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THE NEW SCHOOL SCIENCE, A REPORT TO SCHOOL ADMINISTRATORS ON REGIONAL ORIENTATION CONFERENCES IN SCIENCE.

BY- VIALL, WILLIAM P. AND OTHERS

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INFORMATION ON RECENT CURRICULUM REVISIONS IN ELEMENTARY AND SECONDARY SCIENCE IS PRESENTED. THE CHAPTERS INCLUDE MATERIALS FROM PAPERS THAT WERE PRESENTED AT NINE REGIONAL CONFERENCES OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. THE INTRODUCTORY CHAPTER RELATES CURRICULUM MODIFICATION TO CHANGING SOCIAL STRUCTURE AND CONCOMITANT CHANGES IN THE OBJECTIVES OF EDUCATION. THE ADMINISTRATOR'S ROLE IN BRINGING ABOUT CURRICULUM CHANGE IS ALSO CONSIDERED. SUBSEQUENT CHAPTERS DESCRIBE SPECIFIC SCIENCE COURSE IMPROVEMENT PROJECTS IN EARTH SCIENCE, BIOLOGY, CHEMISTRY, AND PHYSICS. DESCRIPTIONS GENERALLY INCLUDE (1) BACKGROUND INFORMATION, (2) AN EXPLANATION OF THE THEME OF THE COURSE, (3) THE STUDENT POPULATION FOR WHICH THE COURSE IS INTENDED, (4) MATERIALS PRODUCED, (5) ESSENTIAL FACILITIES AND EQUIPMENT, (6) IMPLICATIONS FOR TEACHER EDUCATION, AND (7) FUTURE PLANS. OTHER CHAPTERS ARE DEVOTED TO THE SCIENCE MANPOWER PROJECT, K-12 SCIENCE PROGRAMS, AND ELEMENTARY AND JUNIOR HIGH SCHOOL SCIENCE. A FINAL CHAPTER IDENTIFIES THE RESPONSIBILITY OF SCHOOL ADMINISTRATORS IN SCIENCE CURRICULUM DEVELOPMENT AND IMPLEMENTATION. TOPICS DISCUSSED ARE MOTIVATION OF PERSONNEL, PLANNING, PUBLIC RELATIONS, INSERVICE EDUCATION, PRODUCTION AND STORAGE OF MATERIALS, COSTS, AND EVALUATION. THIS DOCUMENT IS ALSO AVAILABLE AS AAAS MISCELLANEOUS PUBLICATION 63-6 FROM THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1515 MASSACHUSETTS AVENUE, N.W., WASHINGTON, D.C. 20005, FOR $0.25 (AG)

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THE NEW SCHOOL SCIENCE

A Report to School Administrators on Regional Orientation Conferences in Science

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American Association for the Advancement of Science
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Washington, D.C. 20005

Preface

This little book is written for the school administrator. The material contained in it was first presented at a series of nine regional conferences during the spring and fall of 1962 in selected centers across the country.

The conferences were sponsored by the American Association for the Advancement of Science with the cooperation of the United States Office of Education and financed by a grant from the National Science Foundation. The purpose of the conferences was to bring the school administrator material on the new science curricula so that he would be better able to make judgments about their possible adoption in his school or school system.

In attendance at the conferences were superintendents and principals who had been selected by state directors of teacher education and certification with the help of state science supervisors. The conferences generally began with a dinner and one or more addresses and continued another day and a half or two days. At each conference keynote speeches were made by a scientist, a science educator, and an administrator who had been involved in the use of the new curricula in his school system. A major portion of the conference was given over to presentations by teams of college and secondary school teachers. Time was allotted for a general discussion of points of interest not covered in the presentations. Films and slides were used at appropriate times in the program and exhibits of materials were provided.

Each chapter is a composite of several speeches by various topic presenters. In most cases, chapter editors had spoken at one or more of the conferences on the subject matter of their chapters.

Because of space limitations the excellent addresses by the scientists who keynoted each conference could not be presented in full. Because of the differences in approach they could not be brought into a composite form. For these reasons, portions of the speeches were excerpted and used as introductions to chapters so that the reader might have some indication of the thinking of scientists about science, science in our culture, and science teaching in our schools. These excerpts do not necessarily relate directly to the material in the chapter which they precede. The remarks by a teacher of administrators, Francis S. Chase, at the Chicago conference seemed particularly appropriate to introduce the final chapter.

This book is dedicated to the scientific societies and to the independent committees of scientists who have provided the impetus and the leadership required to develop the new science curricula; to the many persons who took part in the program; and, particularly, to those superintendents and principals who demonstrated by their attendance recognition of the importance of keeping well informed in the area of curriculum. It is hoped that this document will be of help to them as well as to the many administrators who could not be included in the conferences. The development of the new science curricula and, indeed, the full cooperative spirit of the conferences are clear demonstrations of the forward movement in education today.

The director of the project thanks the sponsor, the steering committee, and the staff of the National Science Foundation who helped so much in organizing and carrying out the conferences.

Special thanks go to the regional directors who did the real work of the conference series.

William P. Viall
Project Director

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Chapter I

It is one of the functions of science, in our culture, to fix, and sometimes to change, the direction of thought in the process of explanation. For example, in Greek science, chemical and physical changes during growth were explained in terms of teleology and potentials—i.e., in terms of a kind of embryology of matter—whereas nowadays we tend to explain embryology in terms of physics and chemistry. And the direction of thought fixed in science is often used also outside science, in the way we explain the world to ourselves. It is science that gives us some of the vocabulary, and the methods, the questions, the themes or myths, that to a large extent rule what we do and what we think. That is what I call the mythopoeic function of science and technology. It is a function that is too often overlooked.

Let us review very briefly the other main functions of science in our culture. I think most of us would quickly agree that there are two: science as pure thought that helps our mind and our soul to find truth, and science as power that provides tools with which effective action becomes possible. Science as thought allows us to understand the world and ourselves; and the practical results of science allows us to control and change that world. These two functions have been realized since the earliest days. We find them amply represented in our better textbooks.

But the third aspect should not be dismissed. The mythopoeic function always generates an important part of our symbolic language as well as the metaphysical bases and orientation of our current ideology. Plato's attention to apparently irregular, retrograde motion of planets, and his desire to resolve them as a superposition of simple circular motion, gives us a good example. For he thought that the gods, symbolized by the planets, had to be shown by science to move in a regular and dignified way despite the appearance of disorder. In addition, the methods of argument in science, as well as its vocabulary and models, always diffuse into our intellectual lives, and from there into everyday thinking. Once alerted, you can easily discern the debt of our common idiom to the sciences. Terms may in fact have originally entered into science from some other field, as was true of "complementarity," but later they return from science to enrich the general arsenal of imaginative tools of thought. Most important of all, the necessary conceptual foundations of all private and public philosophies share with science such basic ideas as space, time quantity, motion. force, order, law causality, reality, and many others.

Gerald Holton

THE IMPROVEMENT OF SCIENCE EDUCATION AND THE ADMINISTRATOR

Editor: J. Stanley Marshall

The chapters that follow tell of the dramatic new developments in the various science disciplines, of the growing unity of science and the great expansion of knowledge in all of the science fields, of the importance of science as an element in our lives in the second half of this century, and of the excitement that pervades the world of science today. There is no doubt that science is here to stay. It cannot be poured back into the bottle nor be confined to the laboratory. People may view science with fear or with fascination but they do not ignore it. Neither does science ignore people. It draws them into the main stream of events and they in turn respond to its forces.

