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Science Teaching at Bennington College

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Introductory Science Is Given in a Single Unit Called the Science Workshop

THERE is enough inquiry concerning the work in science at Bennington College to make it worth while to prepare a statement which may serve as a partial reply. This report deals with the question most often raised and concerns primarily the teaching of introductory science.

Some of the guiding principles which are involved in all science teaching at Bennington are important to our discussion. The belief predominates that science teaching must be educational rather than merely imparting technicalities or training for a job. Material is adapted to the needs and capacities of individuals and is so planned as to give direction toward continuous development of power. The conviction that the mastery of intricate and laborious technique, although often necessary, is less important than the attempt to approach the truth easily and completely pervades all instruction. The replacement of what claims to be the absolute by probability and the endeavor to measure the probability are common practices. A thorough criticism of the foundations of science is made. Our responsibility in assisting the student in developing an independent philosophy of life is accepted.

The attitude of the instructor toward the student is primarily one of friendly understanding. Contrary to a popular belief, however, self-expression is not necessarily encouraged more than self-restraint.

By great good fortune this college is small enough so that it has not been necessary to departmentalize the scientific work; therefore it has been possible to offer for those students who plan to continue in science a single unit of instruction called science workshop instead of offering separate introductory courses in the several sciences. The content of the workshop course is designed to acquaint the student with main scientific facts and theories, the experimental method, and the scientific attitude through a working understanding of the fundamental concepts of physics, chemistry, and biology. This serves as a preparation for project work. Science workshop occupies half the student's program time for the freshman year which is a minimum of twenty hours a week including classroom, laboratory, and study time. Physics and chemistry constitute the subject-matter for

the first semester. In the second semester half of the workshop time is devoted to biology; the remaining time is divided about equally between physics and chemistry.

The biological part of workshop is distinctly different from the traditional introductory course. Our students are more interested in the physiological approach. Incidentally, most of them have studied biology in school, and preparatory-school work in biology has improved so much in the last decade, due to better-trained teachers and their continued study in university summer sessions, that we do not find it advisable for our students to repeat introductory biology. Moreover, the taxonomic and morphological concepts of biology will be explored in detail in advanced study of botany and zoölogy. It has been found more satisfactory to offer what is called the protoplasm course as the biological part of workshop.

In the protoplasm course we point the work to an analysis of protoplasmic systems and their products by using the chemical and physical principles studied in the other parts of workshop. This gives an excellent opportunity to emphasize the latter material by applying it and has the time-saving feature of using this information while it is fresh in the student's experience without the necessity for review. In certain respects this work is similar to the college course known as general physiology; however, there is a great deal of individual laboratory study and the material is so planned as to include considerable structural detail along with the functional so that the student will get a more comprehensive picture of the whole process.

In arranging the order of topics to be studied in workshop, every effort is made to treat each subject as a functional whole rather than as a separate principle of a certain department of science. Therefore, as opportunity affords, reference is made to the application of material being discussed to other fields in order to emphasize the interdependence of the several sciences. The students will encounter this in a practical way when they begin project work, and the attempt is to anticipate it in workshop. This is readily seen in the arrangement of some of the subject-matter of the workshop program: physics of sound and the physiology of the ear; physics of light, physiology of the eye, and the physics and chemistry of photography including color processes; chemical, physical, and biological aspects of the periodic table; physical, chemical, and biological aspects of surface phenomena; gas laws and respiration; electrostatics and colloidal behavior; electrical potential and nerve action; electrical circuits, ionization, conductivity, electrical potential, bio-electric potential; catalysts, oxidation-reduction systems, enzymes; gas laws, kinetic theory, solution laws, osmotic phenomena; physical and chemical aspects of fibrous structure and its biological significance.

WE HAVE found it more stimulating for both instructors and students to devote the class meetings, not to lecture, but to discussion of information already studied in textbooks and reference books and to its

application in experimental work. Our main concern is how to get information, how to evaluate it, and how to use it. Instead of requiring each student to do standard laboratory experiments we often make a class attack on some larger problem, each student or pair of students designing and carrying out an experiment to test a single phase of the subject being explored. At the next group meeting all results are presented, errors discussed, and the several experiments may be fitted together into a general expression. In the regular weekly conference which each student has with a member of the science faculty, the counselor, there is opportunity for further discussion of any points having to do with subject-matter or its application.

This workshop arrangement for introductory science is important because during the following three years the student ordinarily spends at least one-quarter of the program time working on an individual project. Usually it is more advantageous for a person doing experimental work to be acquainted with the fundamentals of physics, chemistry, and biology than it is to have had preliminary work in only one or two of these fields. We find that even though the student has had a limited experience in science the sophomore project, if carefully selected, is challenging and productive. The students are enthusiastic and they turn out some good results. A list of some of the recent projects is appended. One of the reasons that each student engages in a project during at least one semester of the sophomore year is that promotion from the junior division, the first two years, to the senior division, the last two years, is dependent upon demonstration of the student's ability to do sustained independent work.

