SCIENCE INSTRUCTION.

BY BARNARD S. BRONSON,

State College for Teachers, Albany, N. Y.

In the present state of society and education, science, properly I believe, occupies a considerable portion of our attention and our time. Whether or not science has secured its proper allotment of time in the curriculum of our educational institutions is an open question. This problem by its very nature seems to preclude the possibility of final solution.

This is as it should be. We can, at the best, hope only for a fair adjustment of time for the moment until the needs of the morrow show us that the old is inadequate. There are many who are willing to assume prophetic roles and to show us the follies of following blindly the traditions of the past. To some of these we owe our progress, to others we owe our most disastrous ventures and excursions into the untried and the unknown. All honor, however, to the young men who see visions and to the old men who dream dreams. God hath chosen the things which are not, to bring to naught the things that are. The vision must precede the reality.

In the attempt to solve the problem of the place of science in education, each one of us at present engaged in science instruction occupies a place probably considerably larger than he dreams. Incidentally, however, this position may not be the position of his dreams, but the influence of each is widely extensive. With us, consciously or unconsciously, rests its solution.

Anxious as we are, all of us, to advance those intrusted to us for the best interests of the future, can we say truthfully that the time spent with us has been utilized for the best interests of society? Is it not possible that had that time been spent elsewhere in the pursuit of other branches of knowledge, society at large would be the gainer?

This is the question that society puts to us and from us it demands an accounting of our time and the time of our pupils. Inasmuch as the individual receives ordinarily the major part of his education from its hands, it follows that society is well within its rights in making such a demand upon us, its servants. To a certain extent, latterly, we have freed ourselves from the bondage that originally obtained, that of the slave that literally led the child, the first pedagogue, dependent upon the largess of the individual and his will, but we are none the less the servants

of society at large; by society we are released from certain obligations that are imposed on others. Our mission is to serve, the highest privilege that society may accord to any of its members. We must then with our privileges accept our obligations and we cannot in justice resent the accounting demanded.

In what way does science instruction minister to society's needs? Life consists in the continuous adjustment of the individual to its environment, spiritual and physical. Education seeks to point the way to the end that disastrous collisions of the individual and his world may be less frequent. Education seeks to provide the lubrication that will minimize attrition and its consequent loss.

Nature is relentless and inexorable in her elimination of the unfit. To exist even comfortably, for a time, one must remove himself from this class. "*Natura non agit per saltum.*" In the process of elimination, nature does not advance by cataclysms. Ample warning is given to each. The saddest condition in life is the later realization of a warning unheeded. "The mills of God grind slowly but they grind exceeding small."

"To him who in the love of nature holds communion with her visible forms
She speaks a various language."

Nature speaks. To hear, the listening ear must be attuned accurately to receive and without error to record her messages.

"This our life * * * finds tongues in trees, books in the running brooks, sermons in stones and good in everything."

The aims of science instruction, as I view them, are twofold, the acquisition of a certain amount of desirable information and the development of a certain scientific habit of thought. Neither of these may be subordinated nor neglected without distinct loss to the individual.

Our first thought in science instruction is the acquisition of data. Our most serious mistake, as instructors, I believe, lies in the fact that too frequently this is our Omega as well as our Alpha. We regard our task as completed, our duty well performed, when our pupils have succeeded in acquiring this data. If, in recitation, our pupils are able to repeat, possibly after us, more likely than not in our own words, some particularly

delightful or interesting bit of information, our responsibility ceases and we claim the reward of work well done.

It is with a feeling of a considerable degree of guilt; or at least chagrin, that I find too frequently my own words, phrases and sentences returned to me in oral recitation or upon written examination papers exactly as they were given. These expressions, never having been digested nor assimilated by the pupil, are returned unchanged by any mental process in his mind. As ordinarily my thoughts are not the pupil's thoughts, as the thoughts of one individual can never express exactly the mind of another, so the pupil's words, as expressive of his mind, should not be the exact reproduction of my own. Such statements ordinarily we mark as correct and, quite properly, in the matter of fact. However, they indicate more truly a failure on the part of the pupil from the viewpoint of education.

