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Contained are a statement of the promise of unified science education and descriptions of five unique unified science programs. Within each program the course content and rationale was stated. The five programs chosen were (1) Millburn Senior High School, (2) Saint Louis Country Day School, (3) Monona Grove High School, (4) The Portland Project, and (5) Nova Junior High School. (RR)

American Association for the Advancement of Science

March 1969

Unified Science Education

A movement in secondary schools to teach science as a unified body of knowledge rather than as single disciplines has been growing in recent years. At least thirty experimental programs are in operation this year. This issue of *Science Education News* includes brief descriptions of six of these programs and a rationale for teaching science as an integrated subject.

—A. H. L.

The Promise of Unified Science Education*

During the past decade, a steadily increasing number of secondary school science curriculum projects have been devoted to a unified science approach. These projects have not been accompanied by the large amount of publicity or public funds associated with the various projects funded by the National Science Foundation. Nevertheless, there are indications presently that the unified (or "interdisciplinary" or "integrated") science curriculum may be the structure best suited for general education in secondary schools.

The thirty or more current unified science curriculum development projects have many common characteristics, yet each is unique in one way or another. Each project has been based on a slightly different concept of unified science education. Each has developed a slightly different structure and format of instructional materials.

The Federation for Unified Science Education (FUSE) in its first conference (1966) attempted to distill a common definition of unified science from the several then existing. The best it could do was to define science education as a planned sequence of science experiences in which each unit of instruction utilized subject matter from two or more traditional science disciplines.

Each project has established its own philosophical base and its own rationale for coming into being. The mere fact that the participants in each project have gone through this phase may well be the ultimate source of vitality for each project.

Typically, the total science teaching staff of a school system has become involved in the synthesis of philosophy and rationale for the project. It is tempting to conclude that the real reason for the success of unified science curriculum projects is that the *teachers know why they are teaching what they are teaching*. This is a different situation from *being told* the philosophic base of a new course by its writers. Too frequently, the telling (when it is done at all) is not really meaningful to the teacher.

Without exception, the various unified science projects acknowledge that the primary function of secondary school science should be general education in science. In giving first priority to attainment of general scientific literacy by individual students, the unified science projects do, in reality, what many science educators have been preaching but not practicing for many years.

All of the unified science projects are constructed around concepts, principles, and processes that permeate all science. In most of the projects these factors have been perceived as the core of the ultimate unity of all science. At the same time, recognition of the existence of concepts, principles, and processes that cut across traditional disciplinary boundary lines offers a criterion for selecting what should be taught from an ever-increasing amount of scientific knowledge. An analysis of current unified science projects reveals a striking similarity in those concepts, principles, and processes that are ultimately identified as the common core of all science.

Without exception, the unified science projects exploit

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* A more comprehensive prospectus for unified science education can be found in "New Directions for Science Curriculum Development" by Victor Showalter, ERC Paper in Science Education #2, Educational Research Council of America, Rockefeller Building, Cleveland, Ohio 44113.

the opportunity to pattern instructional materials in a logical and efficient sequence. Repetition can be minimized. Concepts can be developed as they are needed to structure principles at ever-increasing levels of sophistication without restriction to traditional subject-matter fields. Sophisticated content from any given science discipline can be reserved for the upper grade levels while relatively simple content can be utilized at lower grade levels. Material from science disciplines ordinarily excluded from secondary school science (for example experimental psychology) can be utilized and thus expand the learner's intellectual horizons.

A further advantage frequently gained by unified science curriculum developments is in facilitating innovative teaching practices. The burden of methods imposed by tradition is lightened considerably when a traditional course is dropped in favor of a unified science course.

There has been limited research associated with unified science projects. In general these have shown: (a) increased enrollment in high school science, (b) increased scientific literacy among graduates, (c) increased aspiration by graduates to enter science oriented courses, (d) no deleterious effects on graduates' grades in first-year college level science, (e) no disadvantage to graduates in gaining college admission.** —VICTOR M. SCHOWALTER, *Research Associate, Educational Research Council of America.*

Millburn Senior High School

In 1961 a discussion among three teachers at Millburn (New Jersey) Senior High School of the interrelations of the sciences led to the introduction of a unified science course. First a two-year unified physics-chemistry course was used, and from this grew the current three-year unified biology-chemistry-physics course. In two summers of work, the philosophy and general content of the course were established. The basic texts are: *An Inquiry into Life* (yellow version BSCS), *Modern Chemistry* by Dull, and *Unified Science*, Books I and II by Bickel. These do not solve the general textbook problem completely but are the best obtainable for present purposes.

