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PHYSICAL LABORATORIES

IT is well known that chemistry can be taught far better by a laboratory in which the student performs the various experiments, than by any system of lectures. Now, although for many years physicists have been in the habit of instructing their special students and assistants in this way, yet it is only recently that the same plan has been tried with large classes in physics. One of the first institutions to attempt this method, in America at least, was the Massachusetts Institute of Technology in Boston; and as I find many colleges here establishing physical laboratories, I trust that our experience may prove of some interest. The great difficulty is to enable twenty or thirty students to perform the same experiment without duplicating the apparatus, and to avoid the danger of injury to delicate instruments. Our plan is this:—Two large rooms (one nearly a hundred feet in length) are fitted up with tables, supplied with gas and water, somewhat like a chemical laboratory. On each is placed the apparatus prepared for a single experiment, which always remains in this place, thus avoiding the danger of breaking it in moving. A full written description is also given of each experiment, pointing out the proper precautions to avoid error or breakage. Near the door is an indicator or board containing the names of the experiments, and opposite each is placed a card bearing the name of the student. When the class enters the laboratory, they go to the indicator, and each member notices what experiment is opposite his name; he then goes to the proper table, reads the description, and performs it. He next reports his results to the instructor in charge, and if they are correct, his card is moved to some unoccupied place, and he proceeds as before. Care is taken that the number of experiments shall exceed that of students, and there is therefore no delay. The instructor in the mean time is enabled to pass from student to student and to see that no errors are committed. As quantitative work is far more valuable than qualitative, most of our experiments are of the former kind, and the student learns to measure physical constants and to verify laws numerically. For example, in one experiment a steel bar is supported on knife edges, and a weight is applied at the centre. The flexure is then measured by a micrometer screw, the exact point of contact being determined by including the screw and bar in the circuit of a battery and galvanometer. After making a number of experiments with various weights, the student constructs a curve in which ordinates represent deflection, and abscissæ weights applied. The law of elasticity shows that this curve should be a straight line, and the close agreement is convincing proof to the student of its correctness. In the same way the law of the conjugate foci of lenses is tested, and the observed curve compared with that deduced from theory. Some experiments are introduced to accustom the student to general methods of research, such as the computation of probable error by least squares, various forms of interpolation, &c. The graphical method is largely used, as it at the same time enables the student to take in all his observations at one glance, while the instructor can constantly tell how carefully the work has been done. For the microscope a few objects are selected to show certain general methods of using this instrument, as one requiring a diaphragm, a second oblique illumination, and so on. Again, the student views by polarised light such objects as unannealed glass, crystals, designs in selenite, and studies the effects produced by various agencies. By thus handling the instruments he acquires a facility in using them and comprehension of their construction which he could never obtain from lectures. The excellence of the work done by many of the students led to the hope that valuable results might be attained by assigning to different students the experiments in a research, taking care that each should be repeated several times by different individuals. These results, if concordant, would be much more conclusive than those obtained by a single experimenter, since they would be free from all personal bias. In this way some interesting results have been attained on the foci of lenses placed obliquely, the flow of air through straight and curved tubes, and other similar subjects. Photometry and electrical measurement seem especially suited to this purpose, and the application of the latter subject to submarine cables would be both interesting and instructive to the student. During the winter time of 1869 and 1870 about sixty students worked in one laboratory, so that the experiment was tried on a sufficiently large scale to enable us to speak with confidence of its success. We found the system described above worked well, the students were interested in the subject, and obtained results of considerable accuracy. The loss by breakage was exceedingly small, and the current expenses insignificant compared with a chemical laboratory, since there is but little consumption of the materials employed.

There are now in America at least four similar laboratories either in operation or preparation, and the chances are that in a few years this number will be greatly increased. The value of a knowledge of physical manipulation is becoming daily better appreciated, and it is evident that instruction of this kind can be properly given only in a physical laboratory.

EDWARD C. PICKERING

SCIENCE TEACHING IN PRIVATE SCHOOLS

A WRITER of the early part of last century defined a philosopher as one "whose trade was to do nothing, and to speculate upon everything." While philosophers were so lightly esteemed, it is no matter of surprise that philosophy was little cared for as a part of education. But such a definition as the above would not now be generally accepted even by the unscientific public. All are beginning to see that it is to Science they are indebted for so many of the comforts and advantages of civilisation, yet to the many is Science a mystery and closed book. And one great cause of this we believe to be, because it is not taught in our schools.

We purpose, in the present article, to speak only of private schools. If a visitation were to be made of such schools in England, we venture to say that very few, comparatively, would be found, in which Science, in any of its branches, is made a subject of regular education. The boys of most schools would be classed by the masters

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under three heads, classical boys, mathematical boys, and good-for-nothing boys. This last class exists mainly because the proper food for them has not been provided, they are allowed to starve for lack of it, and grow up as men with stunted and impoverished intellects; they have not been educated, the powers of their minds have not been drawn out by the fit means, and they pass through the world as animated failures.

