Experimental and Laboratory Techniques*

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A traveler in the middle of The Sahara Desert was amazed to come upon a man in a bathing suit. "Where on earth are you going?" he demanded. "Swimming," replied the man. "But," said the traveler, "You're a hundred miles from the sea!" "Yes," replied the other, "Wide beach, isn't it!"

I believe, like the man in the bathing suit, that we teachers *do* have a wide beach before us, and that many of us are yet pretty far inland from where we can really plunge into the sea of true learning by meaningful observations, experimentation, problem-solving, and individually and group-planned research. Many school science departments have yet only scratched the surface of the shared-experience type of learning, where pupil and teacher both participate in becoming educated, gain new vantage points of scientific open-mindedness and functional learning, and explore together the charted and uncharted paths of science.

Yes, the beach *is* wide, but more and more teachers each year put on their swimming suits, and are making slow but steady progress toward the sea. We must shake off, as we go, the cloying sands of traditional academic ritualism, the sacredness of textbooks, the threat of district and state scholarship tests—which so often demand that our pupils become walking encyclopedias of biological facts and nomenclature, and by which all too often the "success" of teachers is measured—and our own natural tendency to teach as many of us were taught.

Early this fall a boy in one of my classes accidentally dropped a few grains of albino-segregating corn, with which he was doing some experiments relating to the influence of light on direction of growth, on some matted plants growing in a large aquarium. Within a few days, he noticed that the grains had sprouted, and were growing rapidly, with their roots hanging down in the water of the aquarium. From this observation, he started on a series of experiments and reference readings in soilless plant gardening, using a variety of seeds and experimental set-ups. Other pupils, working with him, noticed the "fuzz" on the corn roots in the water, and embarked on a study of root hairs and their structure and functions; others began experimenting with oxygen intake; others are since exploring the possibilities for growing albino corn plants to maturity through some method of intracellular feeding with dextrose. And so it goes—each year some seemingly routine experiment or clumsy accident becomes a stimulus for all sorts of project investigations for a large group; in fact, the ramifications of this accidental dropping of corn grains into the aquarium, have constituted almost a whole course in plant biology for us this year.

The use of indoor and outdoor laboratory activities in the teaching of biology is often greatly misunderstood by teachers. We may be convinced that "learn-

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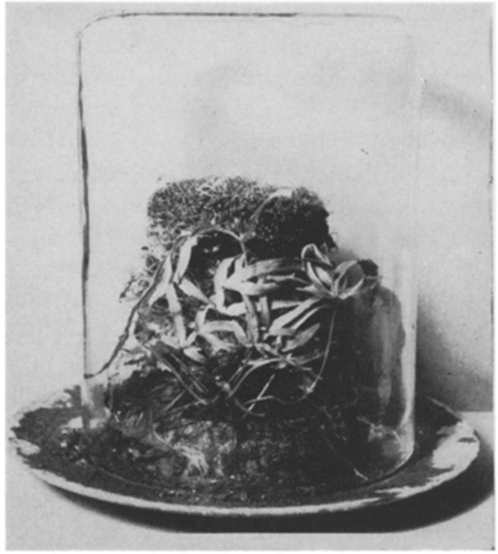
ing by doing" is a valid and workable basic principle of teaching, and so we place great importance on insect collections, blue prints of leaves, dissection of animals, the making of drawings and models—for which we may have very complete and detailed directions—and like activities which involve a great deal of manual work. Thus, we may make a great show of "learning by doing." Certainly we are making much of the first five letters of the word *laboratory*—LABOR—, and have less time for using the final seven—ORATORY! However, if the activity has no intellectual worth, we are pretty much wasting our time. It is intellectual activity, coupled with meaningful manual activity, which makes our pupils wiser and more effective in thinking, appreciating, feeling, understanding, judging, evaluating, accepting responsibilities, willing to withhold judgment until all available facts have been considered, and showing more and more the earmarks of a truly educated individual. There must be developed a genuine spirit of research and investigation, pupil planning and discovery, instead of imitation and blind following, or so-called learning never becomes functional in living.