The first unit in the course introduces the way science works through a study of the malaria problem and how it was solved. The composition of matter, atomic theory, and chemical bonding are studied next. This work in chemistry provides the necessary groundwork for the next topic, "The Chemistry of Life." In this section the students develop an understanding of carbohydrate, fat, and protein chemistry; enzyme actions; pH; and chemical reactions within a cell.

The cycles of life, such as the oxygen-carbon dioxide cycle, the phosphorous cycle, and the nitrogen cycle, can be taught with greater depth of understanding after a student has had background in the nature of bonding, radicals, and energy transfers. The meaning of the electron transport chain can be received by a student after he understands oxidation and reduction.

The molecular structure of viruses is clearer after a student has studied the organic molecules involved in cellular metabolism.

Wave motion leads directly into a study of light. Study of lenses offers a good transition to study of the human eye, and the ear fits in excellently with sound waves. A study of the visible spectrum is followed by an introduction to photosynthesis. The Hill and Calvin reactions of photosynthesis are much more meaningful to students who have had the physics and chemistry background that has been described than to biology students without previous experience in physics and chemistry. The study of photosynthesis includes molecular configurations, energy transfers such as the magnesium atom excitation in the chlorophyll molecule and the ADP-ATP cycles.

The study of electricity opens the door to many types of unification such as the theory of ionization, equivalent weights, electrolysis, and electrical impulses and their relationship to living cells.

One of the decided advantages of a unified course of this nature is that the teacher can return to topics in another year after a student has gained greater understanding through other intermediate work. Light is one topic which is returned to for more study. The particle model and the wave model of light, and various types of spectra are considered.

Atomic theory and the history of how it developed, from Democritus, through Mosely's X-ray analysis, the Pauli Exclusion Principle and Heisenberg's Uncertainty Principle are topics in physical science that can be approached with a greater degree of understanding later in the course than they could in a one-year course in physics or chemistry.

Chemical bonding is another area that is returned to later in the course. After presenting the ideas of ionic, covalent, and metallic bonding early in the course so they would serve as a foundation for study in other areas, this topic is returned to for a deeper study of hybridization, hydrogen bonds, shapes of molecules, molecular orbitals, and other topics.

Genetics is also a topic that is studied in two sections. Early in the course simple Mendelian ratios can be successfully studied. Later in the course (the last unit), the chemical structure of the DNA molecule, the replication of DNA, the one gene-one enzyme theory, cytoplasmic effects, populations, and many other topics are introduced.

The number of overlapping ideas cannot be fully realized through this brief description of the course.

A three-man team teaches the course. This is vital to the full success of unification. At least two planning periods per week are necessary so all members of the team can discuss the work and progress of the classes.

Anyone who introduces this course will probably have more trouble convincing the parents than anyone else that it is a good course. Parents will try to put up

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** A comprehensive longitudinal study of the impact of unified science can be found in "Effects of a Unified Science Curriculum on High School Graduates," Final Report USOE Grant OEG-1-7-068937-3761 by Victor Showalter, Ohio State University Research Foundation, Columbus, 1968.

obstacles such as college boards, what if we move, will colleges accept this, is it as good as the traditional program? These are nagging problems. They may continue to be problems until more and more schools across the nation teach science in this manner.

At present no data show that a unified course is better than three traditional courses. A testing plan is being followed, but the course is only in its second year and we cannot begin to compile data until after the third year. The teachers are convinced of the benefit of the approach and the students say they think the course is great. One girl, not the highly academic type, said, "It's amazing how all these things are so tied up with each other."

As Nobel laureate H. J. Muller said as long ago as 1922, "Must we geneticists become bacteriologists, physiological chemists, and physicists simultaneously with being zoologists and botanists? Let us hope so." —LEONARD C. BLESSING, *Head, Science Department, Senior High School, Millburn, New Jersey.*

Saint Louis Country Day School

The integrated program, E-S-L, at Saint Louis Country Day School, authored by Louis W. Bixby, William W. Scott, and Edson Mitchell, has been seven years in the making. It involves physics, chemistry, and biology (in this order, with many conceptual overlaps) in a two-year sequence. Content includes studies of motion in a straight line leading to mathematical conceptualization of energy, development of heat and entropy as energetic considerations in chemical reactions, and aspects of stoichiometry, periodicity, equilibrium, acid-base theory, and reaction kinetics in chemistry. "Big molecules" are described and constructed as a lead-in to biology, which covers twenty-four "Attributes of Living Systems" and attendant explorations into aspects of these attributes. The E-S-L approach is biochemical and suggests glucose as the prime energy source for living systems. The final chapter deals with plant structure and physiology and reveals light as the *ultimate* energy source for living systems.

