School Science

VOL. II] MARCH, 1903. [No. 9

PREPARATION AND TRAINING OF THE TEACHER OF CHEMISTRY.*

BY DR. LYMAN C. NEWELL.

State Normal School, Lowell, (Mass.)

A recent number of a popular educational journal contained the following significant statement: "One becomes weary of listening to the numerous descriptions of what the teacher ought to be, when teachers are and will continue to be just ordinary mortals." At a first glance this assertion seems true, but a more careful consideration leads us to conclude that it is a specious half truth. The programs of educational gatherings during in the last five years in this country and in England have had one marked characteristic, viz., an unusually large number of papers and addresses on the art of teaching. This is specially true of those meetings devoted to science. At the meeting of the American Association for the Advancement of Science held at Denver in August, 1901, seven papers on the teaching of chemistry were read before the Chemical Section, one of them being the annual address of the vice-president and chairman of that section. These papers covered all branches of pedagogic chemistry, and their presentation confirms the view that, however weary some may be of hearing what a teacher and teaching should be, all are not disposed to ignore the public presentation of this means of improvement.

* An address delivered at the Sixth Annual Conference of the New York State Science Teachers' Association held at Syracuse, N. Y., Dec. 27-28, 1901.

Progress in teaching comes largely from consultation, comparison and publication. Bad methods can never be eliminated by concealment, nor can good ones be spread by hiding them under a beaker or in a water bath. Methods need constant regeneration. Education, specially in science, is evolutionary. There are few long steps, few sudden leaps in our work. We must keep moving; the fountain must be constantly playing. Cessation is stagnation. I hope the time will never come when we can not talk, write, consult and argue about our work.

Teachers of chemistry need a broader, more uniform, and more accurate knowledge of the fundamental facts and principles of chemistry. The foundation is essential to the stability of any superstructure. If our knowledge of the fundamentals is uneven, or out of plumb, then our superstructure will be rickety and in danger of cracking or of falling over at some critical moment. Several reasons lead me to emphasize this factor in considering the preparation and training of the teacher of chemistry.

At the last meeting of the Johns Hopkins University Alumni Association of New England a classmate, who is connected with a large college, said, "The weakest part of our course in chemistry is the general inorganic for beginners." This is true, no doubt, of many other colleges. Several unfavorable conditions attend the instruction of beginners in chemistry in college. The laboratory sections are often too large to permit individual instruction, the text is usually presented to indifferent listeners in the form of entertaining lectures or of an intricate outline, and the course itself is often condensed to ridiculous brevity in order to conform to the unavoidable restrictions of the curriculum. It is true that these conditions are sometimes unavoidable and that the department of chemistry is only partly responsible for them. Nevertheless, the students suffer, and too many graduate from college inadequately prepared to teach elementary chemistry, because their instruction in that portion of the subject has been irregular. It is as true of chemistry as of most subjects, that we know best what we studied last. And many a recent graduate attempts to force his latest work on suffering and helpless beginners. President Remsen once said that when he left the University of Tübingen he could teach the most advanced organic chemistry better than the elementary inorganic chemistry. In many colleges the student passes directly from general chemistry to qualitative analysis, then to quantitative analysis, and finally to organic chemistry or some other advanced work. Seldom does he have a chance to review his general chemistry from a broad standpoint. There is a tendency in some institutions to remedy these defects, and before many years students while in college will be able to lay those broad foundations which are so essential for effective teaching of elementary chemistry.