Last year we found a need for colored charts. The set we had on plant anatomy was in black and white only. After mention was made in class of the desirability of a colored chart of the life cycle of ferns, a boy from our school football squad asked to work on the fern chart. His first question was, "What colors do *you* want on it?" Of course that was the time to say, "I don't know!" The idea filtered through that the type of fern from which the diagrams had been made would be the real source for a color scheme. This chap developed a lasting interest in microscopes, while doing the job, and as a result of his work



—Photo by J. R. Sisco

FIG. 1. A fern spore germinator, made by upturning an old flower pot filled with peat moss in a large dinner plate, beneath a glass battery jar cover.

with a huge old Boston fern borrowed from a neighbor, some clay pots, saucers, peat moss, and fruit jars, devised a set of fern spore germinators (Fig. 1) in which we have a group of little ferns growing now. What started out to be only manual labor of imitation culminated in intellectual ideas and originality.

I have come to believe more and more also that the best science teaching is often done, not by persons who know most all of the answers which pupils ask. Perhaps the best real teaching of biology, or any other science, is done by teachers who understand young people and the basic yet varying patterns of their physical and mental development, who know how to work with them, and who are willing and ready to say, "I don't know the answer to that, but I can help you find out." Teachers who know most all of the answers are often too eager to take the easier way out, *telling* the pupil the answer rather than aiding him in finding it for himself. It is in the devious or simple process of arriving at an answer, or in failing to find an answer, that the most real learning is achieved, and our basic aims as science teachers are approached.

I recall distinctly that school day a few years ago when a man whose encyclopedic learning was astounding to behold, although he was only a mediocre success in his own profession, and who had been exceedingly disturbed a short while before upon finding no one in a class in commercial geography who could bound the Great Lakes (including the teacher, I suspect also), walked into one of my tenth grade classes in high school general biology and asked the pupils to define the word "biology." Not one pupil volunteered a definition, and I believe to this day he has me in his book as one of the slabs of "dead wood" in our city school system's log-pile! I was interested in the reaction of the class and, after the man had left the laboratory disgustedly without attempting to find out what we were trying to *do* together in this group, I asked one little girl why *she* didn't volunteer an answer. Her reply was even more interesting—"I wish he'd stayed an hour or so; we could have *shown* him what is biology; I couldn't just tell the man that biology is the science of life, because something as big as we've found this to be can't be put into such a short few words!"

This same girl was at that time doing a complete study of common molds and their products, and had already succeeded in isolating, pure-culturing, and identifying no less than twenty-two varieties of common molds. Among these, she had isolated *Penicillium chrysogenum* from a cantaloupe rind, a mold which one of the larger manufacturing drug companies announced a few weeks later as the most prolific producer of penicillin yet found. This same girl had worked out a method of pure-culturing by dilution from mixed mold spores, which was quite unorthodox and practical. She continued this project work in her spare time through her junior and senior years, went on to take charge of a university culture room during her first year in college, and then on to heading the technological laboratory of one of our city hospitals. I believe she knew then and knows now what biology is, not from memorizing and parroting back a textbook definition, but by experiencing and using biology. She had also, in the course of her experiments with molds, discovered several errors in the discussion of molds in her textbook.

We must not overlook the appreciation values of biology, as we do indoor and outdoor laboratory work. I once asked a successful business executive what, if anything, he recalled from his course in high school biology. He replied, "Only one thing! On a wintry day, when the snow was falling outside, our biology teacher laid aside a routine textbook recitation and read to us Lowell's 'The First Snowfall.' We then spent the rest of the period outside tramping through a nearby field and woodlot, observing what we could. A class discussion followed the next day which emphasized the effects of a heavy snowfall on plant and animal life, as well as the snow adding to the beauty of the landscape. I date from then my present keen interest in the winter resident birds, their names and habits, and their feeding as a hobby through the winter months."