Pedagogically, E-S-L is a *systems* approach to learning science and involves:

- a programmed two-volume "text" or Learning Guide;
- correlated laboratory experiments with some ongoing long-range investigations;
- audio-visual materials—film loops, strips, films, tapes, and audio-tutorial programs;
- a set of objective tests;
- "Behavioral Patterns and Skills"—a set of criteria for measuring student achievement and progress;
- Program Notes—answers to questions in the Learning Guide.
- Teacher materials are also being written.

Because of the programmed nature of all E-S-L materials, the course may be taught on a strictly individualized basis. The authors are presently working toward this goal with apparent success. Several second-year students will complete the program by April. This development has not been without problems. It has been necessary to utilize a modular time schedule and *individualized* student schedules to bring this about. The teacher's role is that of *guide* and "confessor"—a passive participation which some teachers may find hard to assume. No lectures, as such, are given. This necessitates long-range planning with honor system tests, many individual oral confrontations in teacher-student groups, student-run demonstrations, setting up several laboratory exercises at one time, and particularly keen teacher familiarity with the materials. (Teacher materials, now being written, will take this into account.) We have surmounted all of these problems; thus, success is almost guaranteed. The possibility exists that this success may be an offshoot of almost ideal teaching conditions at a small, private boy's school; the authors have had experience in public education, however, and feel the course can be taught successfully in public schools as well.

Energy-Structure-Life is best presented initially by utilizing team teaching. Teachers must realize that they *can* and *will* learn unfamiliar material as they progress through the course. One objection by critics has related to the "toughness" of materials and concepts. Students, however, do not look on the course as tough; thus, they can and *do* learn E-S-L.

The program is presently being reviewed and revised for publication. It will emerge as two separate volumes—one year of physical science and one year of biological. The courses can be taught separately or sequentially. E-S-L solves several problems in science education. The philosophy of the course includes the need for a science course for nonscience majors, a science course which is unique to high school or beginning student needs—not a "watered down" college approach, a course which utilizes available laboratory materials and equipment, and one which shows the interrelationship amongst all the sciences.—LOUIS W. BIXBY, *Chairman, Science Department, Saint Louis Country Day School.*