A second reason for emphasizing the necessity of a better knowledge of the fundamentals is that in the last five years such an enormous number of facts has been literally hurled at us that those houses which are built on the sand are in danger of being swept away. Physical chemistry, electro-chemistry, chemical inactivity at low temperatures, dissociation at high tempera- atter inert at all temperatures, radiant energy, molecules of eight atoms, molecules of a single atom, and liquefied gases galore have been suddenly thrust on us. I am not a foe to these newer conceptions, nor am I indifferent to the magnificent results obtained by such men as Ramsay, Nernst, J. J. Thomson, van't Hoff and others. But important as these topics are and will become, they should not be allowed to usurp or obscure our conception of the foundations of chemistry. A teacher in a large high school was asked by the writer what use he made of the theory of electrolytic dissociation. He replied, "I did considerable with it last year, but this year I shall do very little because my pupils did not see so much in it as their teacher did." Doubtless a similar vision of the situation led one of the best known teachers of chemistry in this country to say in the preface of his latest book, "In the opinion of the author the time has not yet come for the abandonment of the study of the elements and their compounds in what some are pleased to call the old-fashioned way. Indeed it seems essential that such study must always form the basis of the higher or spiritual study of chemistry." In a few years, no doubt, many of the simpler aspects of physical chemistry will form a part of our elementary courses in chemistry and must therefore be assimilated by teachers, but since physical chemistry is now only a part of the superstructure, it should not be mistaken for the whole edifice. Only the teacher who has a broad knowledge of fundamentals can appreciate the meaning of new details, for such a one alone can determine the value of component parts of the whole. Comfortable teaching is based on an accurate knowledge of the first principles, it rests on unshaken confidence in the primary truths. The teacher who lays the foundations wide and deep need never fear overthrow. On them he can build with assurance as high and attractive a superstructure as desired. A teacher runs no risk of being left behind in taking a year or more to strengthen the foundations. He can easily catch up with the facts, and as he moves onward these facts will find a logical and permanent location in his mind.

A convenient and efficient way to obtain a knowledge of the underlying facts and principles of chemistry is by a judicious and thoughtful study of one of the large manuals of chemistry, such as Remsen's, Mendelieff's, or Freer's, Newth's, Richter's, or Roscoe and Schorlemmer's. Working familiarity with any of these books is an enviable acquisition. They are reservoirs from which we may draw our supply at any time. Make a business of it. Take a year for the task, if necessary. Read with a notebook at hand, or better still mark the margin of the book itself. Determine to remember where and how the facts and principles are treated. Imbibe the spirit of the author, see the truth from his standpoint. Do not be satisfied till the task becomes a pleasure. Gradually the whole panorama will come into view, facts hitherto unknown will assume their proper relation to the whole subject, experiments which one may have thought were his own discoveries will be accredited to the rightful discoverer (possibly Boyle or Lavoisier), laws will reduce themselves to that beautiful simplicity which is an expression of an harmonious nature, theories instead of being mere guesses will inspire to deeper thought and perhaps to intelligent experiment, and out of the vast mass of facts, laws, hypotheses, and theories a foundation will unconsciously be laid on which can be built with confidence and skill a superstructure in which ideas new and old may be harmoniously, artistically, and truthfully incorporated.

The preparation and training of the teacher of chemistry should not be confined solely to this science. Interest should be stimulated in allied sciences. No single science is an independent unit; all overlap. Chemistry has some connection with all the physical and life sciences. Together with physics and pure mathematics it forms the great triangular foundation of physical science. Hence a general knowledge of other sciences is not only helpful but to a certain degree necessary to the successful teaching of chemistry. Such a knowledge keeps one from becoming warped and prejudiced in his judgment of the methods, value, and significance of other subjects in the curriculum. Love and enthusiasm for chemistry should not mean contempt and hatred for physics or biology. In answer to the question, "Do you prefer to teach another science besides chemistry?" 19 out of 20 representative teachers in Massachusetts replied "Yes." Those who taught physics invariably regarded this additional work as helpful. The speaker has found physics and mineralogy exceedingly helpful in interpreting many phases of general inorganic chemistry. A science needs a margin, a sinking fund, a reservoir, just as a picture needs atmosphere or a poem needs inspiration. A knowledge of perspective alone will not make an artist, nor will a knowledge of prosody make a poet. And it is just as true that a knowledge of chemistry alone will not make a good teacher of that science. We need "the more" to apply "the little," something beyond the subject to teach subject-matter. Our point of view, our estimation of values, our humor, our judgment, our mental horizon, our general reading, and our hints for the pupil's reading, all these really depend on something outside of mere chemistry. Photography, astronomy, mineralogy, geology, and physical geography stimulate interest in certain aspects of chemistry. This margin, this finish, this better part is that indefinable something which places the inspiring teacher on the right hand and the dull pedagogue on the left.

