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Science for Human Beings

What measure of success?

NOWADAYS we speak of "Science and the Humanities." A century ago we would have said, "The Humanities and Science." We are apt to interpret this change of order as a directive to reduce the amount of subject matter in the humanities to the vanishing point while expanding without limit the offerings in science.

We have ample encouragement to do so. The National Science Foundation apparently stands ready to support the education of science teachers and to fill the laboratory shelves to overflowing with science equipment. We are led to believe that national survival hinges upon discovering and developing potential scientists at a faster rate than we have done in the past. By following this belief we may concentrate so much upon the technical training of youth that we have no time left for the arts.

While we as educators are obliged to listen to advice from the man on the street about what should be included and what should be left out of the high school curriculum, in the last analysis it is our inescapable responsibility to provide the child with a balanced diet of subject matter. As students of the educational process we know that a child develops best in an atmosphere of varied experiences. We know that a program of general education produces better citizens for a democratic society than does a specialized program. We know that a child is a complex composite produced by the interplay of all the experiences he has had. We know that a child is a human being rather than a machine. With these facts in mind we will not be stampeded into adopting a program of education that omits the human equation.

It is difficult to understand why we should rank either science or the humanities first in importance. They serve two entirely different purposes in the educational process. Science is concerned with the mechanics of the physical universe. Through the study of science the student gains information about the nature of the building blocks which make up his world and about the laws which govern their behavior. The humanities

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are concerned with the effect of science upon human beings. After the laws about the behavior of matter have been formulated, then a man is able to make good use of them rather than to stumble along in ignorance while he injures himself against them. We are interested in science because it assists in the maturation of the individual, which is the fundamental purpose of education.

If we want science to serve as a tool in the growth of the student as a person, then we must reexamine the role of the textbook in the teaching of science. In many of our schools the textbook has become the taskmaster dictating the quantity of subject matter that is to be "covered" in each course. The textbook writer must please all of us, so to be safe he includes as much material as possible.

Yet in our wiser moments we know that education does not consist of the quantity of subject matter which is included in a course but of the extent to which we have whetted the appetite of the child to keep on learning as long as he lives.

Firsthand Experience

With the best interest of the maturing child in our minds, we will begin the new approach to science teaching by reducing to a minimum the amount of vicarious experience and by increasing the amount of firsthand laboratory experimentation. This approach to science must take place not only in high school courses but down through the educational ladder to the first grade. It will require a complete change in attitude by the teacher who sees science only in terms of facts and definitions to be memorized. We need to bear in mind that efficiency in learning includes depth of experience as well as breadth of knowledge.

One means of breaking away from complete dependence upon the textbook is to use the method of teacher demonstrations. The arguments in favor of this method are that the teacher can do anything the student can do in much less time, in greater safety and with far less mess. Indeed, it is also far less expensive in terms of needed equipment to carry out one experiment for the whole group than to do thirty individual experiments. As a clinching argument, research has shown that a student will score as high, if not higher, on an examination covering the subject matter content of the experiment when it is done by the teacher as he will when he does it himself.

We need to recall, however, that it is not the efficiency in the learning of scientific facts that is our primary concern. Rather it is the overall effect upon the child of carrying out a scientific experiment that matters. The child who reads in the textbook that wood burns faster in pure oxygen than it does in air cannot fully grasp the excitement which Joseph Priestley felt when he first saw how substances burned in pure oxygen. Neither will he feel much of a thrill of discovery if he watches the teacher do the experiment. In contrast, the child who burns one piece of wood in a bottle of air and another in a bottle of pure oxygen has had a meaningful experience which has all the emotional characteristics which were experienced by Joseph Priestley. The experiment becomes a personal experience in discovery. It makes no difference whether this child grows up to become a professional in science or an interested layman. What does matter is that he has identified himself with the process of scientific investigation.

So that the child may receive the maxi-

mum benefit from this intimate, personal experience, it is essential that all textbooks and reference books be removed from the classroom. There is no duller experience in the name of education for any person than being told what will happen and then being asked to prove that it will take place as described. The driving force of curiosity has been ruthlessly sabotaged. We would consider it unkind to tell a child what he will find in the packages under the Christmas tree before he has opened them. Yet we as teachers see no inconsistency as we painstakingly give away all the secrets of science which he could enjoy discovering for himself. We should recognize this as an inhumane practice.