Let Science work side by side with Classics and Mathematics—not usurp their places—in the work of education, and the good-for-nothing class will be very sensibly diminished, if indeed it be not entirely done away with. But how is this to be done? In the first place, gradually; in the second place, zealously; in the third place, thoroughly. Gradually, because it is a new thing, and a large proportion of our private schoolmasters have had no regular training in science themselves. Zealously, because if a teacher be not himself interested in what he teaches, he can have no assurance of success, and no encouragement from his pupils. Thoroughly, because a thing worth doing at all is worth doing well.

This is the spirit in which the work must be done, but what are the special means? Are boys to read about Science merely, or are they to touch and handle Science for themselves? It is doubtless a good thing to read about the truths of Science and their experimental illustration; it is a better thing to see those truths illustrated and proved by another; but it is by far the best thing to experiment upon and prove the truths by one's self. There is nothing that comes home so much to a boy's mind as an experimental proof. He may read of the dual character of electricity, and may get some vague ideas on the subject; as soon, however, as he takes two sticks of sealing-wax, suspends one, rubs both, and brings one near to the other, he, as it were, discovers for himself that the same bodies electrified by the same means repel one another, and on experimenting with glass and sealing-wax sticks he learns something of attraction, and is naturally led on from experiment to experiment until the powers of his mind become quite drawn out, or educated in the pleasurable pursuit of the subject. In the Science-teaching of boys, then, practical demonstrations must play an important part. Let reading, hearing lectures, and attending classes, and individual experimentation, be the working tools. A lecture of itself is but a poor tool, it produces an effect for the time, but in many cases no very permanent good. A lecturer must also be a teacher out of lecture hours.

As a commencement of Science-teaching in schools we commend the following plan to the notice of Science-teachers. Let one or two evenings in the week be set apart for lectures on some branch of Science, Experimental Physics, Botany, or Geology. Each lecture to last *not more* than an hour, and to be experimentally illustrated in the way best suited to the subject, always bearing in mind that the simplest experiments, or those most easily imitated by the pupils, are the best. Let the pupils be encouraged to take notes, and let the lecturer sum up in a concise form at the end of the lecture the main points established, which may be written in the form of memoranda on a black board and copied by the pupils. A day or two after the lecture let him hold a conversational class, the attendance optional. He will then briefly run over the matter of the last lecture, find out by questioning what points are not thoroughly understood, re-explain or even re-experiment, and endeavour to leave each mind with a perfect understanding of fundamentals. On a third evening let him give a series of simple—not needlessly puzzling—examination questions, and look over each boy's answers with himself alone, if possible, in order to give an opportunity for a yet more thorough explanation of any difficult point suited to the individual capacity of each. Instead of a string of questions, a subject for an essay in connection with the lectures might occasionally be given. Private reading of text-books should always be encouraged.

Now, as to the results of a system of this kind, taking such a subject as Experimental Physics, it will be found that the lectures are always looked forward to with no ordinary pleasure, and are listened to with no ordinary attention. At the conversational classes the way in which such subjects teach boys to think is often clearly seen; they ask most puzzling questions, yet natural ones, and in many cases seek to go far deeper into the subject than the lecturer had at first any idea of leading them. This general interest incites them to read and perform such simple experiments for themselves as are within their power.

Generally speaking it is not the high classical or even the mathematical boys that have excelled in Science learning, but precisely those who before occupied no prominent place in the school, had no special gift for classics or mathematics, and were considered, more or less, good-for-nothings. And here it is important to remember that a person may have a mathematical mind without being a mathematician.

While such subjects as Chemistry and Physics claim, perhaps, the highest position as a means of scientific education, it is important to vary the programme as much as possible without treating any superficially. Thus Astronomy, Geology, Physiology, and Botany have strong claims. It is certainly most deplorable to think that even now in many of our private schools the pupils are being tacitly taught that the world was made in six days, and that man is but some 6,000 years old. They might as well learn that there are but four elements—earth, air, fire, and water. We look with confidence for better things in the future.

COHN'S CONTRIBUTIONS TO THE BIOLOGY OF PLANTS

Beiträge zur Biologie der Pflanzen. Herausgegeben von Dr. Ferdinand Cohn. Erster Heft. Mit sechs zum theil farbigen Tafeln. (Breslau, 1870. London: Williams and Norgate.)

THIS is the first part of a new periodical established primarily for the publication of the results of the observations made at the Botanico-Physiological Institute at Breslau. The part contains five papers on different microscopic algæ and fungi, and their pathological effects. In subsequent numbers it is intended to give priority to botanical observations which relate to biological questions, or which are more or less connected with practical natural science, medicine, agriculture, &c. It is hoped that the publication may fill the place formerly occupied by Karsten's "Botanische Untersuchungen."

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