If we were concerned most especially with our subject matter, this might suffice, but we are not; we are concerned most especially with the minds and mental attitudes of our pupils. It is our business to teach *our pupils* primarily; this must be accomplished through and by means of our subjects. These are our tools, with these we must work. How often we hear the expression, "I teach biology, chemistry, physics, mathematics," or some other particular branch or, most unfortunately, possibly all of them, or others, and how often we must realize that such a response to an inquiry, though conveying properly the information sought, only too literally defines our occupations. We do teach biology, chemistry, physics, or mathematics, etc., and what are our finished products? Just what we teach, so much photosynthesis, chemical equilibrium, harmonic motion, maxima and minima. We measure our successes or our failures in terms of the perfection of our instruments. It is much as if in visiting a cabinetmaker's shop to see the evidence of his handiwork, he should respond to our inquiries by stating he had a splendidly sharpened chisel or a finely articulating and adjusted lathe. These are necessary for his craft, but it is not in this that our interest lies, unless by chance we, too, are cabinetmakers. What are *our* finished products?

I believe our emphasis is too largely misplaced; we are expending too much time and energy on the perfection of our instruments. In another connection, entirely, but as truly applicable here, I believe, Matthew Arnold has said, "Faith in machinery is our besetting danger, often in machinery most

absurdly disproportioned to the end which this machinery, if it is to do any good at all, is to serve; but always in machinery as if it had a value in and for itself * * * He who works for machinery * * * works for confusion."

In all forms of instruction our data or our informational side is important, it must not be minimized, but it must be made the *agent*, not the end. To be of any value to the individual or to society at large, our data must be in available form. Our second great aim in our instruction lies in thus making our data or our knowledge available. This involves the mental processes that we usually call the thought processes or the processes of thought production. Prof. Gumpowicz, in his *Outlines of Sociology*, however, states: "The great error of individualistic psychology is the supposition that man thinks. The whole belief in the freedom of human action is rooted in the idea that man's conduct is the fruit of his thoughts, and that his thoughts are exclusively his own. This is an error. He is not self-made mentally, any more than he is physically. His mind and thoughts are the products of his social medium or the social element whence he arose and in which he lives." However we may term these educative processes, our knowledge, our data, to be made available must be wrought upon to become truly the possession of our pupils and of society. Availability to the pupil depends upon his arrangement of the data; it is in this respect that he needs our assistance. The specimens and pictures in our mental museums must not be "skied," we must have them at hand where we may reach them conveniently. We do not thus increase our information, but we do increase its utility and thus our usefulness in service and so make our general contribution to the welfare of society. "Reasoning adds no more to our body of knowledge than the arrangement of specimens in a museum adds to their number." However, as in our libraries, we are warned constantly against misplacing the volumes by the sign, "A book misplaced is a book lost," so in our mental libraries, a fact misplaced is a fact lost.

We have sufficient knowledge at hand to revolutionize the world. President Van Hise, of the University of Wisconsin, said comparatively recently: "There have been more advances in knowledge in the past sixty years than there were in the two thousand years before that time. In a large measure, this knowledge is unknown to the people. We know enough about agriculture so that the agricultural wealth of the country could be

doubled if the knowledge were applied. We know enough about eugenics so that if the knowledge were applied to men, the defective processes would disappear in a generation. We know enough about disease so that if that knowledge were utilized, infectious and contagious diseases would be destroyed in the United States, and that within a score of years. Similarly, in other fields, our knowledge has gone far beyond the utilization of the people." As teachers it is our business to discover these facts, this information, to the people. As the servants of society, our aim should be the increased usefulness of its present and its potential members. As instructors in science, I believe we are particularly fortunate in having so definite a place in society. There is no lack in the clarity of call that comes to each of us.

In a considerable measure, I fear the criticism that has been visited upon our work and that of our schools in general is merited. This is not due to low ideals nor to a lack of endeavor on our part to meet society's needs, but it is due rather to errors in the determination of our bearings. Our courses are not properly charted. Society has asked us to educate its future members and we have responded by giving them what we call subject matter that too largely is inutile, hence the social criticism of our work.

Our modern civilization differs from the ancient in its scientific aspect; it is doubtful if our appreciation of art or literature is so far superior to that of some of the eras that have preceded our own. There is no doubt, however, that we are immeasurably superior to all in science. Our work in the schoolroom must take its direction from the needs of the present age.

Naturally, in science instruction, at least theoretically, we conform rather more closely to this spirit. In the study of art and literature, though not expressed so boldly, the veiled aim seems to be conformity; in science, the open aim is, or primarily ought to be, the Truth, the Eternal, the Unchanging, without regard to conformity or nonconformity. In this, the best or the highest will not suffer.

