TEACHING CHEMISTRY FOR ITS CULTURAL AND TRAINING VALUES[1]

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TRAINING the intellect and the development of culture are two of the most valuable assets that can be obtained from any educational effort. That the subject of chemistry is an exceptionally fine medium for both of these has been emphasized in our symposium of last year. It is my purpose to attempt to discuss the teaching of the subject of these particular values. They are, without question, of tremendous importance, irrespective of the vocation the student eventually enters or the particular educational level under discussion. I am attempting to think of the subject of chemistry for its general educational values and not as a professional study for the training of chemists.

As both culture and a trained intellect may be understood in a variety of ways, it seems necessary to define these terms for the purpose of the discussion.

By intelligence I refer to those inherent qualities of mind that are used in thinking, and by thinking I imply clear, precise and logical reasoning. This involves a keenness of observation, which is accompanied by the power of concentration and an accuracy of memory, and also an orderly mind, which permits a clearness of thought and a fine differentiation of ideas. Judgment or the careful evaluating of facts and ideas is also implied. As analytical reasoning consists of keenness of observation, concentration on the subject at hand, a careful selection of pertinent data in an orderly arrangement and then a logical treatment toward a conclusion, the trained intellect must necessarily be skilled in logical thought processes and the ability to correlate facts and ideas.

That the subject of chemistry offers exceptional opportunities for intelligence training along these lines has been discussed somewhat at length in our symposium of last year. That it can be so taught is the burden of our present discussion.

Culture on the highest plane implies refinement and an ability to live at ease and understanding in the most enlightened and cultivated personal surroundings. With these go a familiarity and appreciation of the material environment as well as the human one. Among the usual connotations of the word are good taste and a broad general knowledge.

In a past age, when man had much fewer material comforts and the goal of education was to produce a knowing rather than a thinking intelligent man, culture included and required a knowledge of the classics. To-day we appreciate that the chief goal of education is to train the intellect, and our ideas of culture have suffered a corresponding change. We have compiled such a great volume of information that to know all or even to have a knowledge in all fields comparable with the great variety of people with which one comes in contact in the more enlightened society is quite impossible. A philosophical background with which to understand and appreciate knowledge and a trained mind to correlate and evaluate facts and ideas are much more important for true culture than great knowledge.

In our materialistic civilization of to-day with our innumerable gadgets and with constant reference in our books, magazines, newspapers and other publications to such things as Cellophane, hormones, ethyl gasolene, vitamins, lethal gas, heavy water, etc., a cultural development requires a knowledge and appreciation of the material universe and the varieties and transformations of matter. This, of course, is chemistry. Without this an individual can be at ease with neither his material nor human environment.

Culture also demands an esthetic appreciation of the works of man as well as the beauties of nature. It is the esthetic values of chemistry that are frequently not understood. To appreciate the works of man in this age a knowledge of materials is very important. But much more important than the mere knowledge is the understanding of the basic nature of substance. This is chemistry in the true sense. How is it possible for one to have a broad and deep esthetic appreciation of the works of man and nature without it?

Chemistry itself is one of the finest of man's creations. Our knowledge of the constitution of matter, the structure of its atoms and molecules, and the explanation of material phenomena on this basis is without doubt the most striking example of the power of the human mind. While the whole of chemistry is a structure at which to marvel, the individual pieces of creative activity which have gone to make the whole are gems of beauty and esthetic delight.

If one should smile at the comparison of a research accomplishment with a fine work of art, let it be remembered that it requires a knowledge and understanding to have a cultivated esthetic appreciation of artistic creations. The same is true of the creative accomplishments in science, which in a certain sense

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are forms of art supreme. It is this esthetic urge and satisfaction which scientists feel in their work and which gives them their greatest reward.

It is recognized to-day that the development of an understanding and appreciation of art is of greater moment for general education than the attempt to force all students to become creators of art. The same is true of the sciences like chemistry. Let us reserve the training of the creative or professional aspects of it for those who demonstrate a marked inclination and ability for it.

Although associations on the highest cultural level are reserved for the few, an understanding of the material universe and a foundation in its chemical aspects are of perhaps even greater value for those who find themselves in more ordinary society. The subject offers considerable value in cultural improvement for them, as material considerations play a more prominent part in their lives.

Can chemistry be taught to those students not interested in a career in science in a manner that will develop the cultural aspects of the subject, produce an appreciation of it and at the same time act as a medium for training the intellect? I believe it can. For cultural purposes it is not sufficient to cite numerous facts, interesting or otherwise, and insist upon the student memorizing them, only to have them gladly forgotten at the first convenient moment after the examination. The theoretical aspects must be emphasized, the philosophy of the subject developed and the thought processes made clear. The subject can be rigorous and profound without being technical and involving great masses of facts to be memorized. In this way it is more truly interesting, for the student is most interested in material upon which he can apply his own thinking abilities. The subject thus taught for the greatest cultural development is at the same time the method of teaching for the best mental training. I also believe that the subject taught in this manner is the best method of use for those whose use of it will be professional. The technical aspects can and are given later.