The Need for Change

The need for a reorientation of science teaching in the high schools of America has been apparent since the early 1940's. Numerous factors point to the need for new directions in science teaching—not the least of these is the significance of science in the economy of our nation. It has become apparent that what we need is an education in science different from that ever before offered our young people. Most of the traditional courses are at too great a variance with modern concepts of science and too far removed from the educational needs of contemporary society to meet the demands in the period ahead. A simple curriculum revision could not meet the need adequately. The alternative has been to develop new courses in science—new in concept, in content, and taught by novel means.

The question has often been raised: why has it been, with so many people in positions of leadership saying that changes have been needed over the past ten or fifteen years, that the courses offered in the schools have changed so little and so slowly? In part we may attribute the lethargy to the model of instruction provided in the colleges both in the content considered and in the didactic form of presentation. In addition, most teachers have been unable to prepare new courses because of limitations in their own training and the time available for this kind of work. Furthermore, there has always been the possibility of failure and administrative displeasure resulting from lowered pupil scores on the various standardized tests, especially the College Entrance Examination Board tests. In addition textbook publishers have been hesitant to bring out radically different books, even assuming the authors could have been found to write them, for fear that such books would not sell well and would therefore result in a major financial loss. In a few cases notably different textbooks have been notable failures.

The ills of the older courses are numerous and easy to identify. Those who are even casually acquainted with the history of American education know that most science curricula were developed in a highly uncertain manner and have come down to us in a fashion hardly calculated to build confidence in American education. The courses grew by adding new scientific information and theory without eliminating any of the old. The emphasis was typically on science as a static body of knowledge. There has been a futile attempt at "coverage"; textbooks have become thicker, courses have become a larger inventory of facts, and teaching a mad race from September to June to complete the textbook, with the result that the surest way to develop a neurosis in a teacher is to ask whether or not he is really going to be able to finish the textbook. Still another shortcoming has been the undue stress upon the products of technology. We have emphasized the operation of machines without being properly concerned about the fundamental principles of science on which their operations depend.

It is simply no longer possible either to know or to teach more than a fragment of any field of knowledge. The time when it was possible to do more passed decades ago but the fetish and the delusion of subject matter coverage have persisted both in the writing of textbooks and in teaching practice. The result of all this is that many science courses consist of massive doses of facts without conceptual order, without unity, without a knowledge of how these facts were developed, and without a feeling for the intellectual method that won them from nature. Only the mere skeleton of science has been presented. The facts are divorced from anything that might be called the processes of inquiry; they are sterilized of their beauty and are left dangling without a place in the scheme of things.

For the most part our textbooks have become encyclopedias of organized information. They abound with "essential data," tables of constants and specifications, and they recite seemingly endless facts and formulas—but they do little to encourage the student to think. In the laboratory the facilities and equipment have been such as to provide the student opportunity to repeat the same "experiments" that have been done for decades but rarely to explore an original idea or to take away from the oratory an idea which he did not have when he entered the room.

But the most important problem of all in our science teaching over the past several decades has been in the philosophy of science education held by the science teaching community. It has been for the most part a pedestrian outlook that we have exhibited. The teacher is apt to view his role as a conveyor of information. We have defined science as "classified knowledge," not as a way of learning how and why things happen in the natural world. The excellent teacher of the past has been one who sought to have his students learn—that is to memorize—a sufficient quantity of information in science. Too many teachers have ignored opportunities to help their students see something of the mystery of science and how it teaches us, among other things, that the pursuit of truth in the natural world is often a very sticky business.

It is clear then that changes in science curricula are in order. The need is for an education that will enable young people to live intelligently in the world in which they have to live. What is taught must have value beyond the context in which it is learned. Learning in every course must be durable, counting for the rest of the student's life. Since much of what is educationally worthwhile has not been announced or discovered, students must be provided with an entrance into knowledge. This is to say that young people should be equipped for life-long learning and in a way that they can travel upon their own—an education that is geared to change and which trains for intellectual self-direction. Young people must be qualified to deal with ideas not yet born and with discoveries not yet made. The productive life of students now in high school will extend well past the year 2000 and so must their education.

An objective of any education beyond the pleasure it may give is that it should serve the future. There is too much to know and too much demanded of one today to be able to afford learning that withers into obsolescence before the course is over. Science is by definition oriented to the future; it is characterized by change and progress; it is therefore not to be thought about in the same light as many other school subjects.

Curriculum Reform

There are forces other than those of social change and the impact of science on our culture that have helped to speed the curriculum reform in science, but surely these have been the most prominent. The 1960's began with new science curricula that are quite different in point of view and content from traditional courses. The new programs present science as a scientist sees science and in terms of modern concepts and theories.

Beginning in 1956 the National Science Foundation, working through scientific societies and universities, provided funds to initiate several programs of curriculum development in science. Modern courses in physics such as Physical Science Study Committee (PSSC), chemistry, Chemical Bond Approach (CBA), and Chemical Education Materials Study (CHEM), biology, Biological Sciences Curriculum Study (BSCS) have been designed. The PSSC physics course has been completed. The others are in various stages of experimental tryouts in schools and all will be in textbook form for general use by the fall semester of 1963.

To summarize, all of the new science curriculum projects have included these features:

1. They have sprung from the minds mostly of professional scientists —those who are in the best position to know what science our children most need to study.
2. They have involved, along with the scientists, professional educators—those in the best position to know how the science should be taught.
3. They have had the organizational strength and the prestige to attract substantial financial support, most of it from the National Science Foundation. This has enabled talented people to throw themselves into the problem completely on a full time basis as opposed to taking it on as a preripheral activity along with their regular jobs as is so often the case in preparing new curricula and in writing textbooks.
4. Their emphasis has been on basic science and not on engineering or technology. A student is asked to explore and discover, to develop an understanding of the big ideas in the science rather than to memorize large numbers of facts and formulas, many of which will be out of date in a few years.
5. Their approach has been a total one in which a complete kit of materials has been provided to help both students and teachers.
6. They have made provision for the tryout of the new courses in hundreds of schools with many thousands of students. As a part of this phase, feedback information has been collected to aid in the evaluation of the courses and to guide their further development. In addition, special training programs for teachers have been conducted all over the country.
7. These programs have seemed to awaken interest in education by other professional groups and to stimulate others not directly connected with the schools to consider their responsibility in the improvement of education.

New Goals for Science Education

Let us consider in some further detail the kind of science it is that we wish to teach our children. Let us measure the new courses against acceptable educational goals.

The goals for the new science courses center upon the development of an understanding of the nature of science, its modes of inquiry, and its conceptual inventions; and understanding of natural phenomena and the place of science in the activity of man. The achievement of these goals will result in a student who is literate in science and one who is capable of a citizen's participation in a science oriented society. There is a need to restore the validity of science courses in terms of the present status of scientific knowledge and this is the primary reason for calling upon the research scientist for help; to distinguish the significant from the trivial, the inert from the useful.

Modern science teaching should attempt to:

1. Provide a logical and integrated picture of contemporary science: the theories, models, and generalizations that show the unity of science.
2. Illustrate the diverse processes that are used to produce the conclusions of science and which show the limitations of these methods: the ways of inquiry and the structure of scientific knowledge.
3. Enable the student to reach at some point the shadow of the frontier: to experience the meaning of "we just don't know" and to become sensitive to the progress of science.

In science teaching efforts are made to avoid the fragmentation and discontinuity represented by the unit organization of traditional science courses. Coherence and conceptual structure are sought through integrative themes that provide a logical picture of the course. Series of learning cycles are established to allow for growth in understanding. The framework of the course is strengthened through continuing concern with the characteristics of scientific inquiry. Students are led to feel that science is more a verb than a noun; more a process than a product.