There are, of course, those few teachers who have gone entirely overboard for field trips, experiments, projects, and other activity-type work alone, losing sight of the fact that, in order to become independent thinkers and problem-solvers, our pupils must have a broad fund of significant information with which to form a background for thinking and reasoning. I am inclined to agree with Dr. Francis Curtis, when he says, "It must be realized that there is no method of teaching that is so likely to be poor as the best one we know, if we use it all the time to the exclusion of all others."

Quite frequently biology is the first course high school pupils contact which has possibilities for providing laboratory experiences. General science courses sometimes provide opportunities for laboratory work for seventh, eighth, and ninth year pupils in some schools, but all too often not and, if so, under poorly trained teachers. It would, therefore, seeem almost obligatory that teachers of high school biology make every effort possible to make the course a real shared experience, and a planned opportunity for the curious and already somewhat scientifically minded boy or girl to expand and grow in the ability to explore, plan, and carry through to completion individual project activities and experiments.

Here lies the opportunity also to encourage and promote future enrollment in the eleventh and twelfth year science offerings, or to continue more expanded opportunities in an advanced biology course.

There is also the known fact that a fairly large number of pupils drop out of school during or at the close of their sophomore year. For these pupils, it is vital that the biology course offer them experience in solving their own problems and developing individual responsibility, so that they may intelligently participate in adult affairs in this scientific age.

I come to believe more and more each year, that the only real biological training we provide, and the only scientific attitudes we develop in boys and girls of any school age, from the elementary school through graduate school, are those which relate directly to actual experience, or to as near simulated experiences as possible. I rely more and more each year on laboratory work, our pupils do a great deal more smelling and tasting, get their hands into a great many more messes, engage in more and more individual and group projects of diverse nature and results, and do less and less poring over books and lesson plans. Our room is a combined laboratory and classroom, with a great variety of home-made apparatus and common materials, a rather completely stocked museum—readily accessible at the rear of the room—and a fairly complete reference library of books, pamphlets, clippings, and photographs for enriching factual background as the need arises.

The need for and worth of such a plan was first made very real to me when I entered the high school field of teaching from a college instructor's job, to do some writing. I was assigned to a room with thirty-two folding chairs, a blackboard, a totally unusable set of technical charts detailing plant anatomy at about a graduate school level, six jars of beef extract, five pounds of agar-agar, a set of prepared microscope slides, and one ancient microscope. The biology classes of the year previous were taught in the balcony of the school auditorium, and so we were highly favored in having a room of our own.

Like the turtle that climbed a tree to escape a hotly pursuing alligator, who was breathing down his neck, we *had* to do something to build up a functional course in general biology. Looking back in retrospect, I believe that some of my most effective teaching was done in those days when we were all—both teacher and pupils—of *necessity* working together to make a biology laboratory course come into being. Some of the boys constructed rather efficient microscopes, using as lenses the curved tips of flashlight bulbs, others collected and mounted for our prospective museum all sorts of native plant and animal life.

Two boys undertook the planning and construction of an observation beehive. They built the first one in their woodworking class, installed a colony of bees, and then found all sorts of changes necessary in design, location, and kind of bees most adaptable to an observation hive. Before the year was over, they redesigned the hive and built another. In their study hall time voluntarily the following year they stocked this hive with Caucasian bees, and again found changes to be made. The following year they built another hive, which is the one we now have in our laboratory, and the working construction plans for which are shown in Fig. 2. The boys now started beekeeping at home. One of them had twenty-two hives in his backyard, and made his bee business pay off enough during the depression years to see him through two years of college. He is now a successful Project Engineer with General Motors Corporation, and occasionally visits us and reminisces over his first successes and failures in scientific experimentation.