Probably most teachers of chemistry have at one time or another studied other sciences. It is advisable to arouse this dormant interest and to acquire a generous sympathy, a working knowledge of these sciences. This may be done by reading the scientific journals, such as *Science, Scientific American, Popular Science Monthly, American Journal of Science, Journal of the*

Franklin Institute, and by all means the latest journal, School Science. Avoid newspaper science. It is usually downright absurdity or barefaced error. A few hours' judicious reading during a month will suffice to keep pace with all that one need know of other sciences. Form the habit of reading these journals and stick to it. A German professor was once asked about the progress of a former student. He shook his head and replied, "*Ach, er liest nicht mehr*" (Alas, he reads no more). Let us take care that we are not similarly condemned.

A few years ago the New England Association of Chemistry Teachers sent out a list of questions, mainly to New England teachers, covering all phases of teaching. Among the questions was this one, "What is your aim as a teacher of chemistry?" An answer which typifies the aim of the best teacher was, "To teach pupils a love for truth and for the science, and to develop a scientific spirit." A most desirable requisite which teachers themselves need is a scientific spirit, or, perhaps better, a scientific attitude of mind. The distinguishing feature of science teaching is not merely the provision of an opportunity to observe, conclude and record. Its vital object is to create and foster a scientific attitude of mind. The highest attainable result will follow, if a scientific spirit is aroused.

That attitude of mind called scientific is hard to describe. One of the most scientific teachers of chemistry in the United States said, "It is asking a great many questions, but few foolish ones." Some of its attributes are a determination to know all the evidence before pronouncing a judgment, precision in thought and statement, a desire to deal with the thing itself, not trusting to secondary sources, unshaken confidence in the triumph of truth, fearless abiding by tested results, willingness to change our conclusions when new evidence is presented, disbelief in the traditional superstitions and nonsense of our ancestors.

Sometimes contrast makes a subject clearer, and possibly the term scientific may be made clearer by illustrating an unscientific state of mind. To deny the truth of what displeases us is unscientific. It is also unscientific not to admit our errors, specially our published errors. It is likewise unscientific to accept elastic theories. Prout's hypothesis, the evolution of the elements from a single element, and theories which violate the laws of thermodynamics belong to this class. It is furthermore unscientific to jump at conclusions which we would like very much to draw, if we only had sufficient evidence. How many new elements are annually announced! How many new discoveries are daily heralded which will set the earth spinning from the east to the west as soon as the pseudo-discoverer has obtained a little more evidence! We need more chemists like Morley and no more physicists like Tesla, we need more astronomers like the late lamented Keeler and no more like—well, I must not be captious. I am sure the point is clear.

Probably no general rule can be prescribed for the attainment of a scientific attitude of mind. Yet it can be cultivated. One of the best ways to acquire and foster it is to do some original work. It matters not how extensive or how slight the work, provided it possess the element of originality. Nature by some inscrutable law has decreed that we can learn only of and through ourselves, no one else can learn for us. The soul itself must come to a consciousness of the truth before knowledge is a possession. Every bit of original work coins knowledge. An original demonstration of the hitherto unknown properties of a chemical compound is worth more to the experimenter than a vast mass of memorized facts. The construction of a new piece of apparatus or the improvement of a method demands continuous exactness of thought infinitely more helpful in acquiring a scientific attitude of mind than can be gained by the remodeling of the whole scheme of qualitative analysis. One reason, I fear, why some teachers shrink from the performance of a few simple experiments demanding exact weighing or measuring is their inability—or would I not better say unwillingness—to carry out the train of reasoning involved in such work. A few hours a week—part of our wasted time—spent in the performance of some original work will soon give that attitude toward teaching science which a judge has in the trial of cases. It will give a mental grasp which is comprehensive enough to perceive the exact value of evidence. It will bring one face to face with truth.