Those who would develop new courses in science must raise the quality of learning. Quality in science is sometimes defined as knowing the characteristics of a science, its methods of investigation, and the nature of its data. It is recognized in the student's ability to pattern the conclusions, processes, and theories of science. The student's understanding of the structure of science is revealed by his capacity for logical thinking within the subject.

Grasping the structure of a subject also means understanding it in a manner that permits other ideas and new knowledge to be related to it in some meaningful way. When ideas have been grouped and unified, a student is in an intellectual position to use his knowledge to attack new problems. Through the act of problem-solving, learning becomes more versatile and the student's capacity for thinking increases.

The emphasis upon ordering or structuring of knowledge seems to be the best way in which the common high school science subjects can be taught. It also places the learner in a favorable position for the harboring of new knowledge. It is the most efficient way for original learning to take place if understanding is the expected outcome and retrieval the goal. Even more important, the capacity of the student to generate ideas, to attack old questions and to raise new ones is greatly enhanced.

The ideas expressed here are in contradiction to a teaching procedure which consists mostly of describing the phenomena of science, memorizing its nomenclature, and reciting its laws. They are in contradiction to courses organized into distinct units without thematic continuity in which students have little concern for what has preceded or what will follow.

The rationale for the new approach to laboratory work is both interesting and appealing. Science is based on experimentally derived data; and so must be the study of science in the school. Scientists use the laboratory as a primary source of learning; a similar function should be served in the teaching of science. The purpose of laboratory work is that of acquainting the students with the processes of inquiry as a means for exploring ideas. The student would be concerned with: What questions should be raised in the laboratory? What data are relevant? How can observations be made and expressed quantitatively? How should the data be ordered for interpretation?

Above all, lessons from the study of science itself emphasize how meaningless an "experiment" is if the results are known in advance. An exercise which gives predigested data and a predetermined answer of the kind conducted in many science courses in the past is completely unknown to the practicing scientist. How can a student develop confidence in his own learning when the unexpected answer is always the "wrong" answer. In a situation where there is no opportunity to question experimental results, then surely there is no opportunity for critical thinking.

It may be that we can best express the new philosophy of science teaching in terms of authority. One of the most important ideas for the student of science to develop, is that the authority for science rests in nature itself and not in teachers or textbook authors or experts of any kind. If one finds in searching for answers that nature, the ultimate authority, guards her secrets closely and even confuses the observer at times, this is in itself a valuable lesson in science. The research scientist knows that the secrets of the natural world are not easily come by and that often valuable lessons are learned from what appear to be failures. It is well for the student to discover this early in his study of science.

Evaluation

The projects which have produced the new curricula have been the recipients of a great deal of money and human energy, and we are obliged therefore to extend every reasonable effort to evaluate their worth. The new courses differ in purpose from traditional courses and so must the instruments of evaluation. A student is first of all required to *understand* the facts, formulas, and principles he has learned; therefore knowing *about* science and having the ability to memorize are not sufficient qualifications for receiving a passing grade. The student must be able to demonstrate his ability to reason from concepts and theories and to use these in unfamiliar situations. He is expected to interpret experimental data he has not seen before and he must demonstrate his ability to use the techniques and procedures of scientific inquiry. Factual information is important but not as facts in isolation. The standardized tests which have accompanied the new courses should be treated as an integral part of the instructional program. Not only do they provide a measure of achievement by the student but they also are designed to help students and teachers understand the goals of the course.

If the program of evaluation is to be fair, close and sympathetic attention should be given the old as well as the new. In the end those responsible for curriculum should consider all available instructional materials as they determine the best course to be used with their students. Test scores are not the only and possibly not the best basis for evaluation. The teacher should observe the relevant behavior of pupils in the class, in the laboratory, and even outside of class. The feeling of growth and excitement on the part of students is an important criterion in science, often as important as performance on paper and pencil tests.

It has been suggested that in schools where the new courses are adopted the trial period should extend over a period of two or more years. In addition to the advantage of having a larger number of students on which to base judgments, it is highly desirable for the teachers of the new courses to have developed the perspective that comes from teaching the course the second time. Teachers have said repeatedly that it is well nigh impossible for a first year teacher of so new and different a course to understand fully many of the more subtle points the first time through.

It is plainly obvious that those responsible for the curricula have the obligation to avoid falling into a common trap; that of permitting the new courses to become stereotypes from which no deviation is permitted. If this happens, we can claim no progress for science education. School curriculum must be a dynamic thing, ever changing and constantly being challenged in one way or another by teachers and administrators. If we do accept the new courses as the ultimate in science curricula, our programs of instruction will in time become as stagnant as before. Certainly there is no reason for such a situation to exist in schools where there is aggressive leadership in curriculum. The extent to which it does exist is the extent to which those who have accepted leadership responsibilities will have failed the students they are supposed to serve.

Limitations

It should be emphasized that thoughtful people do not consider the new courses to be the final answer to the problems of instruction. But the courses do possess certain strong features which nearly all agree represent distinct improvements over traditional courses both in the clarity of goals and in the validity of their content. Even the strongest proponents of the new courses list a number of things the courses are not: they are not final; they are not perfect; they are not the only possible approaches to teaching the respective sciences. Compromises among groups and individuals with varying viewpoints were inevitably necessary. For example, the original goal of the PSSC was a two-year sequence unifying physics and chemistry but for various reasons this step was deferred until some future date.

It has been pointed out on a good many occasions that the new courses are oriented primarily toward the more academically able students; those who typically elect science courses in high school. This is perhaps more true for the physics and chemistry courses than it is for biology. There is no doubt than an organized effort to develop a series of science courses designed for the less academically able is urgently needed. It is to be hoped that some distinguished group will address itself to this problem in the near future.

The proponents of the new courses stress their emphasis on fundamental principles to the exclusion of engineering and technological applications. There are those who claim that there is a distinct place for technology in the education of at least a fraction of our youngsters.

The Problem in the Pre-Secondary School Grades

The school years, kindergarten through nine, contain nearly all of the children and nearly all of the future citizens. For many this is all or nearly all of the science instruction they will receive. Many will not complete the secondary school let alone be interested in going to college. For those who do go to college, most will take no more than a minimum required program in the sciences. This problem of a continuous science sequence from kindergarten through grade nine has been the subject of study by numerous committees whose reports indicate clearly the need to create a well organized and integrated continuous science curriculum to encompass the pre-high school years and to articulate closely with the courses taken in high school.

Leadership in science education through grade nine is currently being provided through the Commission on Science Instruction of AAAS which was born of a 1961 feasibility study on the needs and problems of science instruction. The Commission conducted two conferences during the summer of 1962. At these meetings there seemed to be general agreement that curriculum development for grades kindergarten through nine should be more on a regional basis than a national one and that a number, perhaps eight or ten, of regional centers might be established. Each would tap the interests and enthusiasms of many individuals in colleges and school systems throughout the region. Such an organization would provide for local diversity of specifics although all groups would be moving toward the same philosophical and intellectual ends. There appeared to be general agreement also that in the earlier school years the study of science should involve material from all of the sciences but no particular pattern of organization was agreed upon. All agreed that a major role must be played by psychologists and others familiar with the capabilities and learning patterns of children. Developments in this area will likely proceed slowly with limited tryouts in a large number of schools to be followed by frequent revision of the draft material. School people should, therefore, not expect much useful material to be available within the next several years. This means that responsible local efforts at curriculum improvement should continue.

