught. In mentioning values I have omitted several considerations, such, for example, as the giving of useful information, and dwelt rather upon what seems to me to be the chief value of the study of science, viz., the training in certain habits which may be characterized as scientific.

Through the study of science the habit of investigation is acquired. As soon as one begins to explore by the methods of natural science — and a pupil in the primary school is not too young to begin — he feels a strong impulse to investigate further. He finds that his field of knowledge has been extremely small, and that he has been entertaining fantastic ideas concerning that which lies outside of his little

[1] Paper read before the Harvard Teachers' Association, March 9, 1895.

circle. Very many of his ideas break down when he begins to investigate, and correct ideas must be established in their place. Children are generally eager to investigate, but a notion has long prevailed that if they become wise through their own explorations they are not so likely to be good. As a result of this it has happened that nature's feasts have been spread in vain, while we have with one accord made it our excuse that we think it safer to take our knowledge only at second hand. Some one has said, "In this world a large part of the business of the wise is to counteract the efforts of the good." It is the undoubted mission of science to enable the good to become the wise. Dr. Josiah Strong in the *New Era* says:

"Generation after generation has repeated the mistakes of its predecessors at a dreadful cost of suffering and loss, which was as needless as it would be for ships, in clear weather, to split on rocks known to sailors for centuries."

Professor Brinton says:

"The good which we endeavor to attain is scientific truth, the one test of which is that it will bear untrammeled and unlimited investigation. Scientific truth is absolutely open to the world; it is as free as air, as visible as light, there is no such thing about it as an inner secret, a mysterious gnosis, shared by the favored few, the select illuminati, concealed from the vulgar horde or masked to them under ambiguous terms. Wherever you find mystery, concealment, occultism, you may be sure that the spirit of science does not dwell, and what is more, that it would be an unwelcomed intruder. Such pretensions belong to pseudo-science, to science falsely so called, shutting itself out of the light, because it is afraid of the light."

The scientific mind investigates for the sole purpose of finding out the truth, and to the truth all preconceived ideas are subordinated. "It does not assume to know what ought to be, but finds out what is. On this line all the victories of modern science have been won."

Through the study of science the habit of observing relations is acquired. Persons may have the habit of observing to the minutest details things in which they are interested, without practicing scientific observation. Scientific observation is always organized observation. It relates one thing to another, lighting up one fact by another, searching for the relation of cause and effect. The unscientific mind is insensible to the lessons which its observations and experiences would teach. I have discovered a large number of persons, old and young, who have not learned the lesson that when they look into a mirror obliquely they see objects not from their own immediate vicinity, but those situated upon the opposite side of a perpendicular to the surface of the mirror. I have also discovered that it is possible for persons to have much learning and still be oblivious to such an obvious fact. Professor Wesley Mills says:

> "I have known children who did not go to school till seven years of age, who prior to that period had learned to be good observers of what was going on around them, to lose all love for natural objects after being at school a couple of years; and I do also know to my sorrow that many of the young men that enter our colleges neither know how nor care to observe. They prefer not to look nature directly in the face, but try to see her through the medium of books, lectures, etc., and for this our school system is largely responsible."

A college graduate and a candidate for the degree of Ph.D. was asked what evidence he had that air makes a fire burn, and he made a pitiable spectacle trying to recall what the authorities said upon the subject. A boy of twelve when asked the same question said:

"We close the stove draughts to shut out the air when we wish to check the fire, and with a bellows we blow in more air when we wish to quicken the fire."

The *Popular Science Monthly* in an editorial says:

"If there is a fact that experience has overwhelmingly illustrated and established, it is that mere book-teaching of science is void and of none effect, nay that it is worse; that it has an actively injurious effect on the mind, which it deadens with meaningless jargon and befogs with ill-comprehended notions. How hollow, and often how fantastically absurd, are the ideas children acquire of things of which they are told but which they have never seen or handled. Let us turn children out of the public schools ignorant, if need be, of many things that are taught to them now, but let this idea at least be rooted in their minds, that this world is made up of real things; and this further idea, that words are worse than useless unless they can be applied in the most definite manner to well-understood objects of sense or of thought. What a blessing it would be if we could inspire the rising generation with a real horror of vague and meaningless language. It would mean nothing less than an intellectual revolution in the world."

Scientific observation means seeing with one's eyes and having, as a result, a train of thoughts start in one's own brain. Professor Tyndall said that

"Faraday never could work from the experiments of others, however clearly described. He knew well that from every experiment issues a radiation, luminous in different degrees to different minds."

The following is presented as an example of scientific observation. We built a fire in the furnace which smoked much. After it had burned a few minutes we opened the door and found it covered with drops of a dark brown liquid as thick as molasses and having a characteristic odor and taste. A piece of burning paper or wood was dropped upon a white plate. Drops of the liquid appeared upon the plate afterward which resembled closely those found upon the furnace door. A paper tube was burned at one end and the smoke passed through the full length of the tube. The walls of the tube were found afterward to be saturated with a liquid like that already mentioned. A similar liquid was found to drip from the joints of a long stovepipe in a building where wood was burned. A similar liquid appeared to saturate the rind of some ham which had been smoked. A scientific imagination is required to assist in correlating these observations, and a scientific conservatism must be used in drawing conclusions from them.

The study of science is valuable for the purpose of developing a constructive imagination. The scientific imagination is similar to that which enables a sculptor to see a statue in a block of marble, or which enables a painter to imagine to himself the picture he is to make upon the canvas, or that which enables the architect to form an idea of the building he is to construct. The scientific mind uses imagination, not only for discovery, but for appreciating facts. Teachers who suppose that a school laboratory is useful only for teaching the inductive method sometimes say that life is too short for pupils to spend much time discovering truths which have been already discovered. The fact is that very little discovery can be expected to take place in a school laboratory, but nevertheless the laboratory furnishes the only means by which the pupil can reach an understanding of the truths of his science. Through the microscope one sees only minute portions of an object at one time. The constructive imagination needed to form a conception of the whole is slowly developed by working with the microscope. By laboratory experiments we illustrate in a small way the great phenomena of nature — phenomena which are too large to be presented as a whole to our observation. A constructive imagination is needed to make the transition from the laboratory experiment to the natural phenomena. For the purpose of developing a constructive imagination illustrative experiments have a high value, and should be mingled with all quantitative work. Scientific observation and a scientific imagination were developed to a high degree in Laplace to enable him to conceive the nebular hypothesis; and scientific observation, together with scientific imagination, is requisite to all who would appreciate how the nebular hypothesis explains the way in which worlds are made. Scientific observation and a scientific imagination enabled Darwin to do his work, and without scientific observation and scientific imagination we shall never be able to appreciate evolution.

A person who has acquired the habit of making