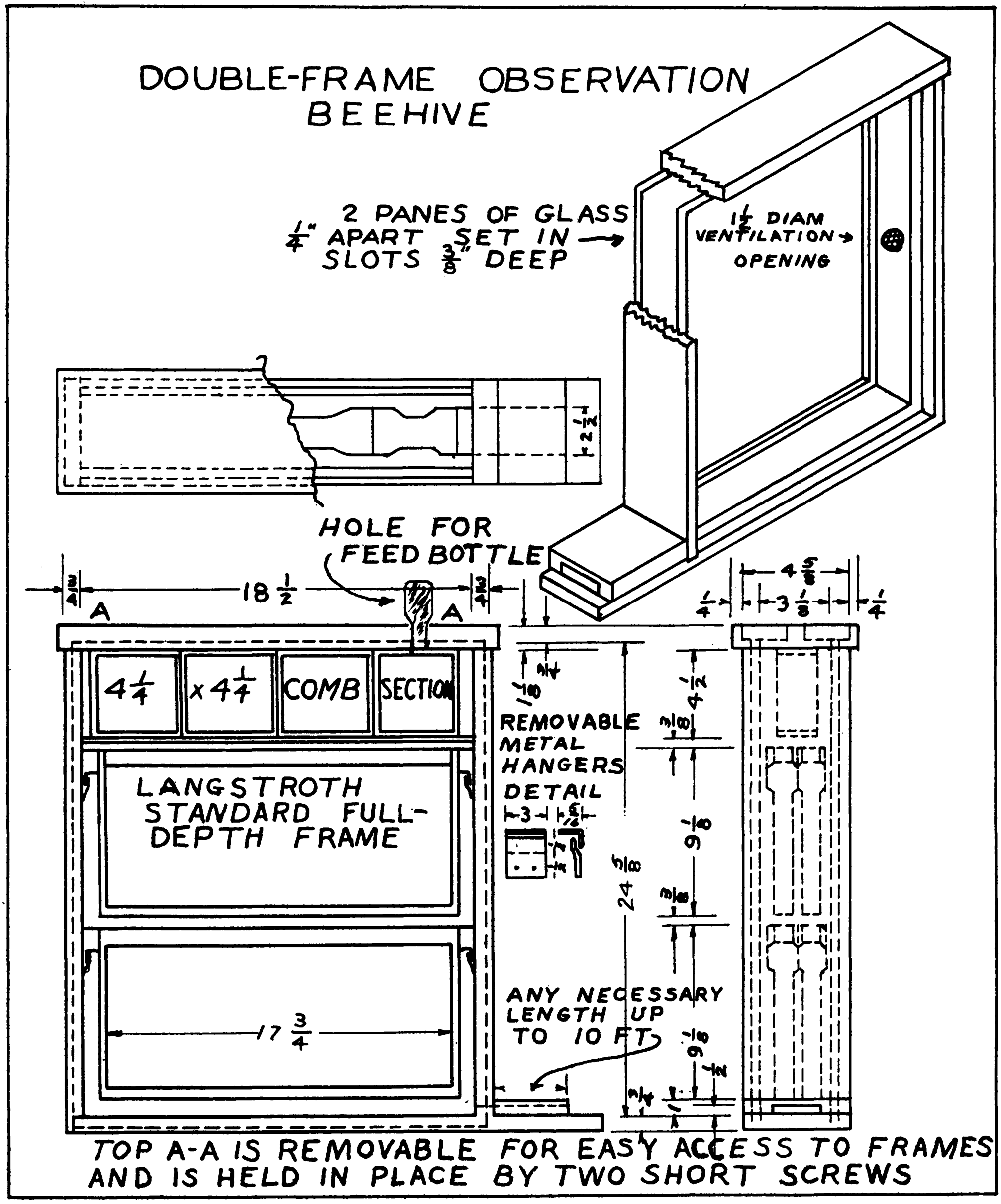
Practically everything we have in our biology room in apparatus, demonstration materials, charts, displays, slides, microscopes, paintings, projectors, and the like—except the furniture and fixtures—are the result of pupils' productive activities over the years in connection with some phases of biological study. They often leave behind, as a contribution, some piece of homemade apparatus, museum specimens, collections, models, and the like as aids to pupils coming along later. Besides the meaningful learning activity at the time, we have a selfish interest in these pupil projects; each pupil seems to take pride in leaving behind some evidence that he or she was enrolled in our school's biology course.