The Administrator's Role

There can be no doubt that bringing together school administrators to consider certain changes in science teaching and the ways in which these changes might influence their own school programs is highly commendable. Many in education have felt all along that the key person in improvement of curriculum is the chief school administrator. In schools where curriculum has been kept up to date and new courses and new methods of teaching have been introduced successfully, the chief school administrator is almost certainly a person who has a deep interest in instructional matters and somehow finds time to acquaint himself with the new developments—this despite the demands on his time and energies of the myriad administrative problems with which all administrators must cope.

The following specific recommendations are suggested as action steps for the consideration of school administrators as you consider your own part in improving your science program:

1. It is the hope of the sponsors of this conference that you will encourage your teachers and supervisory personnel to give thoughtful consideration to the new courses—to examine, compare, and investigate them from every possible viewpoint.
2. Those teachers who wish to try out the new courses should be given every encouragement and assistance. This includes the necessary financial support for textbooks, laboratory guides, laboratory supplies and equipment, films, auxiliary reading materials, and similar items. In addition it may be necessary for you to provide some free time for the teacher who may need very badly additional time to prepare for a vastly different teaching experience.
3. You can render a service of great value to your teachers and students by providing opportunities for parents in the community to learn about the new courses. Experience has shown that parents sometimes become considerably disturbed over educational methods which depart radically from those which they experienced twenty or thirty years ago. Conscientious parents may become seriously concerned when they discover so dramatic a change in the education of their children; for, as one cynic has said, education is the one elementary in our culture which is not supposed to change.
4. Perhaps the most important thing you can do is to provide an atmosphere of positive encouragement that will pervade the classroom and laboratory and will make itself felt both to the teachers and students. This requires your own involvement in the venture and making the rest of the faculty aware of what's going on in science. You must recognize the teacher as a professional person who is master of what goes on in his own classroom but is limited in what he can do in that classroom by a number of factors which only those above him in the hierarchy can control.
5. Do not assume that the new courses represent the ultimate in science curriculum. Further improvisations, local imagination and

creativity are prime ingredients for a steadily improving science program. The leaders of the present projects generally agree that their materials will doubtless be obsolete within ten years. It is therefore imperative that you and your faculty and your students regard the new courses, valuable as they are, as one phase of curriculum through which the program is presently passing.

It is hoped that this report has helped you to become acquainted with the new curriculum in secondary school science and that it contains information and ideas which will have a real impact on the science programs in your schools.

In closing, consider the question of the real importance of science in the world today. If you were asked to evaluate the progress of a new nation, say one of the emerging nations in Africa, on what basis would you render your judgment? It is almost certain that your answer would be phrased in terms of science and technology. You would be impressed by the country's facilities for producing electric power, the state of agricultural equipment and practices, the kind of health facilities available, and the capacity for producing the machinery for modern living. All of these things stem directly from science. The ways in which they are used, of course, relate to the value system of the country but the base, the very foundation of a nation's well-being today, rests more on science than on any other factor. Science has become the major determinant of our culture and its place in the schools must have a major determinant of our culture and its place in the schools must have a major place in the considerations of school administrators.

Chapter II

Just as the "Three R's" are the essential elements of learning in the early grades, so in the upper grades the three important and interrelated elements cf learning revolve around the humanities, the social sciences, and the natural sciences. When we neglect any one, we deprive students of an opportunity for a better understanding of the world in which they live—the world of human beings, the world of the social order, and the world of the physical universe—and we thereby deprive the student also of the opportunity for living a more understanding, a more useful, and a more fruitful life.

We used to be afraid to try to teach mathematics and science to youngsters. Now we know those fears were unjustified, for we have found that youngsters have greater capacities than we thought and we have found that the methods of teaching these things are not so difficult as we had supposed. Those who have seen youngsters respond can agree that to them science can be exciting, it can be stimulating, it can be inspiring, and can be of enormous practical value.

Lee A. DuBridge

THE EARTH SCIENCE PROGRAM

Editor: ROBERT C. STEPHENSON

WITHIN the past decade there has been a rebirth of scientific interest in the earth and its environs. Earth science courses are being introduced into the secondary school science curricula throughout the country at a rapid rate following the success of earth science offerings in the schools of New York State and Pennsylvania.

Fifty years ago physical geology or physiography was taught in many of the nation's high schools. This course, much of which was geology, meteorology, and, to a lesser degree, oceanography, served to introduce the student to the planet that is our home. Then, faced with the rapid advances that were being made in the fields of biology, chemistry, and physics, physiography virtually disappeared from the public school curriculum.

In the meantime, secondary school students received a smattering of physical geology, astronomy, and meteorology in general science or physical science courses. But the history of the earth and its inhabitants was largely neglected. Fortunately, however, some of the better biology textbooks did have sections dealing with fossils, evolution, and historical geology. Thus, those relatively few students who took both biology and physical science might, if their instructor saw fit, be exposed to a bare minimum of earth science.

The Revival of Earth Science

Today, however, this situation is being remedied. Within the past five years there has been a great upsurge of newly awakened interest in earth science as an addition to modernized science curricula. This is due partially to such activities as the International Geophysical Year, Project Mohole, and other recent research on man's physical environment—the earth and her sister bodies in space. Such projects have received much publicity, and consequently considerable glamorization, from many different sources. It appears, moreover, that there is a reawakening of the intellectual curiosity of man concerning the unsolved scientific mysteries of the earth on which he lives.

The revival in the teaching of earth science in secondary schools began in 1949 when one New York school inaugurated an earth science course for gifted students. Originally intended as a substitute for general science, the results of this experiment were so satisfactory that this plan was rapidly adopted by several other schools. Finally, in 1961-62, 420 schools were teaching earth science courses to more than 16,223 students! There were, in addition, more than 159 schools which offered earth science in grades ten through twelve. Approximately 17,261 students were enrolled in these courses last year. Consequently, more than 33,484 students took earth science courses in New York State in 1961-62. Thus, due to the hard work of a handful of dedicated earth science teachers, science supervisors, and school administrators, geology had finally come "home" to the secondary school science curriculum of New York State.

Meanwhile other interesting developments took place in Pennsylvania. During the fall of 1959 the Pennsylvania Department of Public Instruction developed a *Teaching Guide for the Earth and Space Science Course.* The Pennsylvania course, like that of New York, was designed for gifted ninth-graders. Originally taught to 800 students in nine selected schools, today more than 400 schools teach earth science to 38,000 talented ninth grade students.

The introduction of the earth-space science course in Pennsylvania served to trigger an almost explosive development of earth science courses across the nation. At the present time 39 states are reported to have in progress, or in the advanced planning stage, earth science courses or units. Most of these are at the ninth and eighth grade levels.

In addition, many local or county school systems have inaugurated earth science courses without reference to a state-wide program.

In Texas, for example, in more than 50 percent of the junior high schools earth science is currently being taught at the eighth grade level. Some of these are one semester courses, but many are taught for the full school year. The Texas Education Agency estimates that by 1965 almost every junior high school in the State will offer courses in earth science. Likewise in New Jersey there has been a 600 per cent increase in earth science offerings during the past five years.

Thus, today the earth is being rediscovered by scientist and non-scientist alike. Man, in trying to understand better his physical and biological environment, relies heavily on the earth sciences; for the study of geology, oceanography, meteorology, and astronomy may well provide the answers to many of the great mysteries of our universe. Fortunately, some of this newly-created interest has caught the attention of the younger generation. They too are eager for more knowledge about earth and space. But where will these youngsters learn about the earth, the solar system, the oceans, the atmosphere, and problems of space exploration? Even the broadest general science course fails to cover such topics in more than minimal detail. And even more important—where shall we find properly prepared teachers to present this material?