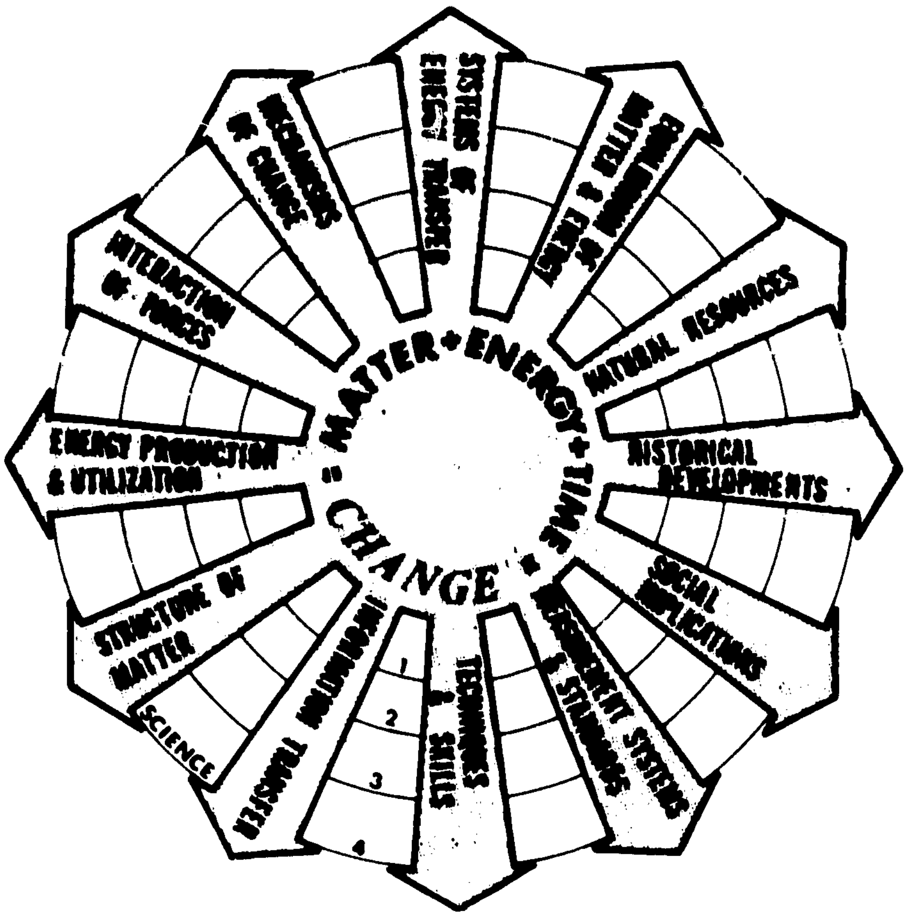
Monona Grove High School

Within the vast spectrum of scientific knowledge one finds that certain ideas pervade the historic disciplines of science. These ideas are so basic to understanding that they constitute the frame of reference for the development and interpretation of new knowledge in every area of scientific endeavor. These same ideas, when "conceptualized" within the minds of individuals, provide the basis for making science relevant to experience at the personal level. The unified approach to science education provides unique opportunities for the realization of this objective.

The unified science program being implemented at Monona Grove High School, Madison, Wisconsin, is a four-year, concept-centered program based on the premise that all science is concerned with the nature of *Matter* and *Energy* and with the matter-energy interactions as a function of *Time*. The consequence of these interactions is *Change* and this "Process of Change" is the central theme of the program.

Twelve unifying themes dealing with fundamental issues in science have been selected to amplify this central idea and to provide guidelines for the selection and organization of concepts to be incorporated into the courses at the various levels.

Unifying Themes



The present structure of the four-year unified program at Monona Grove is as follows:

Year and Course Numbers	Major Theme
Science IA IB	Matter-Energy and the Process of Change
Science IIA IIB	Matter-Energy Interactions Relating to Life on Earth
Science IIIA	Matter-Energy Interactions in Natural Systems
Science IIIB	The Interaction of Man with His Environment
Science IV	Homeostatic Systems — Mechanisms for Survival

The first two years of the program, required of all students, begins with a rather candid look at man, his position in the universe, and his attempts to understand and relate to the process of change. This is followed with an overview of man's ideas about the structure of matter, the role of energy and time in the process of change, and interactions resulting in physical and chemical change. Emphasis then shifts toward man's ideas about the origin and evolution of life. The ideas relating to the nature of matter and energy, interactions resulting in change and the mechanisms of change, first developed with respect to nonliving systems, are then extended to include "processes of change" as they relate to living systems.

The elective portions of the four-year program treat the ideas introduced in the first two years in greater depth. Science IIIB becomes involved with problems of coexistence; IIIA is increasingly quantitative in its treatment of ideas previously developed. Particular emphasis is given to factors affecting rates of reaction and equilibrium, first in macrosystems and then in particulate systems.

Science IV is concerned with a more sophisticated look at the physiological functions and behavioral patterns of living organisms.

The unified program at Monona Grove is now in its fifth year of implementation and its second year since *all* traditional science courses have been phased out of the curriculum. The major problems experienced with the program to date have been associated with the time required to develop, produce, implement, and evaluate curriculum materials. The entire science staff has worked as a team since 1961, including five successive eight-week summer sessions since 1964, in order to bring the program to its present state of development. The team is far from satisfied with many aspects of the existing program. However, preliminary evaluations based on five years' experience have produced subjective and objective evidence which indicate that the unified program represents a more effective means of realizing the educational objectives established for the science program at this high school than was possible through a subject-oriented program.—CARL H. PFEIFFER, *Chairman, Science Department, Monona Grove High School, Madison, Wisconsin.*

The Portland Project

An Integrated Biology, Chemistry, Physics Course

The need to unify the teaching of science—that is, to bring together under one umbrella the now fractured fields of science—results from a number of imperatives: (1) Concepts often treated in one science discipline are crucial as background for the other sciences. (2) Educated men and women must be somewhat literate in several sciences. Most curriculum patterns in today's secondary schools preclude the probability that students will have any exposure to chemistry, physics, and earth science. (3) There is obvious redundancy in science content and its epistomology (the study of theory of origin, nature, *methods* and limits of knowledge) when one looks closely at most present curriculum programs in secondary schools. (4) Today the attack on research problems, both pure and applied, is interdisciplinary. (5) A fundamental goal of science is to simplify and search for unity rather than disparity; so why should not approaches to its instruction be offered in the same spirit?