Pupils have constructed a miniature "greenhouse" (Fig. 3), using five glazed window sash. It has an electrical resistance heater-bar, wired somewhat crudely beneath a shallow water pan. The pan contains water-soaked pieces of soft bricks, which supply moisture for a high relative humidity inside the case. We use a homemade thermostat for temperature control. The case has a slatted rack for potted plant cuttings, seed germination tests, water cultures, etc. A growing orchid plant, which we keep in the warm and humid case throughout the year, blooms each year (Fig. 4) in mid-November. Our small laboratory fees paid for the materials which had to be purchased to build the "greenhouse."

As a result of pupils experimenting with bacteria, we have two homemade bacterial incubators, for each of which we purchased only two $0.25 ether wafers for the thermostat assemblies, scrap

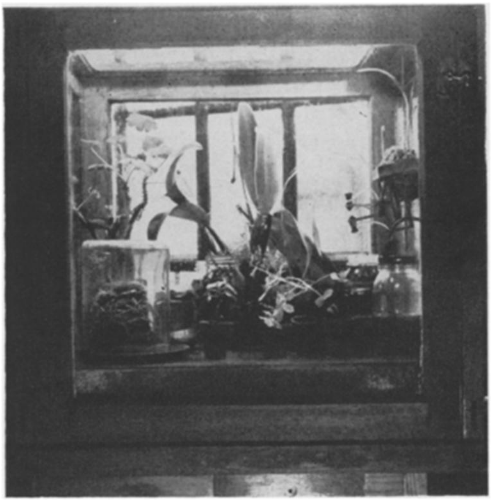
FIG. 2. A narrow board can be fitted under the raised lower sash of the laboratory window, with an opening cut in it to receive the hive entrance. Or a metal funnel may be fastened to the hive entrance, and a section of old garden hose attached to it and run through a hole drilled in the window sash. This allows for the hive to be placed at most any distance from the window. If a hose is used, a flat piece of metal should be fastened just below the outside opening of the tube as a landing, and another piece just above that for protection from rain and snow. The back of the hive should be slightly higher than the front to prevent water running back into it. The screened opening at the rear of the hive is handy for introduction of a queen. The hive is best located on the south or east side of the room.

A stock of bees can be gotten from a local beekeeper, or purchased by the pound from a commercial apiary. The introduction of a new queen into the hive is interesting and instructive. Directions may be given on the package



—Diagram by Forrest Whitescarver

in which she is shipped, or may be found in beekeeping books. The bees may need to be fed during the winter months. Fill the feeding bottle shown with strained honey, or thin cane sugar sirup, and invert the bottle in the opening shown. A small nail hole should be punched in the bottle cap to allow the bees to take the sirup only as needed. An interesting variation of the usual comb structure in the hive is to cut the brood cells in one lower frame into strips, and set them crosswise so that the sides of the outer cells lie directly against the glass. Contrary to what is commonly reported, the queen will lay eggs in these cells, and the young bees can be observed in all stages of development from egg to adult.



—Photo by Sue Neff and J. R. Sisco

FIG. 3. A homemade miniature "greenhouse," constructed of five glazed window sash, with an electrical heater-bar and humidifier water-pan beneath the slatted rack. The homemade thermostat, at the right, can be set for the desired temperature, and the top sash raised or lowered to control humidity.

wood, glass and hinges for the doors. Our dissecting needles are made from discarded odd lengths of glass tubing from the chemistry laboratory, fused around used darning needles. Our dissecting pans are old baking tins with a mixture of paraffin, beeswax, and lampblack in the bottom of each. Insect collecting nets are made from wire coat hangers, cheesecloth, and broomhandles. Most of the rest of our equipment is of similar origin.