What Is Earth Science?

The first problem is relatively easy to solve. We shall simply add earth science to the curricuum. But what precisely is earth science? One soon discovers that an exact definition of this subject is not easy to locate. Indeed, earth science is not even defined in the glossaries of at least two of the major secondary school science texts!

In modern usage earth science deals with the whole earth, not just one part or aspect of it. Thus, earth science is concerned with the study of a scientific system composed of the solid part of the earth (the *lithosphere*), the liquid part of the earth (the *hydrosphere*), the gaseous part of the earth (the *atmosphere*), and the reaches of space. To study this intricate scientific system, one must rely on the concepts and techniques of biology, chemistry, physics, and mathematics. Earth science may be defined, then, as dealing with the scientific phenomena of the earth and its environs in space. As such it is composed of a family of interrelated fields of science including geology, geophysics, oceanography, meteorology, and astronomy. To this has recently been added a broad field known generally as astroscience or space science which in some instances is taught as a part of earth science.

What Can Earth Science Contribute to the Science Program?

Earth science contributes greatly to the understanding of the geopolitical, physical, and biological environment of men. If educated people are to deal with broad social and economic problems of their environments, they should understand the controlling factors. For example: the entire economic wealth, hence political status of a nation, in the main, is controlled by geologic history. The distribution of fuel resources, of ores, soils, rain distribution, trade routes, and many other aspects are geologically related.

Earth science taught by well prepared teachers can serve to illustrate the interdependence of the various basic sciences. Astronomy permits study of the laws of motion, gravity, mass attraction, etc., meteorology permits study of the gas laws and heat flows, while geology permits study of the application of chemistry to the atomic structure of minerals, chemical bonding, surface chemistry, and chemical reactions. Examples of the application of physics, biology, etc., can also be shown.

The study of earth science affords excellent opportunities to discipline the mind. Rarely do phenomena of earth science fit into tidy little boxes, so to investigate them and to understand them one must develop an intuitive ability for arriving at reasonable answers with limited factual information. Thinking geologically, for example, involves not only consideration of three-dimensional models, but is also complicated by consideration of a fourth dimension—TIME.

A rigorous earth science course can stimulate interest of students in methods of scientific inquiry and investigation essential to successful mastery of subsequent basic science courses.

Grade Levels for Earth Science

Elementary school children are particularly interested in their environment. Almost any elementary school teacher will vouch for their competence as rock and fossil collectors, and many a fourth-grader knows considerably more about astronomy and prehistoric life than does the average adult!

Teachers find these young pupils generally attentive and particularly receptive when earth-space science topics are being discussed. Consequently, much introductory material of a factual nature can be successfully taught in the elementary classroom.

As for a full course in earth science, recent experience has shown that the ninth grade appears to be the ideal level to present this material. There appear to be several reasons for this:

1. Modern science programs have caused much of the material formerly presented in general science to be taught in the lower grades. There is now a need for a more advanced science course at the ninth grade level.
2. Most ninth grade students have acquired the necessary reading ability to understand basic earth science subject matter and to master the required vocabulary.
3. Taught by competent teachers, earth science can be used to illustrate the interdependence of the various basic sciences in the study of scientific concepts and processes of the earth and space.
4. A challenging, well-presented earth science course can introduce the student to the basic methods of scientific inquiry and investigation. This should prove helpful when more advanced science courses are taken.

Some state education departments suggest that earth science be offered as a one semester course at various levels from grades seven to ten. Others suggest the introduction of short earth-space science units in general or physical science courses. Such offerings, although a step in the right direction, tend to be quite generalized and considerably watered-down. As a result they are not sufficient in breadth or depth for the college-oriented student, and probably do very little for those students of less than college capability.

On the other hand, some school systems have introduced a twelfth-grade course in geology or the combined earth sciences. Designed primarily for students who have completed courses in chemistry, physics, and biology, a few of these courses are actually of college caliber.

Selection of Course Content

One of the major problems encountered in planning the earth science program is the proper sequence in which the material should be presented. There is also the question of deciding how much time should be allotted the various areas that must be covered.

It is recognized that not all phases of earth science be treated equally. The teacher should, however, see that the more important phases of geology, oceanography, meteorology, astronomy, and related sciences be adequately covered and the proper sequence in which they should be presented to the student. An inadequately prepared teacher is not likely to be able to decide the proper weighing of science content.

The amount and complexity of the material to be taught will depend, of course, upon the grade level at which it is presented. The ability of the student must also be taken into consideration. Since some of the more recently developed courses in science have been designed to be taught in the ninth grade, many students complete their study of general science in the eighth grade. In situations of this sort, special attention must be given the material presented in seventh and eighth grade courses. Subject matter presented in these grades should cover basic scientific principles in order to provide an adequate foundation for subsequent science courses. For example, life science taught in the seventh grade and physical or general science in the eighth grade would form an excellent background for a ninth grade earth-space science offering. Thus, the student would utilize many of the basic principles of biological and physical science that he learned at lower levels.

Earth science taught at the ninth, or even the eighth grade level, should emphasize concepts and problems rather than merely require the memorization and regurgitation of a mass of half-digested factual information. Attention should be directed to unsolved geologic problems, and every opportunity should be taken to introduce mathematics, physics, chemistry, and biology into the course whenever possible.

At the present time, the balance between the various subject matter areas may vary somewhat from one course to the other. The Pennsylvania program suggests the following time allotments: Introduction, 2 weeks; The Changing Earth, 11 weeks; The Earth in Space, 9 weeks; Weather and Climate, 9 weeks, and, The Oceans, 2 weeks. In general, subject matter balance in most courses for the geology and related materials, astronomy, and meteorology parts are in a 2:1:1 ratio.

The manner in which the material will be presented will vary from teacher to teacher, but whenever possible instruction should center around familiar phenomena in the immediate geographic area. Scientific processes involved in the study of earth science are usually of great magnitude and the student must develop new concepts of time and space in order to develop and solve geologic problems. Many of these concepts are best developed by "doing" and for this reason earth science should be taught as a laboratory course. Laboratory work, indoors and out, should emphasize fundamental methods of scientific investigation and should be planned around exercises dealing with rocks, minerals, fossils, and maps. Included also should be instruction and practice in the use of the telescope, weather instruments, "star finders," and similar equipment. Special demonstrations and field trips should be utilized at every opportunity.

A properly conducted earth science course offers splendid opportunities for outside reading and independent investigation. Some instructors require a term paper on some topics such as fossils, the stars, the oceans, space travel, weather forecasting, or some related subject. This further broadens the student's background and introduces him to earth science literature.

Projects should also be an important part of the course. These may include use of Geiger counter, cloud chamber, and telescope, construction of relief maps, the collection and classification of rocks, minerals, and fossils, models demonstrating weathering and erosion, or a study of weather observation techniques.

Field excursions are particularly important. Geology is best learned in the field and this is the logical place to acquaint the student with his environment. Such trips can be used to collect rocks, minerals, and fossils that can be used to develop worthwhile outside projects or science fair displays. This is also the place to introduce and develop more fully such geologic topics as weathering, deposition of sediments, rock formation, the reconstruction of earth history, and related subjects.

Visits to museums, weather stations, marine laboratories, and planetariums will also generate much interest among the students.