Course Content and Rationale

The Portland Project Committee is developing a three-year integrated science sequence that cuts across the disciplines of biology, chemistry, and physics. Year One is divided into four parts: (I) Perception and Quantification, (II) Properties of Matter, (III) Energy and Work, and (IV) Mice and Men. Part I, "Perception and Quantification," begins with the perceiver of nature—the student. He is made aware of his marvelous abilities to obtain information from the environment through his senses. Confrontations with anomalous observations lead him to a need for precise measuring instruments, but he soon learns about human and instrumental error which motivates the subject of significant figures. Part II, "Properties of Matter," offers him opportunities to try his newly gained quantitative observational skills on simple physical systems. Much of this content is taken from Introductory Physical Science (IPS). Part III, "Energy and Work," constitutes a thread which runs through the fabric of science. Students are introduced to these ideas only on a semi-quantitative basis with examples from the three disciplines of biology, chemistry, and physics. Recycling at the second- and third-year levels in more formalistic ways is calculated to reinforce and extend his knowledge about these fundamental topics. Part IV, "Mice and Men," emphasizes the organism, population and energy interactions and conversions. Knowledge about the organism and its interaction with the environment identifies the population within the community. The decision to emphasize this kind of knowledge was made because it is fundamental to an appreciation of the critical problem that confronts man today—that is, control of human population, and the cumulative effects of food, air, and water pollution.

The first-year course was intended to be both a terminal course for average students and also an introduction to precede the second- and third-year levels. An excessively formal and quantitative approach is avoided in the first year for several reasons. Students at this level do not extract essential meaning from such presentations of information; furthermore, encounters with new ideas should proceed from an intuitive, nonquantitative confrontation to one that is more quantitative. In addition, biological topics that were selected for Year One assume little knowledge of chemistry. Biochemistry awaits conceptual maturity which hopefully will come with continued immersion in this science sequence.

The second year, like the first, contains four parts: (I) Motion and Energy, (II) Chemical Reactions, (III) Fields and Particles," and (IV) Chemistry of Living Matter." The second year course is more quantitative because students are now more mature in their abilities to cope with abstract symbolism, teacher counseling identifies those students who can profit from more abstract instructional content, and quantitative chemistry and physics is essential for understanding of molecular biology which is emphasized strongly in later stages.

Part I, "Motion and Energy," begins with kinematics, moves on to dynamics and Newton's Laws of Motion. There follows quantitative development of the conservation laws with special applications of conservation of energy to biological systems. This introductory material serves as excellent background for Part II, "Chemical Reactions," the study of chemical phenomena as ionic and covalent bonding, reaction rates, equilibrium and oxidation-reduction reactions. Part III, "Fields and Particles," presents electrical phenomena with special attention to the concept of "field." This part is concluded with the study of radioactivity and its biological applications. Much of the content presented thus far in Year Two is extracted from CHEM Study and Harvard Project Physics. The second year is completed with Part IV, "Chemistry of Living Matter." This is a unique addition to a secondary science course. What has gone before in the first year and one-half serves as a foundation for understanding the most basic chemical facts of living matter, namely, the needs for bio-catalysts (enzymes), an information storage and retrieval system (genes and DNA), and a container (cell) for these specialized macromolecules. The fact that these macromolecules are generally polymers leads to a discussion of monomers, how they are polymerized, and how the polymer chain folds on itself to achieve a unique three-dimensional shape. Concomitantly, the nature of the weak forces stabilizing these shapes is developed, along with the idea of complementary surfaces. Part IV and Year Two conclude with development of the need for a cell as a container for these biochemical processes. Year Three, though it is not planned in detail, will likewise consist of four parts: (I) Electrons, Quanta and Radiation, (II) Modern Physical Theories, (III) Energy Capture, Growth and Replication, (IV) Responses to the Environment.

