INDUCTIVE ELEMENTARY PHYSICAL SCIENCE WITH INEXPENSIVE APPARATUS, AND WITHOUT LABORATORY EQUIPMENT

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Experimental Science Series

I.

INDUCTIVE

ELEMENTARY PHYSICAL SCIENCE

WITH

INEXPENSIVE APPARATUS, AND WITHOUT LABORATORY EQUIPMENT

BY

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PREFACE.

THE course in Elementary Physical Science, of which these sheets form the first instalment, is the outgrowth of various experiments made first in the public schools of Michigan, later in Dr. Felix Adler's Workingmen's School in New York City, and finally, during the past four years, in the private school of Mrs. Quincy A. Shaw in Boston — a school founded by Mrs. Shaw, the daughter of the great naturalist, Prof. Louis Agassiz, for the purpose of developing methods of nature study that will secure to the young student the best preparation for holding through life intimate converse with nature.

The endless source of happiness which this gives is a heritage that Mrs. Shaw has believed will come always to all students who are introduced to the study of the earth by the natural method. The author's educational views were so fully in accord with her own, that she gave him perfect liberty in laying out the work in the Physical Science branches of nature study for pupils from twelve to eighteen years of age. The results reached have been such that many of the best educators of Boston and vicinity have recommended and urged that the course be given a wider field of usefulness.

While this work has been largely the result of class-room experiment, indebtedness is freely acknowledged to various sources, especially to the excellent little manual on "Home-made Apparatus," by Prof. John F. Woodhull, of the New York Teachers' College.

For any testimony that may be wished in regard to the merit of the course, the following are referred to: Mrs. Quincy A. Shaw, Boston, Mass.; Charles F. King, Head Master of the Dearborn School, and Superintendent of the National Summer School; W. A. Mowry, Superintendent of Salem Schools, and of Martha's Vineyard Summer School; S. T. Dutton, Superintendent of Brookline Schools; Larkin Dunton, Head Master of Boston Normal School; A. E. Winship, Editor of The Journal of Education; and Frank A. Hill, Secretary of Massachusetts Board of Education.

F. H. B.

6 MARLBORO STREET, BOSTON, MASS.

January, 1895.

TO THE TEACHER.

No previous knowledge of physics is absolutely necessary, but a clear conception of the *object* aimed at is imperative, in order that the work may be done in a truly scientific manner, and the highest success attained. That object is not primarily to give the pupil a few physical facts out of the great abundance of truth, a few essentials of which is all that is possible in any course, but to cultivate his powers of observation and independent thought. Every young child possesses these powers and is eager to use them, but a system exclusively of book-education tends to destroy them. Some one has truthfully said — "No injustice would be done to a teacher if his skill and the educative value of his lessons were measured by his success in making children reason out conclusions from observed or stated facts"; and we may add that for the best discipline those facts should be observed, not stated. *That* education is of the most value in every walk of life which not only enables its possessor to reason correctly upon facts possessed, but which gives him the power of keen and accurate observation by means of which to collect the facts for himself, and prevent imposition from others. Seeing is not so simple an act as many suppose. Every scientist knows that it is one thing to turn the eyes towards an object, but quite another thing to see what is there. Every one's observational powers need cultivating, and "Observation Lessons" are of value for this purpose, but doubly valuable when so arranged as to become an incentive to logical reasoning.

In planning this course these two objects have been kept in view, and they should be continually before the teacher in charge. If the course is properly taught, pupils who have been in the habit of learning, or trying to learn, without independent thought, find that it is impossible to do so in this work. They are compelled to use their eyes in collecting facts, to put these facts together, and to draw conclusions from them. These processes at their command, they are then prepared for the great school of life, but without having acquired these processes no amount of accumulated facts are of much value. Teachers who have never tried this method will be astonished by the ease with which children adopt it. At first, if their previous instruction has been entirely by the memory method, this one seems to fail completely. The pupils can use neither hands, eyes, nor minds. They cannot experiment successfully nor see more

than a small part of what happens when the experiment is done, to say nothing of thinking out what it all means. But I have not yet had a pupil whose habit of leaning upon book or teacher was so strong that it did not give way, within a brief space of time, and let some degree of self-activity show itself. In training the pupil to self-reliance, it is at the very beginning that the skilful teacher has the opportunity of doing his best work. I have tried several methods; one extreme is to assist the pupils in every step at the beginning, and wean them gradually; the other, to throw them entirely upon their own resources from the very beginning. Of the two extreme methods the latter is the better, provided the pupil can be prevented from becoming discouraged before he gets a start.