The Urgent Need for Teaching Resources

Although the school administrator is faced with the probem of finding well-trained earth science teachers, the teachers themselves are not without problems. Not the least of these is the lack of suitable teaching materials. Since this subject has not been generally taught for many years, little new learning material has been produced. There is, therefore, an urgent need for well-organized updated teaching resources. To date there has been no massive program in the earth sciences comparable to PSSC, BSCS, and the other NSF-funded course content improvement programs.

Several fairly satisfactory earth science texts are currently available. All of them, however, suffer somewhat because of the lack of editorial review by professional earth scientists. There is a need for additional authoritative textbooks with a more modern and imaginative approach. Teachers' guides, laboratory manuals, laboratory and classroom experimentation, and demonstration equipment are also essential. There is a particular demand for up-to-date, well-planned and scientifically accurate audio-visual material.

But the production of new teaching aids moves slowly and in the meantime we must do with what is currently available. Fortunately, the situation is not hopeless. The existing earth science texts must be used to the fullest and they can be augmented by various publications specifically designed to help the teacher.

Such audio-visual learning aids as are now available can be evaluated and selected from the more than 500 films in the annotated listing of the *Directory of Geoscience Films*. This and the three pamphlets of the *Geology Reference Series* are available from the American Geological Institute.

Certain government agencies also provide educational aids. For example, *Project Ideas in the Earth Sciences* can be obtained at no charge from the United States Geological Survey, Washington, D. C. In addition, many of the State geological surveys have produced non-technical publications on rocks, minerals, fossils, and the geology of various state parks and other areas.

Educational materials are also available from such scientific societies as the American Petroleum Institute, American Geological Institute, American Astronomical Society, American Meteorological Society, the Committee on Oceanography of the National Academy of Science–Nation Research Council, and the National Aerospace Education Council.

The most recent and useful teaching resource yet produced is the *Geology and Earth Science Sourcebook* prepared under the direction of the American Geological Institute. This book was written by a carefully selected team of 30 science educators and professional geoscientists during a six-weeks conference supported by a grant from the National Science Foundation. It is a solid piece of geologic writing and a veritable treasure house of geologic information. For each of the 23 topics covered (such as minerals, earthquakes, volcanoes, astronomy, etc.), there is an introduction, suggested method of presentation, suggested problems and demonstrations, projects, and experiments, teaching aids and references. A course within itself, this book is published in paperback form by Holt, Rinehart, and Winston for the almost unbelievable price of $2.96 and is now in its second printing. No school and no earth science teacher should be without one. The American Geological Institute has also completed another paperback, the *Dictionary of Geological Terms*, published as a Dolphin Reference Book by Doubleday, Inc.

The American Geological Institute in February 1963 received an initial grant from the National Science Foundation to launch its Earth Science Program (ESP) for secondary schools. This program will be comparable to the major secondary school curriculum efforts in biology, chemistry and physics. Its headquarters will be at Boulder, Colorado under the direction of Robert L. Heller. The program will begin in the summer of 1963 with planning and writing conferences. Experienced earth science teachers and subject matter specialists from the various areas of the earth sciences will produce textbooks, teaching guides, laboratory manuals, classroom and laboratory demonstration materials, films, monographs and other learning aids. Considerable attention will be given to the importance of teacher education in earth science.

For use at the elementary school level, the American Geological Institute in cooperation with Encyclopaedia Britannica Films, Inc. is producing a series of about 25-30 films. These films will be made with the guidance of competent earth scientists, and the finished films will be reviewed by the institute. Teachers' guides will be prepared to accompany the films. There will be supporting film strips. Other printed classroom materials also are being considered. The first films of this series should be available by late 1963 or early 1964.

The Problem of Teacher Education

The second problem, that of finding qualified teachers, is not so readily solved. It is, in fact, the greatest dilemma facing school administrators who wish to add earth science courses. School officials in New York State and Pennsylvania found this to be one of the major stumbling blocks in the inauguration of their programs.

There must be some attempt to overcome the deficiencies of science teachers who are currently called upon to teach earth science. How deficient are these teachers? A recent survey made by the New Jersey State Department of Education has shed considerable light on this problem. It was learned, for example, that among the 99 earth science teachers who responded, 75 percent could be considered as not having proper preparation in the earth sciences. These 99 respondents are 91 per cent of the earth science teachers in New Jersey.

It was further learned that little more than half of them had completed one or more courses in geology, that only about one third had studied astronomy and meteorology and only ten per cent of the respondents had completed a course in oceanography. But even more alarming is the fact that at least 20 per cent had not earned a single credit in any of the earth sciences!

The New Jersey survey revealed two striking facts: 1) the incidence of earth science in the New Jersey secondary school curricula had increased 600 per cent in five years, and 2) most of the teachers assigned to this course were not properly prepared to teach it. If similar surveys were undertaken in the other 29 states offering earth science courses the results would undoubtedly be similar.[1]

Some attempt to overcome teacher deficiency has been made by the National Science Foundation science teacher institutes, and special extension, evening, field, and inservice courses offered by certain academic institutions, state survey, and geological societies. But only a small percentage of earth science teachers have been able to take part in such programs. For instance, only about two-fifths of the New Jersey earth science teachers had participated in summer or academic-year institutes in science, and most of these were in subjects other than earth science. There is a pressing need for more earth science institutes and inservice training programs to equip existing teachers to instruct in the earth sciences.

School administrators desiring to initiate inservice programs should consult the geology, earth science, or a science education department in a nearby college or university. Most college departments are acutely aware of the lack of qualified earth science teachers and are quite anxious to help remedy this problem. In general, they will be willing to develop and conduct inservice training programs, extension courses, or short courses to strengthen the background of existing science teachers.

So much for the existing science teachers. What about the earth science teacher of tomorrow? If the earth science boom continues, as surely it must, institutions preparing teachers must assume the responsibility to provide more and better preservice education in the fields of geology, astronomy, meteorology and oceanography. One way this can be done is to broaden the scope of preservice college training of future science teachers. Better still let these institutions offer a professionally planned sequence of earth science courses leading to an undergraduate major in that subject. It is encouraging to note that several colleges and universities have programs of this type under way and that more are being planned. Such programs generally tend to be more effective when produced by the combined efforts of the geology and education departments.[2]

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[1] For a report of this problem nationally see—American Association for the Advancement of Science, *Secondary School Science and Mathematics Teachers: Characteristics and Service Loads,* NSF 63-10 Superintendent of Documents, Government Printing Office, Washington 25, D. C. (Catalog No. NS 1.2:T 22/2) 35 cents.

[2] National Association of State Directors of Teachers Education and Certification and the American Association for the Advancement of Science, *Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathematics* (Appendix, Earth & Space Science), Washington, D. C. 20005, 1961, 32 pp.

Obtaining qualified teachers and teaching materials is a persistent problem, but this is especially true in the case of the earth science course. Subject matter is drawn from fields of science in which the average secondary science teacher is not well-trained.

One thing appears to be certain—earth science will not achieve its rightful place in the secondary school science curriculum until enough competent teachers are available. In the meantime, academic institutions and school administrators must work together to provide the best instruction possible under the present circumstances.

Conclusion

Thus, through the combined efforts of professional geologists, oceanographers, meteorologists and astronomers dedicated earth science teachers and teacher training institutions providing suitable teaching resources, we can expect rapid strides to be made in initiating earth-space science courses in the nation's schools. The next five years will witness continued growth of this educational phenomenon, and within the next ten years earth science courses should be as widespread as physics, chemistry, and biology are today.