Course Evaluation

Year One of the sequence is now in its second trial year in twelve Portland metropolitan schools; Year Two, in its first trial year in eight of these schools. The Year One course presently enrolls 860 students, which is just about double the number electing the course the first year it was offered. A large number of science teachers distributed nationally have expressed an interest in implementing the course in their schools if permitted to do so. The Portland Project Committee is not encouraging adoption by other school districts until the entire course sequence is completed and tested. This should have been accomplished by the fall of 1970.

The retention of students from Year One to Year Two is about 65 percent. This figure is well above the historical percent of students in the Portland area who elect chemistry after having had biology. Figures on the number of students who elect Year Three should soon be available through preregistration data.

Some results of a free response questionnaire given to students in Year One classes yield the following information. When asked to identify what they liked about the course and what they did not care for, they responded in this way: 62 said they liked the lab experiences, 41 said they enjoyed the freedom the course offered to be on one's own, 67 liked the variety and new experiences offered them. Compiled negative comments revealed that 28 objected to the way the content "skipped around," 19 had difficulty with the math, 14 said the course was too abstract for them.

Difficulties

There are difficulties that need to be anticipated in considering adoption of this kind of course sequence. Recognition of them and thoughtful action can alleviate or eliminate most of them. (1) Teachers fear their preparation is not adequate to the task; therefore, training looms as a significant part of integrated science course adoption. (2) Students and parents must be prepared for this new experience. In the absence of sound counseling and communication to homes, difficulties can arise. (3) Facilities are the most serious limitation in that many classrooms are not tooled-up for single science disciplines. Rigid chemistry tables with protruding electrical and gas outlets and sinks often limit their utility for certain physics and biology experiments. Fortunately for integrated science, multipurpose rooms are gaining favor with science teachers. (4) Cross-disciplinary type experiments appropriate to the secondary level need to be developed. The Writing Committee has been successful in devising a number of these, but much still needs to be done in this area.—MICHAEL FIASCA, *Co-Director, Portland Project, Portland State College.*

Nova Junior High School

The Nova Schools (Fort Lauderdale, Florida) were in the unique position of being able to develop curricular patterns before the schools were opened. The developers traveled, observed, and searched for programs that seemed promising to them.

The outline for the junior high school science subject matter was given by Dr. Leo Klopfer, then at the University of Chicago, in his design for a unified science course for the secondary school. Dr. Klopfer's original description was revised by the Nova staff and ultimately appeared as this outline:

- *Measurement*—one unit, to be basic to all others.
- *Organization*—six units, two in biology, two in chemistry, and two in physics, each to build upon the others.
- *Beginnings*—three units dealing with the formation of the earth, oceans, and atmosphere, and with evolution.
- *Fundamental Particles*—six units, two each in biology, chemistry, and physics.
- *Reason*—one unit, concentrating on the use of models to explain behavior.
- *Explanations*—two units, elementary probability and statistics.

In all, nineteen units cover a reasonable number of processes and concepts in a sequential pattern that gives the student opportunities to simplify complex situations in his universe and analyze the simplified situations intelligently. The entire program is strongly based on a laboratory approach to concept formation.

The science curriculum is organized in carefully developed sequences, with new learning experiences built upon old experiences. The student progresses through these sequences, strengthening his foundations and confidences and expanding his understandings. Since it is difficult to understand the problem of science without facing some of these problems personally, it is important that the student work in an environment consistent with the scientific experience.

It is interesting to note that *The Science Teacher*, October 1964, carried selected conceptual schemes and major items in the processes of science. The Nova Junior High School sequence gives emphasis to five of the seven conceptual schemes listed and, in addition, covers one other.

Students "discover" by data intake and processing; the concepts that they uncover are broadened into schemes and with these schemes complex problems are simplified. Confidence is developed and enthusiasm is high. This enthusiasm is evident in the fact that this material has been presented to approximately 3500 students in an atmosphere of relative freedom with as many as fifty-two students to a teacher. Discipline problems and acts of destruction to equipment are remarkably low.

What does a student do? In the first unit he constructs his own measuring system and subjects it to the tests that a measuring system must pass: Is it consistent? Can it be duplicated? What is its accuracy? Its precision? How can mass, volume, and linear measure be related? He constructs his own data sheets and

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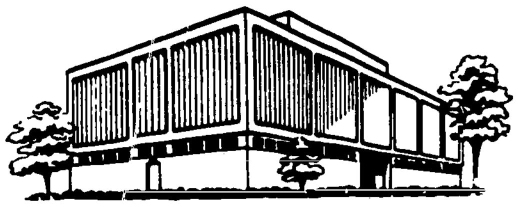

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compares a single measurement with the average of many for consistency among his and other students' results. He is expected to apply these principles in all other science units.

