Bulletin. This cracks the nut. Projects for general science should do the same thing. General science should not be crystallized between two covers of a book, but should consist in a variety of projects, one suggesting the next for a while so as to give a unity to the child's mind during this period. Only in this way can we hope to give a science that will attract and satisfy the child and the public, and give something that will be lasting and useful in later life.

THE USE AND ABUSE OF THE LIBRARY IN THE TEACHING OF PHYSICS.¹

BY THOS. E. DOUBT,

Armour Institute, Chicago.

In the consideration of the use and abuse of the library in the teaching of physics, the welfare of the child must be our foremost thought. No two children are exactly alike, yet all have common requirements in mental discipline, in opportunity for growth, and in intellectual assimilation. The sterling traits of individuality are worth all it costs to preserve them.

Good teachers would not have much difficulty in imparting instruction in physics without books. In fact, this would be an ideal way if economy of time and teaching effort were no object. The ancient Greeks were masters of this method of teaching, and used it effectively in giving instruction in philosophy. The positive dislike of Greek thinkers for detailed experimental inquiry delayed the progress of science two thousand years. For instance, instead of acquiring facts about optics they spent their energies in speculating about the nature of light.

To secure the best results for the normal child with this method, the requirements are the ideal teacher and unlimited time. In intermediate and secondary schools, individual instruction is altogether too limited. Time is wasted on nonessentials. Students are rarely encouraged to follow up their own initiative.

The textbook must be available whenever the teacher cannot be appealed to and for guidance, the library must furnish most of the attractive signboards and projected illumination on the roads which the student seeks to travel.

Though physics originated less than four hundred years ago,

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much biographical material is available and would be attractive to any student who enjoys reading good books. Biographies of living men are more attractive than those of earlier times. This furnishes a rich field for the current magazine which the wide-awake librarian will not be slow to preëempt. New discoveries are always alluring and legitimate subjects for wide reading.

Perhaps with adequate guidance, we would occasionally have boys like James Clerk Maxwell who was experimenting on elastic solids at the age of eleven and at fifteen, he was reading that prose poem of mathematical physics, Fourier's *Analytical Theory of Heat*.

Certainly it would not lessen the interest of girls in physics to read incidents in the lives of Caroline Herschell, Madam Curie, or of the late Mrs. Professor Draper. For boys contemplating the engineering profession, the story of what Rowland did at Niagara Falls; what Kelvin did for the Atlantic cable or what Eads did for the Mississippi river would be interesting reading. Not less interesting would be the sketch of what our two noble Americans did at Panama, the achievements of one in medicine and the other in engineering having been recently recognized by Congress.

Prof. Millikan told me that his son, only eleven years old, has read the book *How It Works* through with absorbing interest and is a constant reader of the *Technical World*. All children are interested in the "go of machines"; why not supply them with books that would stimulate this interest?

This spirit of wonder which a child has, assuredly should not be dampened as the child grows older, but should be intensified and deepened with maturity. Great men frequently show this spirit of wonder in striking form and it is a privilege for young people to be associated with them. The library furnishes the means for bringing this companionship even to the humblest child.

Lord Lister, the famous antiseptic surgeon, manifested this receptivity to a remarkable degree. His senses were highly developed and they all seemed to be keenly alive to every impression. With his brother, the curator of the British Museum, and Sir Michael Foster, he was walking across a western college campus one summer day. The grasshoppers were thick and flying frequently with a clattering noise. Lord Lister was immediately attracted by the noise which to him was new. All his senses were aroused. The novelty of the phenomena attracted him and he

sought by question and observation to become more thoroughly acquainted with those insects.

Another illustration might be cited. In the great library of Prince Louis Napoleon, where ponderous volumes were ranged shelf upon shelf—such works as were created by Humboldt and Bonplandt after their return from South America—a conversation was being held in honor of the Congress of Physicists in Paris in 1900. The exhibits were such things as X-rays, wireless telegraphy, liquid air, multiple telegraphy, Tesla coils, all new at that time. Among the many distinguished guests were Lord and Lady Kelvin. Lord Kelvin showed this same spirit of wonder, heightened curiosity, all senses alert for every possible sensation. It was impressed upon me then and the conviction has grown with observation and reflection since that great men are direct in their actions. Their greatness is made up of simple elements greatly intensified. They bring to their help not only well-trained senses but eyes gained by knowledge. This attitude of mind is characteristic of unspoiled children. Alas, how seldom we meet with it in secondary schools. The library has no small function to play in fostering and keeping alive this natural prerogative of child life.

But, how frequently have we observed the spirit of inquiry killed in a bright student when he is sent to an encyclopædia to look up a certain subject. The article in question is usually written by an expert for experts. One illustration would show the folly of such a use of the library. In the old *Encyclopædia Britannica*, there is an article on "Wave Theory" by Lord Rayleigh. It was used by a university professor as the basis of a course of lectures four times a week for three half years to graduate students. The last edition of the *Encyclopædia Britannica* has this article split up into a number of sections and distributed throughout that great work; nevertheless the principal paragraphs are as difficult reading as in the preceding edition.

However, we must admit that a man should have a wide use of reference texts and encyclopædias. To learn an effective use of these resources, the student must have guidance that is readily accessible. Not only should a good card catalogue be available but bibliographies with some estimate or appraisal of the different articles should be accessible on important topics.