We have our own workbench, miscellaneous tools for repair work, an ancient but quite usable electric refrigerator donated to us by a downtown department store for the cost of transporting it to the school, and an old-time electric stove whose oven does amazingly well for dry heat strilization. Animal cages are designed by boys working in the sheet metal shop. Live plants and animals are brought in by pupils; almost always we can contact former pupils in other parts of the country or abroad for biological materials not to be found nearby. Models are contrived from all sorts of odds and ends, and museum jars from assorted fruit containers. There is no lack of materials or apparatus when we intelligently substitute what is available for that which is beyond our means or out of our range.

In conclusion, may I suggest that the following matters, which concern laboratory and experimental techniques and attitudes, should be held as goals in the minds of science teachers, from the elementary grades through the colleges:

—Photo by Charles Bass

FIG. 4. A tropical orchid blooms each year in the miniature "greenhouse."

1. That we can assume that young people in our schools today, at any grade level, have more of a factual background, desire, and need for science instruction than at any time heretofore. It does not necessarily follow, however, that they have had even as much opportunity to experiment and explore for themselves outside the school as in earlier times. This situation calls for an upgrading of science offerings throughout, enlarged

laboratory facilities and field opportunities, and increased emphasis on the intellectual aspects of " learning by doing."
2. That "cookbook" type experiments and teacher-planned demonstrations be reduced to a minimum or discarded, and pupil-planning and individual and group research project activity be fostered, stimulated, and promoted wherever possible.
3. That science instruction be started as early as possible, while young people are yet open-minded, inquisitive, and interested in finding out the how and what of things around them.
4. That a shared-experience type of science instruction be planned and organized as an integral part of the program of studies in all elementary schools, and carried on through the whole of the learner's formal schooling.
5. That at least one year of a laboratory-type natural science course, and one year of a laboratory-type physical science be required for graduation from high school.
6. That the facilities of our science laboratories, no matter how meager, be made available at all times of the school day for pupil use, under competent guidance, much as the school and public library are available for reading research.
7. That we all place increasingly greater emphasis on in- and out-of-school shared laboratory experiences, and on individual and group experimentation, planned and carried through by the individuals or groups themselves to the greatest extent possible.
8. That we, as teachers, make every effort to develop as fully as possible in as many of our learners as possible, and to a greater degree within ourselves, those qualities of open-mindedness, critical thought, tolerance, flexibility, personal responsibility, creativeness, and discerning judgment which can only come about as a result of experience and experiment, and which are necessary for both intelligent leadership and followership, as well as being true stabilizing influences in economic, social, and religious life in these confused times, as they have been and will continue to be in all ages.

The Biology Teacher's Responsibility to Society*

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If any relatively small group of human beings has attracted more attention, and given rise to more feelings of consternation on the one side and appreciation on the other than the atomic scientists, I'd like to know who they are. In many ways these shrewd and able workers with fissionable materials have set an example for the rest of us. For one thing, they seem to have been unusually far-sighted in assuming a certain social responsibility for the application of the results of their studies. As a result of their realistic facing up to some of the possible results of use of the atomic and now hydrogen bombs, we are in a far better position to anticipate what may happen, to guard against threatening dangers, and to promote beneficial uses of the new discoveries.

Perhaps, as teachers of biology, we may well take a leaf from the notebook of the atomic scientists. Obviously we biologists should be no less concerned with the applications of our findings than are the physicists with theirs. I

* An abridgment of a paper presented as a part of the program of the annual convention of The National Association of Biology Teachers in Philadelphia, Dec. 29.