From measurement he moves to the study of organization in three areas of science: biology (classification), chemistry (periodic table), and physics (major divisions). These units utilize measurement and data sheets, and provide basic theory in the three areas. They also give the student opportunities to sort information and make judgments, then consult reference material for verification of what he has "discovered." His experiences are with material he can see and feel, and with direct measurement.

The next unit allows the student to extrapolate what he knows to areas beyond his immediate observation. He is given practice in using information and techniques already learned and applying them in a process of retention of ideas—possible methods of the formation of the earth, oceans, and reasonable methods of measurements to determine "what was" or "what will be."

The units on fundamental particles again call on all of the student's mental resources. With the exception of the units on cells, he must arrive at decisions based on indirect evidence. He cannot see the particles he is studying. Atoms and molecules are the particles in chemistry, and charged particles in physics.

The unit on reasoning allows him to form mental pictures of the invisible and go beyond indirect evidence to the prediction of behavior beyond what he has studied. It is "molecular engineering" of sorts, dealing with structural chemistry.

The last units, probability and statistics, are by far the most difficult, and are the termination of the sequence. Our feeling is that the student needs all the processes and concepts of the sequence in order to master these last two units.

Each unit has built upon the preceding units, strengthening them and offering reinforcement to the learning of the student. Throughout the sequence concept seeking and concept formation are the central objectives. Students involved in concept seeking must base decisions on experience. Since the experiences of many of these students will be limited in the areas of investigation, the laboratory precedes discussion. Students may return to the laboratory after the discussion for verification of their findings or to search for additional information.

Nova students who develop concepts have considerable factual data at hand. Care has been used in the selection of material and an attempt has been made to eliminate useless information.

We have found that as we investigate basic areas of science we use very basic equipment. It did not require any large expenditure of money to institute this course. Each unit suggests extensions that could carry the student into more advanced equipment but this will vary with the students, the teacher, and the school.

Nova does not consider this curriculum completed. There must be much additional material; for example, we must develop parallel experiences for the disadvantaged student. We foresee a never-ending task of improving and updating the course methods and content.—PAUL BETHUNE, *Nova High School, Fort Lauderdale, Florida.*

Recent Publications

The bibliography below was prepared by DONALD J. DESSART, University of Tennessee, Knoxville.

Annual Report: Division of Mathematical Sciences, July 1967-June 1968 (National Academy of Sciences, National Research Council, Washington, D. C. 20418, 97 p.).

Includes three main sections: (i) minutes of the annual meeting of the Division held on March 11, 1968; (ii) a statistical summary of fellowship and research associateships for 1967-1968; and (iii) annual reports of divisional committees. In the first section undergraduate and graduate education in mathematics, pure mathematics, applied mathematical sciences, and partly mathematical sciences are discussed. The second and third sections deal with summaries of the projects of the Division. The report should be of value to anyone wishing to obtain a concise picture of mathematical activity and associated problems of today in the United States.

Constructing Behavioral Objectives, by Henry H. Walbesser (The Maryland Book Exchange, Inc., 4500 College Avenue, College Park, Maryland 20740, 1968, 90 p.).

Innovations in education usually require careful statements of objectives or purposes. Quite frequently behavioral-type objectives are advocated based upon the belief that this kind of objective provides the investigator with precise information which he can use to evaluate whether or not the objective has been achieved at the conclusion of an educational experience. The writing of clear behavioral objectives is far from a trivial task and is further complicated by the lack of readily available instructions to guide the neophyte in constructing behavioral objectives. This volume, a most praiseworthy attempt to fill that need, is a "must" for anyone wishing to write such objectives for an educational undertaking.

Contemporary Practices in Teaching Science: Elementary and Junior High School, by Ronald B. Townsend (Cooperative Educational Research Laboratory, Inc., Box 815, Northfield, Illinois 60093, 47 p., $1.90).

A booklet designed to help science teachers identify goals for their own teaching and to give them opportunities to compare these goals with those recommended by specialists and researchers in science education. Opens with "Samples," that is, a list of some 40 goals of science instruction in which the teacher checks the extent of his own practice of the particular goal as well as his opinions concerning the soundness of each practice. In the "Supplement" which follows, each goal is discussed with detailed references given. Should provide an enlightening experience for any science teacher.