Chapter III

Let us consider the problem of the transmission to the next generation of the scientific heritage we have produced. Our educational system is very poorly organized to cope with the transmission of a selected core of facts, concepts, and principles from an exponentially increasing body of knowledge. In the first place, consider the teacher. The teacher of today is the student of yesterday, who passes on largely the knowledge he learned while a student. If the teacher continues in his profession for thirty or forty years, his skill in transmitting knowledge may greatly increase, but his stock in trade is outdated by a generation or two. And this situation is aggravated because the secondary school teacher learns from a college or university teacher who in his turn, unable fully to keep up with the development of science, is also in danger of presenting an antiquated picture of it. One does not escape this dilemma by adverting to the writers of textbooks, for they are in the same position as the rest of their university colleagues. Unless they remain avid learners throughout life, and unless they acquire rare skill in critical evaluation and synthesis, they too suffer from a horrifying rapid obsolescence. *H. Bentley Glass*

THE BIOLOGICAL SCIENCES CURRICULUM STUDY

Editor: PAUL DEHART HURD

AT NO other time in the history of our country has a curriculum reform in biology been more urgently needed and vigorously sought than at present. In the biological sciences, the significant knowledge is doubling every ten to fifteen years. The result is that much knowledge taught in high school is obsolete and contributes little to the understanding of modern biology. If new discoveries continue to increase at an exponential rate, our science curricula must be organized to provide the student with an entrance into the growing fund of knowledge. The Biological Sciences Curriculum Study (BSCS) has worked to invent biology courses for use in high schools that more accurately reflect modern biology and are more appropriate to the education of young people living in a science-oriented society.

This is not the first time that high school biology has been studied for the purpose of improving both course content and the manner of teaching. The previous efforts toward curriculum reform are reviewed in the BSCS Bulletin, Number 1, *Biological Education in American Secondary Schools 1890-1960.*

Here, one may trace the evolution of biology teaching from offerings in the separate science (botany, zoology, physiology) through the efforts to develop an integrated synthesis of biological concepts to form a unified course. Despite many attempts to formulate a science of biology around pervasive principles, the subject remained "a morass of isolate facts and simple generalizations." As the years passed, the content of the course became "fixed" and the disparity between the state of knowledge of contemporary biology and what is actually taught became ever wider. The time lag between discovery of new information and its inclusion in high school textbooks became longer and longer. High school biology drifted away from the course of modern research in biology. The working biologist often found the content of the high school textbook strange material indeed.

It was not until 1950-1960 that educators and scientists alike became fully aware that the existing curriculum in science was inadequate for a rapidly changing society and inadequate for conveying an understanding of current science. After reviewing high school biology textbooks, Joseph J. Schwab commented: "In brief, neither the old textbook nor the more recent one was satisfactory. Each had advantages but each had weaknesses which might have been corrected by the influences which shaped the other. What was needed was a collaboration among the different competences responsible for these different texts —between scientists on the one hand and the teacher on the other, between close contact with the field of knowledge and close contact with experience and knowledge about teaching and education."

The problems in biological education were obviously of such magnitude that cooperative action by the best minds in science and education were needed to meet the challenge presented. This cooperative approach to the problems of science teaching is one of the most encouraging developments in the history of science education. Contrary to the commonly held conviction that "never the twain shall meet," teachers from the classrooms, scientists from their laboratories, and educators involved in teacher preparation were at last ready to sit down together in serious collaborative work, in mutual respect, motivated by a common interest and sense of urgency—their challenge: to develop a biology curriculum appropriate for the education of all youth. This was not to be an encyclopedic reorganization of facts and principles of traditional materials, but the organization of materials carefully selected to reflect the present state and changing scope of science.

H. Bentley Glass, BSCS Chairman, describes the task in this way:

"There are two major aims in studying any natural science. One aim, the lesser in importance, is to become acquainted with the significant scientific facts upon which rest the major concepts and theories of science. These are the ideas that have so profoundly altered our views of man's place in nature and have so tremendously enlarged human powers over the forces and resources of nature. In biology, this objective also includes a firsthand acquaintance with living organisms and the outstanding features of their lives.

The other aim is indispensable to young scientists and non-scientists alike—to everyone who hopes to participate intelligently in the life of a scientific age which so constantly demands difficult decisions and real wisdom. This second objective is to know what science really is—to recognize its spirit and to appreciate its methods. Science is not magic, and a scientific civilization surely will not endure if most people of intelligence regard science as a sort of magic. It is a way—or a composite of many ways—of finding out reliable, confirmed knowledge about all natural phenomena. It is compounded of the observations of the human senses and the inferences and deductions that can be derived from such experiences."

Origin and Purposes of the Biological Science Curriculum Study

In 1955, the American Institute of Biological Sciences (AIBS), a professional society representing 85,000 biologists, began discussions of plans to improve biological education at all levels. The Biological Sciences Curriculum Study (BSCS) was organized in the fall of 1958 by the Education Committee on the American Institute of Biological Sciences. Major financial support has come from the National Science Foundation. Additional grants to support the international aspects of the program has been given by the Rockefeller Foundation.

The function of the BSCS as stated in the original proposal to the National Science Foundation was as follows: "To evaluate the content of present biology course offerings, to determine what biological knowledge can and should be learned at each level, and to recommend how this latter goal can be achieved."

The policy-making body for the BSCS is a steering committee composed of 27 members, including research biologists, high school biology teachers, science supervisors, education specialists, medical and agricultural educators, and university administrators. H. Bentley Glass of Johns Hopkins University was chosen Chairman of the Steering Committee, and Arnold B. Grobman of the University of Colorado was appointed Director.

The High School Biology Program

The BSCS committee decided to focus its attention at the secondary school level. In about 80 per cent of American high schools, the first course in biology is offered in the tenth grade. A smaller proportion offer it in the ninth grade, and a few high schools offer the first course in biology in the eleventh or twelfth grades.

The Steering Committee decided early that it would design a course appropriate for general education in biology, rather than to attempt to design a more sophisticated course for a select minority. Grobman summarized reasons for choosing the tenth grade as the level of focus of the BSCS materials as follows: "In tenth grade biology, for the students who do not go to college, the biology course is the last chance in the classroom to prepare these students, who will comprise over one half of our adult population, for the rapid changes in scientific knowledge and the concepts they will face in their lifetimes. It is tho last chance to teach them how to handle and evaluate new scientific knowledge as it becomes available. At best, this is a difficult task, but the difficulty is compounded by the fact that a realistic general biology program must take into account a wider range of student ability, interests, and potential than exists in other high school science courses. It must be a course that most tenth grade students can handle, and at the same time prove challenging to the above average student. For these reasons the committee thought it undesirable to limit the course to a single design."

Different Approaches to High School Biology

The committee recognized that a valid course in biology could be developed from several points of view. For example, courses could be organized that represent all of the levels of biological complexity; the molecular level, the cellular levels, tissue and organ level, the individual organism, the population, the community, and the world of living things. A biology course developed at any one of these levels could be equally effective. The committee has carefully avoided any statement or action which, even by implication, might cause anyone to infer that there is a "best" approach to teaching biology or that a particular emphasis is necessarily most appropriate for all situations.

The Three Versions

The task of preparing preliminary experimental materials for a high school biology course was assigned to three writing teams who met for the First Summer Writing Conference at the University of Colorado in 1960. The teams totaled 70 members made up of equal numbers of research biologists and high school biology teachers. The materials prepared by each of the three teams utilized a different approach to the high school biology course. The three approaches were designated th "blue," "green," and "yellow" versions.