It is imposible, however, for all teachers of chemistry in secondary schools to do research work. Numerous duties consume all spare time, apparatus and materials are not readily obtainable, and books and chemical literature are not always available. On the other hand, it is possible for such teachers to do some work possessing the element of originality. The simplification of apparatus, the wider application of new methods, the qualitative examination of some mineral, rock, mineral water, or industrial by-product offer ample opportunity for original work. Again, if no such work can be done, the teacher should write. Exactness of statement is a mark of exactness of thought. And exactness of thought may be acquired by critical writing. Put your thoughts into accurate language. Tell us about some interesting natural phenomenon in your locality, an example of chemical erosion, a piece of apparatus which has helped you over a hard place, write a brief biography of some of the living chemists, tell us about anything which interests you. What interests you will surely interest someone else. A managing editor of *The Sun* (New York), when asked by a correspondent what to write up, replied, "Anything that interests you—nothing else." Stevenson always carried two books in his pocket, "one to read in and one to write in." Publish what you write, read it before some association or to a friend. Help overcome the false notion that a scientist can not write clearly and entertainingly. Help make it impossible or at least untruthful for an editor to announce in a prospectus, "We assure you that these articles on science will be both good writing and good science, a combination that is unfortunately too often lacking."

Till about a decade ago chemistry was taught in high schools almost exclusively by a textbook. The pupil studied the book, recited what he had time to memorize, and occasionally listened to lectures or talks by teachers who often did some experiments. This unscientific method of teaching the science of chemistry began to be abandoned about ten years ago. Some schools went to the other extreme in allowing the pupils to do all the experiments, while the teacher did the studying and reciting. Fortunately the evil effects of this second unscientific method of teaching the science of chemistry were soon discovered, and it is gradually being replaced by a judicious combination of individual experimental work done by the pupil, study, explanation, and recitation of textbook by the pupil, and informal lecture instruction by the teacher. It would be profitable to discuss the bearing of these three elements on the preparation and training of the teacher of chemistry, but the discussion will be limited to one phase of one element, viz., the supervision of laboratory work.

It seldom happens that a method of teaching changes suddenly, but when the change is abrupt, the application of the new method is attended with more or less misfortune. The laboratory method of teaching chemistry came on us rather suddenly, and in many schools its use has not only been injudicious but unprofitable. We know very little about its psychology and still less about its ethics. Many teachers can not account for their failures, and hence they are not slow to condemn the laboratory method, whereas it is the fault of the teacher, not of the method. Though my views on this question have appeared in print, I can not refrain from repeating some of them, because I believe the failure to grasp certain psychologic principles accounts for much of the aimless work done by pupils and for some of the unrest, discomfort, and inefficiency shown by many teachers in all sections of the country.

Laboratory work is concrete labor. It employs the hands as well as the head. Concrete labor is difficult to shirk. In studying history, geometry, or language the mind easily wanders. But when the mind is following an experiment in the laboratory, it does not readily ramble. Something is constantly happening; the mind being carried quickly from concrete to concrete has little or no time to roam. Apparatus must be arranged, chemicals collected, the experiments started, watched, controlled, or stopped. If, however, the teacher or the principal does not favor laboratory work, if the program restricts the experimental work to a pitiable minimum, if the teacher persists in explaining in the classroom what the pupil can think out unaided in the laboratory from his own data, then it is folly to expect the laboratory work to yield mental results. There must be enough carefully prepared and judiciously supervised laboratory work to prevent the normal tendency to shirk, as well as to teach the pupil the supreme value of mental self-reliance. Again the experimental work must be dignified enough to command the self-respect of a thoughtful pupil but not so difficult or repulsive as to frighten him, for in either case the tendency to shirk will be hard to overcome. Furthermore, the laboratory work must be followed up by searching questions, for if the pupil once gets the idea that he need not think after he has completed his experiment, then you have opened for him a broad avenue for shirking. Each pupil should be taught at the earliest possible moment that he or she may be asked any reasonable question on any experiment. If such a spirit prevails, pupils soon learn to get from this concrete labor that invaluable acquisition, so often needed in later life, viz., the power to complete a piece of work accurately, quietly, quickly.