Free and Inexpensive Teaching Aids for Science Education, compiled by Muriel Beuschlein (Chicago State College, 6800 South Stewart Avenue, Chicago, Illinois 60621, 1968, 55 p.).

A compilation designed to provide elementary and secondary teachers with a handy reference list of materials to aid in teaching students about their physical and biological environments. Topics ranging from animals and astronomy through water and weather are included in the compilation which lists publication titles, addresses and costs for ordering. Updates and revises two previous lists which appeared as supplements to the *Chicago Schools Journal* in 1949 and 1959.

Research
Ideas
Practice

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CURRICULUM Report

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Number 13

May 1969

Once again the American Association for the Advancement of Science has given NASSP permission to reprint an issue of *Science Education News* and to include it in our *Curriculum Report* series. We are most appreciative of this professional courtesy. While frequently we are reminded of the rate at which new knowledge is coming into being, we tend to overlook the significance of the new relationships being discovered among the parts of already existing knowledge. The schools mentioned herein are undertaking to enrich their instructional programs by exploiting such relationships among the several fields within the natural sciences. We compliment the faculties of these schools and are pleased to be able to bring their efforts to the attention of their professional colleagues.

Owen B. Kiernan
Executive Secretary

How To Make a Collection of North Dakota Insects, by Richard L. Post and Gary L. Thomasson (State Department of Public Instruction, Bismarck, North Dakota, 1968, 34 p.).

Written in a language understandable to junior or senior high school students and containing valuable information on collecting insects including the proper equipment needed as well as methods for proper care of specimens. The many diagrams should aid students in identifying insects, and the illustrations should help them in learning the common names of these insects. The intention of the booklet is to lead students into a study of the environment of the insect as well as into actual collection.

International Chemical Education: The High School Years, edited by O. Theodor Benfey and Saul L. Geffner (American Chemical Society, 1155 16th Street, N. W., Washington, D. C. 20036, 1968, 135 p.).

Chemical education in Australia, Brazil, Canada, England, Italy, Japan, Scotland, Sweden, and U. S. A. are discussed in this booklet which is a report of the proceedings of a conference held in the summer of 1967 in Washington, D. C., and sponsored by the American Chemical Society. With the avalanche of new ideas and new approaches to teaching chemistry being generated throughout the world, the opportunities to share these new ideas among nations are not frequent enough. Such a publication as this will help bridge the gap.

Selected Titles in Chemistry, edited by Harold G. Walsh (American Chemical Society, 1155 16th Street, N. W., Washington, D. C. 20036, 1968, 48 p., free).

An annotated bibliography of 215 inexpensive books for students, teachers, and general readers which updates a similar booklet published in 1966. Includes a general subject index and a classification according to the levels—high school, college, or general reader.

Preparing High School Physics Teachers, Report of the Panel on the Preparation of Physics Teachers of the Commission on College Physics, by Ben A. Green, Jr. (Department of Physics and Astronomy, University of Maryland, 4321 Hartwick Road, College Park, Maryland 20740, 1968, 22 p.).

A serious educational crisis is developing in the area of physics education in the high schools of the United States where the fraction of students electing physics has been seriously declining during the past several years. The reasons for this decline are probably varied, but the shortage, and in many cases complete absence, of competent physics teachers is a major cause. Part of this shortage is attributed to the fact that many well-known, prestigious physics departments do not offer programs specifically designed for prospective high school teachers; consequently the burden of the preparation of physics teachers falls upon the teachers colleges, which cannot meet the current demands. This report offers many helpful suggestions for implementing a strong program for preparing physics teachers.

Testing and Evaluation in the Biological Sciences, Report of the Panel on Evaluation and Testing, directed by Martin W. Schein (Commission on Undergraduate Education in the Biological Sciences, 1717 Massachusetts Avenue, N. W., Washington, D. C. 20036, 1967, 108 p., free).

The Panel on Evaluation and Testing of the Commission on Undergraduate Education in the Biological Sciences (CUEBS) was established in 1965. This report by the Panel is designed to serve as a resource for an instructor preparing questions for a course examination. The test items are categorized by behavioral objectives as well as type of content. The aim of the report is to encourage the development and use of better evaluation instruments in biology.