In life from his earliest years, the pupil has been engaged in acquiring facts and in endeavoring to fit these into his system of life. He is confronted daily with phenomena and crises unknown to him previously and upon these he must act and upon his decisions he must succeed or fail. In the schoolroom, the pupil has been concerned too largely with the thoughts of another. Leaving his own thoughts, he must learn from a text

what another has thought and to this he must conform. From another he must endeavor to guide his actions and to derive his judgments. Is it any wonder that the child fails? No other has lived his life, no other knows his life, his mental content, but another must decide for him. As teachers, we are considerably at fault in this respect because of our insistence upon the authority of the text, or upon our own authority. The child is taught to disregard his own opinions, to subordinate them to, or at least to subscribe to, those of his superiors to such an extent that it has been charged that we as a people are in danger of mental atrophy through the disuse of our mental capacities. That the child and the inferior should be guided is axiomatic. The spiritual, the mental and the physical welfare of such demand that he must know and must respect, in so far as is possible, the "best that has been thought or known." To this extent we must recognize authority, but it is the insistence upon the lesser authority that, carried to its extreme, develops the inferior mind, one that must know another's thought before it may dare to formulate its own. How frequently we must recognize this in the classroom when in recitation we receive at first from the pupil only a meaningless jargon of words expressive of nothing. The pupil has endeavored to recall the authority, has succeeded but imperfectly and has not dared to substitute his own thought, with the result that we receive this jumble expressive of neither the authority nor the respondent.

To such instruction, too largely a goodly part of our secondary and, may I say, also our higher education tends. The province of science, I believe, is, in so far as possible, to counteract and to repress this tendency. Science abjures authority, in its realm it is sufficient unto itself. For another's opinion as stated in the text, we properly confront the pupil with the phenomena itself and ask him to formulate his judgment concerning it. His first introduction to the subject matter or content of his course is the reality itself and from this he proceeds to the expression of it. It is in this that our science instruction differs from most other forms. It is this converse method of presentation that involves the student in so much difficulty in his first courses in science. He is unaccustomed to this method in the schoolroom. His tendency is to perform his laboratory work in a more or less perfunctory way and to consult his text, or authority, again, before he ventures to give an expression to his opinion of it. In this he is too often aided and abetted by his instructor for the

purpose of gaining time and covering the required ground. Why should the pupil not avail himself of the information at hand? Carried farther, since our elementary class is not the place for research, why should the pupil do any laboratory work at all? All has been done before, all is known. If when the pupil thus meets with difficulties he is allowed to substitute for his own thought or expression that of the teacher or that of the text, he, in so far as this substitution takes place, nullifies the whole spirit of science and thus is allowed to deprive himself of that for which all our science stands. Why should the pupil concern himself with the action of heat upon potassium chlorate alone and then with the action of heat upon potassium chlorate and manganese dioxid, only later to turn to his text and discover from that that the latter action is catalytic? If this is his method, can we properly justify the time spent in ascertaining this fact so accessible to him? Granted that the experiment is desirable, is not the whole purpose that the pupil should thus discover this fact for himself? He then possesses the fact and also makes himself the master of the method by which he ascertained it. In this particular instance, I believe pretty much of the whole value of that experiment lies in the latter, the method.

Our instruction in the laboratory and in the classroom should be directed less to the inquiry of "what" than to the inquiry of "why." The latter presupposes the former, where too frequently the instruction of the pupil entirely ceases. In our newer forms of instruction, we are directed to turn our instruction away from those things that heretofore largely have occupied our attention and to direct them into more "practical" channels. It is desirable probably that we should do this, that we should, for instance, teach by "project" whatever this may come to mean.

By such "practical" instruction the pupil probably may gain something, but if the method of instruction remains the same, both the pupil and the instructor may find that they have been lured over the stile into Bypath Meadow, and they will sooner or later be confronted by Doubting Castle and its grim occupant, Giant Despair.

It matters much less what we teach than how we teach it. A remark attributed to one of our most eminent chemists is that, the best course in science he ever pursued was first-year Greek. Here, evidently, the value derived consisted not in the content, but in the method of the course. By the introduction of laboratory work into our courses, this method is to a certain extent

realized. The word "introduction" is used here with a full realization of its import. The pity of it is that it is also recognized largely by our pupils. With an acumen, not often attributed to them, they recognize too frequently the futility or the inutility of this part of our work and give it the attention that it properly merits.