Again laboratory work is suited to relieve mental fatigue. It is restful work, if rightfully performed, because it affords opportunities for harmonious activity. But, if the laboratory period is too long or too short, if confusion reigns, if there is no opportunity for pupils, especially girls, to sit down in the laboratory while writing notes, consulting reference books, or performing slow experiments, if the directions for performing the experiments are brief, long, or so vague that their interpretation demands an excessive amount of mental energy, then mental fatigue will be increased, not relieved. The laboratory work under such circumstances can not afford that mental rest which it is designed to provide. Mind and body will refuse to act normally.

Third, laboratory work is a grand medium for the production of the highest grade of reactive conduct. Reception is followed by reaction, impression by expression. Motor activities are the expression of thought. But, if the laboratory work is inadequately supervised, owing to large divisions, program irregularities, or pedagogic inefficiency, then the reactive conduct will be of a low, perhaps the lowest, grade. The pupil who is called on to be doing something constantly should be stimulated by an environment which will enable him to do the right thing in the best way. Good expression can not come from bad or meager impression. Teachers of chemistry who let the laboratory run itself, who do not help a confused pupil to regain mental poise, who do not realize that beginners need constant advice and direction, are unprofitable servants of the science of chemistry. The teacher's place is beside the pupil, showing him how to form good habits of observation, teaching him the difference between accuracy and vagueness, preventing him from doing slipshod or slovenly work, stimulating him to cultivate mental self-reliance, not telling him facts which he can observe himself, but suggesting legitimate channels for the application of his total power. I recall with pleasure my work under President Remsen, because he never discouraged me when I needed help and he always left me to myself when he saw that the best avenue to escape was through my own mental efforts.

Again, we must not be satisfied because our pupils are curious. Curiosity is a good sign, but at best it is only a means to an end. It should be encouraged at first, but, once active, it should be rationalized. Pupils must be led from curiosity to interest, from mere indiscriminate desire to know disconnected facts to an intelligent craving for systematic knowledge. The transition from curiosity to interest is a critical time for both teacher and pupil. Too often a thoughtless word, an unintentional oversight, or a palpable lack of interest on the teacher's part may upset the delicate poise of the pupil's mind and turn to permanent indifference or reckless curiosity what might have become lifelong interest. Special care should be taken by the teacher to gather up the disconnected observations made by pupils and place them before the learner in such a light that the threads of curiosity will become the fabric of interest. Once interested, the pupil should be led on into the realm of voluntary attention. It is this factor that we all need to develop, for it is of incalculable value in the acquisition of knowledge; it is essential to complete psychic life.

Pupils seldom see the importance of voluntary attention. They are contented to "do experiments" and stop there. They need to be taught the fundamental value of learning to complete with success an experiment requiring patience, skill and confidence. The necessity of teaching voluntary attention is one reason why I believe so firmly that simple quantitative experiments should form a definite part of an elementary course in chemistry. Such work cultivates voluntary attention. As I have watched my classes for several years perform simple experiments involving accurate weighing or measuring, I have been forced to conclude that this work is the most effective way of teaching voluntary attention. It requires an effort of the will for spirited pupils to sit quietly before a balance till the pans stop swinging, to wait for a solution to run down the inside of a burette before the volume is read, to let a thermometer remain in a liquid long enough to assume the temperature of the liquid. But this very effort of the will is needed day after day when the pupil leaves school. It must be acquired, if one is to be a successful worker in any field.

Whatever or wherever our occupation, we shall always need the power to think continuously, work skilfully, and judge accurately. We do not need chemists half so much as we need men who will voluntarily attend to their work. The problems which are coming on us as a nation need for their solution men who have been trained to do things accurately, with dispatch, with a regard for all the evidence, with a profound love for truth, for that truth which is so forcefully exhibited by the laws of chemistry, for that outer truth which arouses in one a consciousness of inward truth.