At the Armour Institute of Technology, I am giving a course in "Radiation" as an elective to about a dozen advanced students. Our librarian worked up the bibliography of the subject and the

result was forty typewritten pages of titles and this included only magazine articles within the last four years. If carefully classified and evaluated this should prove of good service to the student.

The reading room of a library should be a place where any child would be delighted to go, not only for a few minutes but regularly. An extension of the library may readily be made by the use of the opaque projector. The page of any book may be shown to a large audience. Thus the large cabinets of lantern slides no longer need to be indefinitely expanded.

The use of numerous texts for collateral reading is not an efficient plan. No two texts are written with the same idea in mind, so that the student is discouraged and his energies dissipated in attempting to get the new author's viewpoint. There is exhilaration to the student in having definite requirements in the text for each day after the instructor has given an introduction. The student gathers momentum as he progresses if he is held for these definite assignments.

Encyclopædias, reference works, and collateral texts are of great use to the teacher and large expenditures may be justified by the librarian for such books on the ground of secondary effect upon the students through the instructor.

Clerk Maxwell has been mentioned. He is worthy of all honor and confidence. His treatise on "Electricity and Magnetism" has been the point of departure for most of the researches on the subject for the last forty years. He wrote a little book, *Matter and Motion*. It is a classic, a model of its kind and has been recommended to high school teachers for the use of their pupils. What is difficult reading for the average college student certainly cannot be easy reading for students of less maturity.

Newton's *Principia* would not be a good book to put into the hands of a high school pupil if we would have him learn how pressure produces motion nor would we give him Maxwell's *Treatise on Electricity and Magnetism* to be used as a text, admirable as these works are, but we should encourage the spirit of play such as Newton exhibited in his study of soap bubbles or a better instance, because more modern, the way in which Faraday played with wires and needles in his researches in electricity and magnetism.

A number of years since, I gave a college course in physics without the use of a textbook. My students were supplied with mimeographed notes of the important statements in each lecture

and referred to the library for the bulk of the subject matter usually given in a text. We began with the subject of heat and developed the principles of mechanics as the need arose for them in dealing with thermal phenomena in much the same logical order that Maxwell followed in his initial course in experimental physics at Cambridge University. The course was largely illustrated with experiments in the lecture room and supplemented by a closely correlated course of experiments in the laboratory.

I followed this plan for two years. The students seemed to have developed the scientific attitude more readily and while not depending upon memory so much, their thinking was more precise and dependable than the students who used the textbook the three previous years. High school students are not usually prepared nor have they the ability to take good notes of lectures. Even college students usually have difficulty in mastering a subject given only in lectures. Hence a textbook properly interpreted by the teacher supplies the omissions in the lecture and even corrects the mistakes of the teacher himself.

Is not one of the aims of a course in physics not so much to develop the habit of reading as to encourage the use of the ability to think? It is true as Maxwell points out that we should imbue the minds of our students with correct dynamical principles and "provide for the diffusion and cultivation not only of true scientific principles but of a spirit of sound criticism founded on an examination of the evidence on which statements apparently scientific depend."

Helmholtz made considerable progress in pure mathematics after he had accomplished his monumental work in sound. A student will make much more rapid progress in the study of physical principles by means of books after he has a firm foundation in sense perceptions from a good course in laboratory work. Deductive physics may be good for advanced work in college but it does not commend itself to me for use in secondary schools.

Those who are studying radioactivity tell us that there are sources of energy locked up in atomic structures which are almost limitless and so far we have been able to appropriate these stores only to a very slight extent. Anything that we can do does not seem capable of accelerating or retarding the rate of evolution of this primordial energy. The analogy to the educational problem is obvious. We subject the pupil to observation, to various conditions more or less favorable to his development in the hope that we may discover an environment which will unlock the soul

of the child and set free his boundless possibilities. We seek to teach by practical methods the elements of letters and of science and the art of accurate expression, the ability to think and to control the will. And undoubtedly we can believe with Michael Faraday that that point in self-education which consists in teaching the mind to resist its desires and inclinations until they are proved to be right, is the most important of all, not only in things of natural philosophy but in every other department of daily life.

Physics is an experimental science. There are real and great difficulties in the subject itself to every earnest student. Speculation has a very subordinate part without we use detailed experimental enquiry for the acquiring of facts and the testing of hypotheses. Too often the child is encouraged to spend his energies in speculating like the ancient Greeks about the nature of phenomena instead of giving real descriptions of the facts. The test and proof of our efficiency is found in reviewing, in re-thinking, in reknowing, and in reproduction of the subject matter in language at once appropriate and precise.

Professor Fitzgerald of the University of Dublin once wrote that the cultivation and training of the practical ability to do things and to learn from observation, experiment, and measurement is a part of the education which the clergyman and the lawyer can maybe neglect because they have to deal with emotions and words but which the doctor and the engineer can only neglect at their own peril and that of those who employ them. Sir John Morley says the essential thing for progress is to leave all ways open for the advent of your hero, for no man can possibly know by which road he will come; and this is as true in science as it is in the affairs of government.

The total production of all kinds of steel ingots and castings in 1913, according to the American Iron and Steel Institute, whose figures are accepted by the United States Geological Survey, was 31,300,874 long tons, against 21,599,931 long tons in 1912. The production of steel by the electric process in 1913 amounted to 30,180 tons, compared with 18,309 tons in 1912. In 1908 only 55 tons of electric steel was produced. On December 31, 1913, the number of completed plants which were equipped for the manufacture of steel by the electric process was nineteen, an increase of five over the number a year previous.