Relation of the work in the laboratory to the realities is most highly desirable for the purpose of dispelling the listlessness or perfunctoriness of our pupils. They should be made to see that the work possesses more than an academic or purely scientific value. The interest of the pupil ought to be considered on its merits in the selection of our laboratory work, but it should not be made the sole guide. The danger lies here in that we are likely to o'erleap ourselves and fall on the other side. The exercises should be selected because of their general relation to the entire course, that they may serve as a means of mental development and that they may illustrate certain desirable principles or phenomena. If at the same time we can interest the pupil, well and good, the pupil is the gainer in that the normal resistance to the educative process is by this interest so much lessened.

By making this interest, however, the criterion of desirability, the pupil then becomes the judge of the value of the work; this, needless to say, is improper because of his inexperience and his general incompetence to assign to the various exercises their true values. The interest motive is a powerful ally of the instructor and should not be disregarded. Whenever possible, the exercises should present to the pupil a real problem, the purpose of which is not, however, the possession of the fact that presents itself in its solution, though possibly we may allow the pupil to regard it in this light. The true purpose is to develop the capacity of the student by making him observant of small differences; by causing him to find definite relations in phenomena apparently widely diverse; by making him assign to the varying conditions their relative values; and, finally, he must be led by his own processes of method and thought to a correct and unbiased expression of the observed phenomena or its causes.

In the classroom, our concern is mainly the same but our method should be somewhat different. What are we to do for the pupil as he thus meets us? Our great function is to teach the pupil how to live. When we consider the complex activities of life, how may we live best with the greater part

unknown to us? We may live only by noting small differences and likenesses and predicating of the unknown what we have observed of the known. In other words, our greatest aim in science is generalization. The details must, in greater part, remain unknown always to the most of us, but upon this we must proceed, nevertheless, to formulate our judgments. In our first steps our methods must be inductive. In our life, in our application of these principles, our method is deductive, but induction always precedes deduction. By this continuous method of presentation in the classroom, we must bring the student to an understanding of these relations. The first method we must employ in the establishment of our principles and the second in our application of them to life. Here it is most largely that we must connect our subject and our laboratory work that has ordinarily preceded it to the world's realities and to the life of the pupil particularly.

Inductively, the laws of Boyle and of Charles grow readily out of the experiences of the pupils, and should come to them only as a more definite statement or restatement of well-known conditions frequently observed by them. By rather definite questions, Avogadro's hypothesis follows very closely upon this presentation, and, by the presentation of facts in their proper order, the student is quite ready to venture as his own explanation of the observed phenomena that the solution *may* lie in the fact that "equal volumes of gases * * * contain the same number of particles or molecules." For such presentation the teacher must bide his time until he has accumulated a number of facts that demand explanation, and must awaken in the mind of the pupil a desire to know why such phenomena occur. He has then overcome in a large measure the necessity of trying to impress upon his pupils the reality of his subject. The reality exists and is recognized by the pupil before it is presented formally. Our classroom work should deal largely with the "why," in so far as this can be presented. Comparatively early, before our course is half completed, we should rise to the heights of our subject, in that the pupils should become acquainted with our greatest generalizations, and they must be taught to watch for these and to recognize them, if possible, however obscurely they present themselves.

One great aim must be recognized, in addition to those above named, definiteness and accuracy of expression. Dr. John H. Finley, in a recent address, stated that he found

in untruthfulness three underlying causes—first, ignorance of the fact; second, a deliberate misrepresentation of a known fact; and, third, an inability to state a known fact through the inadequacy of expression. With all of these conditions the instructor must deal. The best interests of society demand of us that we inculcate in those with whom we come in contact the truth, that society itself may benefit by its more extensive promulgation. It is not enough that we inculcate alone the desire for truth. By this alone society would advantage; we must disclose the truth as we see it and we must prepare others that their vision may be more keen to extend our horizon and our ken more widely and they must be prepared to give expression accurately to their brightest visions. To a certain extent, we minister to this aim in our demand for laboratory reports accurately and carefully presented. In the classroom it is again more particularly our province to demand accuracy of interpretation, possibly first, but first only because of necessity, that is, first in point of time, but not in importance, then accuracy in the expression. This expression must be the expression of the pupil, not of another, not the expression of the text, nor of the authority, but of the fact. It is our business to see that the pupil is confronted with the fact or phenomena first and then is able to proceed to an accurate and complete expression of it.

If we can to a certain degree increase the capabilities of our pupils along these lines, I believe we need have no fear of the accounting demanded of us by society. They then will join with us and will ask that the allotment of time to science may be increased and that its hands may be lifted up and sustained until the going down of the sun.