Closely related to curiosity, interest, and attention is the principle of inhibition. It was thought about half a century ago that certain nerves checked the action of certain muscles. This is doubtless true, but it is a narrow interpretation of a more general function of the nervous system. This conception of arrest has been extended to cover our mental life, irrespective of nerve stimulus as such, and is called inhibition. It is not necessary that an inhibiting idea be specially strong to arrest another idea, for here as elsewhere the mental machinery is delicately adjusted. A strong motor idea may be easily and completely inhibited by a simple and apparently foreign idea. Faint impressions on the confines of consciousness may throw a strong idea completely off the track. Some trivial observation may upset a thought which is seeking expression, and either arrest it completely or so modify it that the final judgment is delayed or even completely abandoned. Pupils should not be allowed to yield to unwarranted inhibitions. Provision should be made in all laboratory work for allowing the pupil's mind to travel without needless inhibitions from the object of the experiment through the manipulation to the conclusion. The work should be so supervised that pupils will see the whole field of consciousness and not yield to reckless impulse or foolish inhibition. Many books now in use actually prevent the mind from acting calmly, continuously, and logically. Experiments to be mentally profitable should be so expressed and arranged that the average pupil can not fail to grasp the title, the exact method of procedure, the essential observations to be made, and the probable conclusion which the observations will permit. The title of each experiment should be known so that the pupil may have an initial idea, a mental start, a guiding star. Unless he begins correctly, he may not, probably will not, end correctly. A knowledge of the exact method of procedure is essential, otherwise he will not know how, when or where to begin his work, nor can he carry it on intelligently, confidently, profitably. A great deal of time is wasted in a laboratory because pupils do not know how to work, and in many cases they are not to blame for this aimless, fruitless labor, because they were not at some time told or shown how to work. They yield to some foolish inhibition or reckless impulse, simply because they see no other path. Again, the desired observations should be indicated in some way. Pupils are learning how to observe; one object of experimental work is to teach observation. Surely we ought not to assume what we are trying to teach. Beginners do not know the difference between the trivial and the important, the scientific and the unscientific. They must be pointed toward the path having the fewest inhibitions, even though such direction reveals some truth which they might possibly discover if sufficient time were taken. Finally, each experiment should lead to some definite result. Otherwise the student is left suspended, is actually robbed of the inestimable privilege of drawing a conclusion. Experience shows, however, that this conclusion must be indicated. It need not be deliberately told, but it can be suggested by appropriate questions. Such questions eliminate inhibitions, they conduct the mind along a logical path, they extend a helping hand to a halting thought, they train the mind to pass from cause to effect.

If you ask how the teacher may attain the power to apply these principles, the answer is simple. Study your pupils and yourself, but yourself the more. The problem has only two unknown quantities—yourself and your pupils. Success depends on the teacher's knowledge of his own psychologic and spiritual life as well as on the discovery of mental crises in his pupils. He must create an atmosphere which fosters calm, deliberate, confident, tranquil mental action. He himself must have passed through the gates of curiosity and interest into the temple of voluntary attention before he can lead others to the same spot. He must acquire that spiritual insight which perceives the truth in himself, he must be constantly conscious of that better self, for it is this unseen self which teaches.

HIGH SCHOOL BOTANY.

BY V. A. SUYDAM.

Supervising Principal, Public Schools, Ripon, Wis.

(*Concluded from page 438.*)

In all subjects we aim first at a mastery of the broad general facts, in order that we may get a perspective of the subject as a whole, and then, if it is pursued further, we study into the details. After the subject has been mastered in its broad general outlines a study of minute details can be taken up with profit, and not before. This study of details is the work of the specialist, is the work that the college aims to do, but which can be pursued with profit only after the student has mastered the broad general facts in schools below the college. Says L. H. Bailey, "The youth is by nature a generalist. He should not be forced to be a specialist." If we