The particular method in which you conduct your class will, of course, depend upon circumstances. Only general directions can be given. Though you have no *teaching* to do, that being done by Nature, the best of all teachers, nevertheless you should *teach* (if we may use the paradox) by the most successful method — that of example. *Be* a student of nature with your class, and *acknowledge* yourself such. Have a set of the apparatus, try the experiments, and write your inferences just as your pupils do, either at the same time or previously. You will become interested in the work, and that interest will spread to every pupil. That, at least, has been my experience. Children are imitative, and when they see you doing and enjoying interesting experiments they will wish to do them also. At the same time you can easily appeal to another element which is still stronger in most children — that of emulation; not an unworthy incentive to appeal to, especially if it is done with skill. They will compare their inferences one with another. Get them to compare with yours. You should also examine their written work, and commend all of it that shows independent effort. Frequently you can commend pupils for their discoveries, at the same time that you criticise their statements of facts. Always commend when you can, and criticise with moderation.

There is no better way to become acquainted with your pupils, and no better opportunity for doing individual work. It is sometimes claimed that it is impossible to individualize with the pupils in our public schools when the classes are large; but by this method it becomes comparatively easy. After school you have in your possession the notes written during experiment hour, and through them you rapidly become acquainted with your pupils, and see just how you can best help them. Frequently they need no help, with the exception of some brief marks agreed upon to indicate the mistakes you wish them to correct. Some pupils may need a word of encouragement or direction, and this is usually more valuable if given in writing, though sometimes it is better to speak to them privately. I seldom speak to a pupil in class, unless it is in a whisper, for the class hour should be a silent one on the part of teacher as well as pupils. If you would have it quiet, keep quiet yourself.

For suggestion for correcting books or papers, see note to "Author's Letter to Pupils" (Lesson Sheet No. 1). This method of studying science furnishes one

of the best opportunities for discipline in English composition; for pupils have something to write about, consequently essay-writing becomes easy and pleasurable, and pupils form the invaluable habits of writing upon subjects about which they know something, and of expressing their own thoughts and discoveries. In fact, the many incidental benefits derived from the course are of more value than even the physical knowledge gained. Moreover, aside from the particular physical facts that the pupil discovers, there are general ones of much greater value which can neither be understood nor appreciated unless reached through the individual experimental method; such as the fact that the answers obtained from nature depend upon the questioner, that they approach the truth in proportion as the question is properly put, and the answer carefully read; the immutability of the operation of nature — the fact that exactly the same causes always produce exactly the same results; the fact that there is no such thing as chance, every effect having its cause; the fact that the so-called "natural laws" are simply our explanation of Nature's uniform operations. By this method of study, as one of our critics has put it, "the pupil comes to see things as they are, and not as he thinks they ought to be."

APPARATUS.

Of no less importance than the outline of the course in physics is the apparatus with which the experiments are performed. To meet the wants of grammar schools, the apparatus should be neither extensive nor expensive, but it should be sufficient and of an interesting character. In order to obtain from it the best discipline, not only should the apparatus itself be carefully considered, but the means by which it is provided. Theoretically, the plan for using home-made apparatus is the best, but this plan has usually failed to be very satisfactory in practice, because of the crudeness of the method by which it was attempted. Pupils will do much in the line of making their own apparatus after they have become interested in the work, but generally not at first.

We have found it the best plan to provide the pupil at the beginning with simple apparatus for trying interesting experiments; then to lead him, after his interest in experimental science is aroused, to increase his stock by such pieces as he can easily make for himself. No matter how simple it is, he takes more interest in experimenting with apparatus provided for the purpose, especially if it is of his own make, than in using articles not set apart or especially fitted up for his purpose. Just as the little girl loves her corner play-house, with its miniature tea-set or shelves of broken crockery, so the older child loves a little work-shop or laboratory, with its supplies of his own making.

Interest the pupil in experimental science; then provide him with files and a little glass and rubber tubing, and he will find his own cans and bottles, and make his own