METHOD IN SCIENCE TEACHING.*

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A man's power depends on three things; his native ability, his environment, and his education. It is only the latter that can enter into a discussion on method.

Much has been said about what education is, but of all its alleged components I regard two as adequate,—informing and training. Education begins with the first of these almost solely, being, later, supplemented by the second. The child's earliest acquirements are impressions and these become information stored in the mind, to be followed by the discipline of later school years and experience in life. This, too, has been the natural method in the growth of education.

The humanities being the earliest knowledge possessed by man, naturally formed the first material for an education and were simply acquired and handed down, exercising chiefly the memory and requiring little effort except attention on the part of the recipient. There was little exercise of thought, little comparison, judgment, or conclusion. Even the faculties of attention and retention were pampered by repetition, this feature giving rise to the Jesuit maxim, "*Repetitio est mater studiorum.*"

When progress enough had been made in science to win for it recognition as one of the elements of an education, it was imparted by the method employed in the teaching of the humanities, and there was no distinctive method in science teaching. The deductive sciences, philosophy and mathematics, were the earliest taught and continued to employ largely the same method for a long time after experimental or inductive science became independent enough to break away and use its own method.

A part of the real value of the laboratory method—observation at first hand—is gaining knowledge by experimentation; and this is the practical application of the syllogism of philosophy which has been the classical method of mind training. The labora-

*Condensed from a paper read before the Detroit Principals' Association, April, 1901.

tory method has given us this most efficient way of learning facts of science, making them a part of our knowledge instead of parroted wisdom. But experiments teach not only facts and principles; they also train, and give power to find new data and laws, and so contribute to human knowledge.

Not only the mind, but the avenues of the mind must be trained. Manipulation, observation, reflection, comparison, judgment,—all must be exercised. Because the student *himself made the experiments and observations* in specially fitted rooms, called laboratories, instead of *being told about them* in lecture halls, this method of natural science study came to be called the laboratory method. Its first introduction into schools was in connection with biology, and in England, Huxley, and in this country, the elder Agassiz, were its champions, to whom it owes much.

Theoretically this method is the re-investigation of causes, facts, principles or laws that underlie natural phenomena, but re-investigated under instruction and guidance, the most favorable circumstances that can be imagined. So the process is a stimulating one, if the material is adapted to the age of the student in such a way that his powers are constantly exercised but not overtaxed. For early education it has the advantage of proceeding from the concrete to the abstract, from the simple to the complex, from the known to the unknown—following the order of the developing mind.

Practically it has been much abused by instructions and directions given in such a way that the student becomes a mere verifier,—an intellectual drone,—asking “What is to be seen?” and “What conclusion is to be drawn?”, instead of being encouraged to a much needed independence.² There are at present several idealists: Those who tell nothing; those who direct the student in such a way that he can independently find the important data; those who tell all. The last are usually the old school scientists who hold, for instance, that the student must first learn the laws of gravitation before he experiments with falling bodies. They object that there is not time for rediscovering principles or laws that scientists have spent a long time in understanding. But we

(2) Dr. W. F. Ganong's *Laboratory Course in Plant Physiology*, 1901, of which notice was given in the November No. of *SCHOOL SCIENCE*, is a model book in this respect.

answer, that the man who discovers something, in order to do so, must have had more power than his fellows and he has developed this power along his line of discovery by slow increments. May not the student, by this very method, gain a power which will carry him far in advance of the point he would have reached by the old didactic method of science work? It is not so hard now-a-days to get an affirmative answer, since it is generally conceded that even in secondary schools discipline is more important than the amount of knowledge stored. The latter may be forgotten or misapplied, but the former gives power to reproduce forgotten facts or to find new ones. But before giving power, laboratory work begets a habit of thoughtful and accurate observation, careful consideration of all phenomena or facts—a most important preliminary step in all education.

Now, while it was said no more time need be given for finding facts and rediscovering principles than required for another lesson, this means a lesson of equal value. It is important in the laboratory method to give time enough for each experiment to understand fully the factors included, separating those not touching upon the question from those involved in its decision. The next step in the process is the comparison of facts observed, or the results of an experiment with those of another experiment or with some experience. All this is necessary before the final step, the drawing of the conclusion. Here we see a striking difference between this and the informational method. In the latter nothing further is required than to receive, and apply (?) that which is received. And when students in our schools learn to acquire things by the laboratory method they are doing what advanced scholars used to do, and in so far our present system is ahead of the old. Is it surprising that students have to be urged to compare related facts and draw conclusions when it is adult nature to follow prejudice rather than facts and their consequences?

Going a little more into detail of the method in natural science teaching, we may say it is the easiest one to follow. In the first place, it is the observation and comparison of the evident phenomena in nature, and this is akin to analysis. Thus to learn the use of fleshy fruits, these are examined, and it is observed that

all fleshy fruits have some food material, bright colors and agreeable odors and flavors, which can be of no direct use to the seeds they contain. These have nearly the opposite qualities. Now, when it is asked what will happen if an animal, attracted by these inducements, carries away and eats the fruit, the inference (synthesis) that the seeds because of their qualities are rejected and thus scattered, leads to the larger truth that fleshy fruits are solely for the distribution of seeds. This general method of observation of things themselves, comparison and inference, has been found so valuable that it is no longer employed in science alone, but also in other studies, being used to some extent even in language teaching. While the observational method in general has been applied to other studies, the experimental method can be used in science alone.