The science of chemistry has greatly changed in the past fifteen or twenty years. From a more or less descriptive science it has developed into a precise and theoretical one. It is philosophical in its outlook and demands much more thought and reasoning than pure memory. It is to-day a much better medium for both cultural development and intelligence training than it was a decade ago. It not only embraces the old subject of natural philosophy, but it is also the basis upon which our modern material improvements are made. It is not only esthetic and philosophical but extremely practical and practicable. Surely an intelligent, cultured individual requires some knowledge of it, and as surely there is a way of teaching it which will develop intelligence and culture and at the same time be extremely interesting.

The major content of such a course must necessarily be the theoretical structure of the science. It must emphasize the hypotheses upon which the science is built, and many of these have now been so firmly established as to be regarded as truths. It must stress the thought processes involved in the correlation or explanation of phenomena. It must build the science not upon a chronological or historical basis but in a consistent logical fashion. Naturally its chief aim for the beginning student is to instil in him the concepts of the atom, molecule, ion and electron (not to mention the neutron, photon, etc., which have not yet been sufficiently investigated to be included in an elementary course). It should attempt to develop in him the ability to think in terms of these primary particles of matter and relate its macroscopic properties to them. At least an introduction to the elements with their relationships and those of the simpler molecules formed from them should also be given. It should include a consideration of the properties of matter in bulk and show the correlation of the physical properties of the different states of matter with their structure of the primary particles. In other words, it should attempt to rationalize matter in the minds of the students. Modern chemistry is taught in this manner.

Such a rationalization tends to make the individual more at home in his material environment and develops an understanding and appreciation of the substances of his civilization. It also gives the basis for the esthetic appreciation of material structures. This is true cultural development.

As more emphasis is placed upon the thought processes than upon the factual material, this is also the way of teaching the subject for its greatest training values. Mental development, that is, training the mind in logical thinking processes, should be the prime goal of education, irrespective of the level.

There must necessarily be given a certain amount of factual material upon which to build the thought structure and with which to illustrate the principles. This, however, should be drawn as far as possible from that mass of chemical facts that can be considered necessary for the cultured, educated person. He should know the chemical basis of ordinary and frequently used substances. Modern chemistry is, however, not taught by reciting to the student, either in the form of lecture or text, a mass of facts, irrespective of how essentially interesting and amusing; and then requiring him to parrot these back in the form of recitation or examination. This might be the easiest method for the teacher, but it surely is not teaching the science of chemistry. I understand that this has been done in some so-called "cultural courses," but

emphatically it is neither cultural nor chemistry. Unless the subject is somewhat profound and rigorous it can be neither.

A certain amount of problem work is necessary in chemistry in all educational levels to develop the quantitative and exact side of the subject, but for the best teaching this is not of the nature where the student substitutes numerical data in some given formula and obtains an answer without any thinking processes involved. Mathematics is used in the science as the language of logic but not as a substitute for it. The more problems used of the thought-provoking nature the better the results of the teaching.

It is my opinion that certain factual material can be left out of the general courses, or at least given but little emphasis. These include the history of the science, biographies of famous chemists and descriptions of industrial processes. These may be brought in by the teacher on occasion to illustrate some point or enliven the subject, but surely the student should not be held for them. They are of unquestionable value and interest in themselves, but there is not sufficient time to really develop the subject adequately and deal with them also. For the specialist they are of greater interest but should be given some time late in their training. For cultural and training values they are of much less importance than the science itself. They are sometimes included in courses for general students for the purpose of exciting interest. I question the value of this, for the subject is of greater interest without them. The student is apt to look upon the history as just more names and dates to be memorized and upon biographies as the lives and works of some old fogies. The industrial processes given in some texts are unquestionably out of date and frequently only represent more memory drudgery to the students. When those things are brought in informally by the teacher from his background, it enlivens the subject much more than when they appear in the text.

Obviously the teacher at any educational level must have a much greater background than the subject at that level. To teach modern chemistry a philosophical rather than factual minded individual is required. To teach it for its cultural values requires a person with sufficient knowledge of the subject to have a keen esthetic appreciation of it. To use it for its training value demands an active thinking individual. As the subject contacts so many of our other fields of knowledge, a teacher with a broad knowledge can make the subject a better medium for cultural development than one whose background is more limited.

Our best teaching is done in the laboratory, for here the student and teacher come in intimate contact; and the student is kept actively at work mentally and physically under the guidance of the teacher. It is here where we accomplish what some of our greater universities are attempting in their tutorial systems. For training purposes it gives us our best opportunities. As it develops a realistic familiarity with substances by intimate contact, it produces a sounder appreciation of them than lecture or text-book material. It is this appreciation which is of such great cultural value. In modern chemistry courses the laboratory is not conducted by giving the student recipes for his work, which he follows blindly. Selected problems are given, which require the student to think about what he is doing and how he is doing it. Frequently, he is guided by means of a set of questions. What could be a more ideal way of teaching?