Honest Reporting

One other value to be realized from the firsthand experience is training in recording observations accurately and honestly, free from the pressures imposed by the textbook. For example, the element hydrogen is described in high school chemistry textbooks as a colorless, odorless gas. After having read this statement in his textbook, the student goes into the laboratory and prepares hydrogen by the reaction of zinc on hydrochloric acid. On his report sheet he is asked to describe the odor of the gas he has prepared. The student faces an awkward decision. If he decides to be honest, he must report that the gas he made has a very distinct odor. If he decides that an "A" on his laboratory report is more important than an honest answer, he suspects that it would be wiser to agree with the description he read in the textbook. He may be puzzled when he does not agree with the author of the textbook but of one thing he is certain from years of indoctrination and that is that the textbook is infallible.

What a glorious opportunity for a thoroughgoing discussion of the variability of human observation has been lost! How much better it would have been to let the student record the odor as he detected it. Unless the teacher believes in the principle of honest reporting wherever it leads, he is denying himself half of the excitement of good teaching.

It is important, of course, that the child not be left with a collection of properties which disagree with accepted descriptions. The teacher knows in advance that the hydrogen which the student will prepare will not be pure. Before he evaluates the student's observation, he discusses with him other ways in which hydrogen might be produced, such as by the reaction of sodium on water or by the electrolysis of water. The student then prepares the gas by several alternate procedures and again records, among other properties, the odor of the gas he has made. He will be struck by the fact that the odor of hydrogen made by different methods is not the same. Under the guidance of the teacher he sets out to discover why and ends up trying to purify his product to bring about consistency in his records. When at a later date he compares the properties of hydrogen as he observed them with the properties he finds in his textbook, he will begin to sense how long and arduous the path of man has been as he has gathered accurate information through the ages to bring us to our present state of knowledge.

The purpose behind individual experimentation is to give each child an opportunity to interact with the materials of his environment under controlled conditions and to uncover for himself a portion of the knowledge which man has gained about the universe. The depth of understanding we seek will consume

a great deal of time both for the student and for the teacher. It calls for a more intimate association between teacher and student and this can be effective only if the teaching load is reduced. The National Defense Education Act has made possible an opportunity for every child to have the raw materials he needs for an individualistic laboratory experience. Once we have accepted the gift of these materials it now becomes our obligation to use them. We have an obligation both to the federal government and to the children in our care.

When we use the textbook as our sole source of information about science we neglect the principle of learning that for the maximum effectiveness all of the child should be involved. As many of his sense organs as possible should be involved. Just as a baby learns more about heat from touching a hot stove than he gains from hearing his mother talk about it, so the high school student gains a deeper understanding about anatomy through the dissection of animal specimens, about electricity through experimentation with a Wheatstone Bridge and about hydrogen by burning a sample of the gas.

The "open-ended" experiment represents our deep seated desire to give the child an opportunity to create, and thus tap the most priceless treasure in the human race. Under this plan the student is told the general area in which he is to work and then is given only enough help to give him a sense of direction. Let us see how this might apply to the study of the properties of oxygen. We would give him several stoppered bottles of oxygen and a wide assortment of materials whose behavior in the presence of oxygen is to be observed. He is told that he is free to try the effects of oxygen on other materials of his own choosing. He is told that he is to add a few drops of water to any bottle in which a reaction occurs and then to test the solution with litmus paper. Finally he is told to organize the information he has obtained into some systematic pattern and formulate any laws of behavior which seem to apply. The teacher has an opportunity to observe how he attacks the problem and how well he is able to synthesize the information he obtains into an integrated whole, as a maturing human being, a process which can never be observed in a laboratory where students spend their time following the unimaginative trail of step-by-step directions.

The measure of our success in teaching science is not to be found in how well the student is able to manipulate laboratory equipment, how well he is able to follow a set of laboratory instructions, how many different kinds of problems he can solve, how many species of botanical specimens he has dissected and labeled, nor how many scientific terms he can define. Rather, the degree of success is to be found in how well we have helped the student see his relationship to the physical world about him, not as a helpless puppet under its control, but as a means for assisting him to grow in wisdom.