Our experience indicates that the workshop plan has some additional advantage over the arrangement of college science courses wherein the student concentrates in one of the departments of science and does not find it convenient or necessary to study introductions to other sciences until the last two college years. For example, it often comes about that a student in biology may begin the study of chemistry early in the college program but postpones the study of physics until the junior or senior year, thus missing the advantage of working into the developing understanding of living systems important physical concepts which are so useful and necessary in studying organisms.

Some of the attitudes which we aim to encourage in the student are: a consciousness of the inertia of superstition, ignorance, and nonsense; an awareness of how much emotion and purpose accompany any particular bit of knowledge; the ability to understand another's beliefs and practices without necessarily sharing or accepting them; the postponement of immediate action on impulse, until observation, information, and judgment have intervened; the ability to deal intelligently with any idea whether it be new, generally accepted by competent persons, or outworn; an appreciation for the danger involved in being satisfied with current abstractions; a reasonable definition of "the truth"; a balanced growth of individ-

uality and the creation of power of intelligent self-control; an appreciation of the idea that knowledge is not nearly as important as one's constant endeavor to obtain it.

PROJECTS[1]

SOPHOMORE—

Measurement of bio-electric potential with potentiometer and hydrogen and calomel electrodes, including setting up the cells and the circuit
Effect of antuitrin on reproduction in frogs
Laboratory culture of slime mold—effect of changing environmental conditions
Oxidation-reduction systems in organisms
Plant nutrition—elements essential to growth
Liquid crystals—preparation and characteristics
Preparation and study of thixotropic colloids
Tissue culture—in vitro
Chemistry of plant gums
Comparative study of vertebrate skeletons, including their preparation
Linkage in *Drosophila*—identification of two new mutations (one of them found by this student) in the sex chromosome pair
Study of why an unexpected phenotype of fly (*Drosophila*) emerged from moire x brown matings
Search for a simple and reliable method of detecting the lead content of maple syrup
Velocity of reactions at different enzyme concentrations
The reducing action of ascorbic acid (vitamin C)
Survey of local algal flora
Survey of local moss flora
Survey of local fern flora
Survey of local woody plant flora
Identification of bacteria in local river
Effect of temperature on pigment formation in *Serratia marcesens*
Effect of various methods of treating willow and poplar cuttings with auxin
Study of life history and specific determination of a water mold from the Canal Zone
Study of spectra including the construction of a condensed discharge light source
Embryology of a lethal fish hybrid
Genetic study of mice
Synthesis of certain drugs
Study of local weather conditions

JUNIOR—

Effect of various wave lengths and intensities of light on growth and reproduction of algae
Plant growth substances and the measurement of their effect
The chemical nature of the pigment of *Physarum polycephalum* (slime mold)
Germination of moss spores, including the effect of auxin, and cultivation of protonema in different nutrients and at different pH levels
Tissue culture—in vitro
Drosophila salivary glands—preparation of slides and mapping of chromosomes
Design and construction of a time-lapsing circuit using vacuum tubes and relays for motion photomicrography
Measurement of wave length of various spectral lines
Extraction of enzymes and hormones
Growth and life history of Panamanian myxomycete

SENIOR—

Blood sugar level in normal and cancerous rats
Photomicrography, including the design and construction of camera
Pituitary metabolism*
Bacterial metabolism—oxygen consumption and carbon dioxide production of Serratia marcesens with glucose and fructose media, including design and construction of respiration apparatus
Electroencephalography*
Use of phytin (an organic phosphate) in bacterial nutrition
The design of a course in useful mathematics
Change in number of human erythrocytes (red cells) under varying conditions
The sulfonamide derivatives and their use in the treatment of scarlet fever*
Electrophoresis of ragweed protein using moving boundary technique (including electroendosmosis of the pollen extract through the skin)
Preparation of organic developers (photographic) in the phenylenediamine series to be used for comparative developing tests
Modern atomic theory and its historical development
Germination and growth of fern spores in media buffered at different pH levels, including the effect of auxin
Studies on the respiration (Warburg apparatus) and growth of yeast and oat seedlings including the effect of auxin
Symbiotic nitrogen fixation including the effect of oxalacetic acid on assimilation of nitrogen by nodules
Relative importance of the several senses in maze learning
Study of student attitudes toward health
Agglutination of mixed red cell types in human blood
Cinematographic study by time lapse of growth and development of mosses
Effect of colchicine on chromosome number in beans and peas
Study of a position effect in *Drosophila*
Quantitative studies in biochemistry of blood
Vernalization in tomato plants by media control
Design and construction of a vacuum tube feed back microammeter
Design and construction of a vacuum tube and relay thermoregulator

[1]All projects, except the five marked by an asterisk (*), consisted primarily of laboratory study.