In some circles the opinion is or was common that the use of the hands is unrefined and menial. This is quite opposite from the truth. The anatomical structure of man's hand and arm, which make them such a uniquely useful organ, is quite probably the basic cause for the development of the brain. Man's hand is just as superior in flexibility to analogous organs of animals as is his brain. In the history of civilization the invention of new tools has either preceded or paralleled new ideas or philosophies. Performing intellectual tasks through the use of manual processes is one of the best means for mental training. It makes the material more intimate and realistic. For this reason also the chemical laboratory, with instruction given from a modern point of view and designed particularly for training and development rather than for the accumulation of facts or performing routine, is an excellent means for the achievement of cultural and training educational values.

In order to use the subject educationally to its best advantage it is not necessary that all the latest facts and ideas in the science be incorporated in the elementary courses. It is much more important to weed out unessential facts, ideas and points of view that have changed with the advance of the science. As the entire outlook has changed in the past decade, it is important that this change be made in our teaching. This requires that we treat the subject on a logical and philosophical basis rather than a factual or descriptive one. As it is on this basis that it is the better training and cultural medium, it is especially important that it be treated in this manner for the non-professional students and on the more elementary levels. It is my opinion that students in general have a keener interest and appreciation for the philosophical aspects of school work than most teachers recognize. Taking advantage of this improves our educational effort.

As chemistry is growing and changing at a very rapid rate, it is difficult to keep the school courses up to date. This fact, however, enables the teacher to handle the subject as a living thing. He can disagree

with the text and show how the subject has advanced since the text was written. This disagreement is excellent for the mental development of the student. It creates a more critical attitude and helps destroy the feeling that the written word is absolute truth. As an example, I have a habit of demanding that definitions be made at the time required and not committed to memory with the expectation that they are fixed and inflexible. It is by changing our definitions that advances are made, and I hope to impress this upon the students. In the same way I require that mathematical expressions be derived for the particular purpose at hand and not memorized to use as a mental crutch for all similar problems. I expect the student to understand the ideas underlying the formula so that it can be derived easily at any time rather than committing to memory a group of symbols.

As a cultural subject of the first rank and as a medium for mental development, chemistry has exceptional educational merit. The modern philosophical point of view has made it possible to utilize it much more fully for these purposes. For the most truly cultural use the subject must be made rigorous and sound rather than factual. The laboratory gives the teacher an excellent opportunity to use it to its fullest extent. Because it is so widely taught and because it is of such potential value, we should insist that its teachers be competent and above all be adequately trained in the subject and have its modern point of view.

OBITUARY

EDWIN OAKES JORDAN

EDWIN OAKES JORDAN was born in Thomaston, Maine, on July 28, 1866, and died on September 2, 1936. He took his bachelor's degree in science at the Massachusetts Institute of Technology in 1888 and the degree of doctor of philosophy at Clark University in 1892 where he had been fellow in morphology for two years. Caught in the migration from Clark University to the newly founded University of Chicago, he came to the latter in the fall of 1892 as associate in anatomy. In 1895, however, he was made assistant professor in bacteriology—one of the earliest academic appointments in this country in general bacteriology—and thus began a steady advance (he was given the rank of professor in 1907) and expansion leading to the organization in 1914 of the department of hygiene and bacteriology of which he was the head until his retirement in 1933. The previous year the university awarded him the Andrew MacLeish distinguished service professorship.

He was married in 1893 to Elsie Fay Pratt, who survives him. There are three children: Henry Donaldson, professor of history in Clark University; Edwin Pratt, physician and clinical instructor in Rush Medical College of the University of Chicago; and Lucia Elizabeth, physician and married to Dr. Charles L. Dunham, assistant in medicine at the University of Chicago.

Dr. Jordan soon built up a well-organized center in bacteriology. The number of students, advanced as well as beginners, grew large and many are the bacteriologists now scattered far and wide in various lines of work who received instruction from him and inspiration from his quiet enthusiasm for the advancement of bacteriology. He was a clear, kindly and cultured teacher, placing the emphasis on fundamental principles. He was a master of exact statement. In 1899 he published a translation of Hueppe's "Principles of Bacteriology," but his main contribution in that line is his "General Bacteriology," a leading textbook from its first publication in 1908 and now in its eleventh revised edition. Himself an active investigator from the start, his laboratory was always a focus of significant research on bacteriologic and sanitary problems. He was ever on the lookout for able students who might be trained in research. As the general interest in public health developed his influence increased in widening circles and with it the recognition of the scope and importance of his work.

He took active part in the work of many scientific associations. He was a founder and president of the Society of American Bacteriologists, which elected him to honorary membership on his retirement. In the American Public Health Association he was an influential member of a committee on methods of water analysis, the report of which, a standard of its kind, has passed through several editions. He was president of the Chicago Pathological Society in 1906 and of the Institute of Medicine in 1932. He was for a time a member of the medical fellowship board of the National Research Council and served for several years on the International Health Board of the Rockefeller Foundation and later as a member of the board of scientific directors of its International Health Division. He also served on the council of foods of the American Medical Association. The health commissioner of Chicago leaned heavily on him for guidance, and when the present board of health was organized he was one of its members.

A paragraph may be devoted to his relations to the John McCormick Institute for Infectious Diseases, of which he was a trustee. He was joint editor of the *Journal of Infectious Diseases,* published by the institute, from the issue of the first number in 1904.