Since not all of nature's processes are open for inspection of cause and result, a large number of phenomena must be determined by what is known as the method of experiment,—that is by modifying the natural conditions in such a way as to get definite or special results, and from these artificial conditions to obtain facts or data from which the natural processes can be inferred. As the experiment is so important both in science and in science teaching, and has been so much perverted, it may be well to go more into detail on this part of the subject.

Some one has said "An experiment is a question put to nature." Another view is, that an experiment modifies the conditions of nature in such a way as to show what are the natural phenomena. This seems to me more comprehensive.

I believe it is the consensus of opinion that an experiment is a test or trial to find out something; and since it is to reach some conclusion it is in the nature of a syllogism and must embody two premises. If this is true, a moment's reflection will show that a great many so-called experiments in our text books are merely illustrative or confirmatory. This is always the case where the proposition is stated first, or where the object of the experiment foretells the conclusion. Such experiments might as well add the "*quod erat demonstrandum*" of our geometries.

In order to determine any point by an experiment we must

have two sets of facts, one of which may be the conclusion of a previously performed experiment. Thus if the learner is to test unknown substances for starch he must apply iodine, not only to the substance, but also to some known starch. In the student's training it is very important that this step be taken; simple though it seems, it is fundamental for inculcating accuracy. After the experiment has been observed a sufficient length of time we have two distinct results, and by an act of comparison and judgment from these two, the thing to be found out, or conclusion, is drawn. Accordingly, the chief points of an experiment are conditions, results, and conclusion.

It is the experience of nearly every teacher that the pupil remembers the apparatus better than he does the essentials of an experiment, better, even, than the conclusion. Having learned by experience that the apparatus impresses itself on the pupil's mind to the detriment of the real principle, the teacher would better have him describe only the conditions as brought about by apparatus, operation, or any modification of natural conditions. This has another advantage; it does away with the necessity of describing the object of the experiment, in which operation, very frequently, the conclusion is too nearly hinted at, and the pupil becomes a verifier instead of an independent observer.³

Another great difficulty is in getting the student to see clearly the difference between the results of the modified conditions and the conclusion that can be drawn from such results. He often states the conclusion and gives it as a reason for the result or he cannot get any conclusion at all. Frequently this is because the experiment takes into account experiences that the student has not had. On the whole, it is a lack of perception of the relation between cause and effect and is a part of the student's training that needs serious attention.

All this can be remedied by patient questioning, shifting premises, etc., but a better way, I believe, is to give some simple experiments leading up to the one in question, or, it may be, several different experiments leading to some of the most important

(3) Out of many high-school textbooks on science that I have seen only two are practically free from this fault of "giving away" the conclusions of experiments.

principles to be fixed. There is another value in giving more than one experiment, and that is, more perfectly clinching the fact or principle taught, to say nothing of the discipline. It will lessen the tendency of placing the apparatus in the foreground, since the final result is obtained with different apparatus. It will also do away with the temptation to make experiments easy by prefacing them with, "to show so and so," in which case most students, even when the experiment fails, will draw the prefixed conclusion. This is pernicious, as it changes the experiment into a mere illustration, warps, by its insinuation, the pupil's too plastic judgment, and lessens his independence.⁴

The making of several experiments for one conclusion also recognizes the time element in education. To grasp any idea well, the young mind, especially, must have time in proportion to the difficulty of the idea; but the time is not profitably put in if the idea is beyond the experience of the pupil. Here, again, there is danger that the pupil will be carried along by the teacher instead of being allowed to pick his own way. To do this independently a few simpler experiments can be given as preliminaries, leading up to the principal one. To illustrate: a test for oil in seeds should be preceded by an experiment on a seed known to contain oil; the experiment for starch-making in leaves should be preceded by the test for starch, then by an experiment for starch in a normal leaf, then by one on an etiolated leaf.

Naturally the lack of school time for this method will be the overwhelming objection urged by all. But since this kind of training and the knowledge gained is so fundamental, the old adage of "a stitch in time" was never truer than the assertion that right here the pupil's whole intellectual future is at stake. He would better take time at first to save it at the last.

The application of the science method in primary schools might begin with nature study in the grades, and for this it would be best if we did not study any special science but some part of nature as a whole. It would be most profitable if the study were largely observational, few inferences being drawn until many data

(4) Professor N. A. Harvey (SCHOOL SCIENCE, Vol. 1, No. 3, p. 121) records similar experiences.

are at hand. The observations may be along the line of experiences rather than experiments, at first; thus, instead of making experiments, as is done in the high school, for determining the conditions necessary for the germination of seeds, let the pupil simply place seeds in favorable conditions and watch them germinate and grow, thus realizing that they are alive and can do something.

External general observations as to form and parts are simple and easily made and may lead to simple inferences.

In the higher grades general relationships and some classification of phenomena would give a bird's-eye view and prepare for the studies following.

Some of the easier parts of physical geography might be taught in the eighth grade. This should be followed by the more difficult parts of the same study in the ninth grade, by botany, zoölogy and physiology in the tenth grade, by two courses of chemistry in the eleventh grade, and two courses of physics in the twelfth.

It is not an infrequent complaint that the work in science does not show for as much as that in the languages or mathematics. Is this to be wondered at when the pupil begins the latter studies with his entrance into school and continues them through his whole course, while he may have anywhere from but one to three terms in science? And his science teacher frequently has this as an adjunct to several other studies. How can such a teacher be expected to practice any particular method or make any strong impression on his pupils?

To give natural science studies and their method of educating a fair chance would mean consecutive and logical arrangement of things studied from the first grade up; continuousness or sequence to be followed out through the whole school course even if only a small amount of time be given daily.