These experimental materials were tested in 1960-61 by 118 teachers with 14,000 students in experimental centers located in various sections of the country in both urban and rural schools. In addition, the materials were reviewed by a number of outstanding biologists, educators, psychologists, and high school biology teachers. The extent to which these new curriculum materials were tested, modified, and retested with students is unique in American educational history. The revised experimental edition of BSCS high school biology was tested in 1961-62 by 500 teachers with 50,000 students. The comments of teachers and students were obtained on a systematic basis throughout the year and were used in preparing a third and final re-writing of the textbooks.

Criticisms and suggestions from many sources were considered carefully by the eighty writers who prepared the revised experimental edition of BSCS High School Biology at the Second Writing Conference, in the summer of 1961. The conference included several research biologists and high school teachers who had attended the first writing conference. New members of the 1961 Summer Writing Conference included teachers who had used the preliminary edition of BSCS High School Biology with their classes in 1960-61, and additional research biologists.

Differences Between BSCS and Conventional Biology Textbooks

One of the questions most frequently asked concerning the BSCS is: How does the BSCS High School Biology differ from conventional biology courses"? Briefly, BSCS differs in several ways:

First, it is the product of the cooperative efforts of teams composed of research biologists, high school biology teachers, and other educational experts.

Second, it is constructed on a basis of up-to-date ideas and concepts in the field of biology. It is not simply a revision of old concepts and ways of thinking.

Third, it places considerably more emphasis on laboratory work than do traditional courses. Moreover, greater stress is placed on exercises of an investigative nature that introduce the student to science as a process of inquiry rather than on the traditional illustrative type of laboratory exercises. Some of the ways the approach to inquiry may be characterized are as follows:

There are liberal uses of such expressions of uncertainty as,
"We do not know."
"We have been unable to discover how this happens."
"The evidence about this is contradictory."

Frequently, the BSCS materials replace authoritarian *statements of conclusions* with accounts of the development of our knowledge. That is, current views on a subject, such as genetics, are developed step by step through a description of the experiments performed, the data obtained, and the interpretations made of them.

The laboratory work is organized to convey a sense of science as inquiry, For example, the conventional illustrative type of laboratory exercise is frequently replaced by simple investigations. Some of them treat problems for which the text does not provide the answers. They introduce the student to situations in which *he* may participate in the inquiry.

The laboratory "block" programs engage the students in an investigation of a variety of biological problems, each of which is a meaningful introduction to scientfic research.

New teaching material, invitations to inquiry, designed to show how knowledge arises in biology and how it may be interpreted and used to provide specific experience in the many phases of inquiry. Each invitation to inquiry reveals something about the nature of science as well as adding to one's understanding of biology.

Fourth, although the three versions of BSCS High School Biology differ in the emphasis placed on the various levels of biological organization, they possess in common nine themes which serve as unifying threads:

1. Change of living things through time—evolution
2. Diversity of type and unity of pattern of living things
3. Genetic continuity of life
4. Biological roots of behavior
5. Complementarity of organisms and environment
6. Complementarity of structure and function
7. Regulation and homeostasis: the maintenance of life in the face of change

8. Science as inquiry
9. Intellectual history of biological concepts

The first seven themes define the content of the BSCS courses; the last two convey the logical structure of each course. The specific content in each version differs, but whichever course the pupil studies he will be developing an understanding of the same unifying themes.

The three versions of BSCS biology are alike as to purpose. The BSCS committee was of the opinion that a secondary school course in biology should: (1) present the most significant concepts of biology; (2) focus on the nature of scientific inquiry; (3) provide the student with a coherent picture of contemporary biology. They are also alike in that the writers of all three versions have attempted to present materials and related concepts in such a way as to develop those attitudes and skills which are regarded as basic objectives of American public education. The three versions are alike in that the laboratory materials have been designed to represent and reveal the structure of modern biology—the state of its knowledge, its objectives, and its methods. In all three versions a greater importance has been assigned to laboratory activities than in most conventional courses. Although the laboratory exercises have been selected to reflect both the investigatory and the illustrative function of laboratory work, greater emphasis has been placed on real experiments and open-ended problems. Moreover, each version places emphasis on a quantitative approach to biology. Finally, they are alike in that they represent attempts to prepare materials that are interesting, useful, and challenging to students as well as to teachers.

After a consideration of ways in which the three versions of BSCS high school biology are alike, the question frequently arises: How are the three versions different?

The *Blue Version*, (*Biological Science: Molecules to Man*) approaches biology at the molecular or biochemical level with a basic emphasis upon recent advances in physiology and biochemical evolution. The chapters of the textbook are organized into the following sections: (1) *Biology: the interaction of facts and ideas*—science as inquiry, varieties of living things, the means of evolution, the origin of living things; (2) *Evolution of the cell*—the forerunners of life, chemical energy for life, master molecules, the biological code; (3) *The evolving organism*—light as energy for life, the evolved cell, the cell theory, the multicellular organism; (4) *Multicellular organisms: new individuals*—reproduction and development; (5) *Multicellular organisms: energy utilization*—photo-synthetic systems, transport systems, respiratory systems, digestive systems excretory systems; (6)

Multicellular organisms: integrative systems—regulatory systems, nervous systems, muscular and skeletal systems, the integrated organism and behavior; (7) *Higher levels of organization*—population, societies and communities.

The *Yellow Version* to be published under the title of BIOLOGICAL SCIENCE: *An Inquiry into Life,* incorporates the nine basic themes found in the other BSCS textbooks, but does so with an organization of content that differs from the other versions. The text is divided into the following sections: (1) *Cells*—introduction to biology, unit of structure in life cells, the search for the chemical "key" to cell life, living chemistry, balance of energy in life, cell reproduction; (2) *Micro-organisms—viruses*, bacteria, and balance of life, fungi, (3) *Plants*—evolution and diversity of plants, photosynthesis, life processes in plants; (4) *Animals*—the animal way of life, diversity among animals, life processes in animal; (5) *Genetics*—patterns of heredity, the chromosome theory, genes and their action, genetics in populations of organisms; (6) *Evolution*—history of evolutionary theory, mechanism of evolution, the origin and history of life, human evolution, cultural evolution in man; (7) *Ecology*—populations and communities, man and the balance of nature.

The *Green Version* of BSCS will be published under the title of HIGH SCHOOL BIOLOGY. The textbook approaches biology through its ecological and behavioral aspects. The major emphasis is upon the biological community and world biome. The sections of the text are as follows: (1) *The biosphere dissected*—the living world, individuals, populations and communities around diversity, plant diversity, microscopic life; (2) *Patterns in the biosphere*—life on land, life in inland waters, life in the seas, the history of life, the geography of life; (3) *The individual dissected*—the cell, the functioning plant, the functioning animal, reproduction and development, heredity; (4) *Evolution, behavior and man*—mechanisms of evolution, behavior, the human animal, man and the biosphere.

The uniqueness of each BSCS textbook is apparent, yet they are each built around the same nine themes. Approximately two-thirds of the core content is the same for all versions. Differences that do exist are principally those related to the manner of approach, organization and sequence of topics, and emphasis. Differences are not related to levels of student achievement.

How do BSCS courses *differ in content* from conventional courses? The BSCS courses place a much greater emphasis upon molecular and cellular biology; upon understanding the community and world biome; and upon the study of populations. Traditional textbooks place the major emphasis at the organ and tissue level of biology. BSCS textbooks devote less space than conventional texts to a discussion of the applied aspects of biology. Rather, biological principles are developed which may be used to interpret or solve a wide variety of biological problems. The specific application is something that the teacher brings to the course. The "science" of biology is universal; the problems of applied biology should be those of the local community.

The Laboratory Block

To develop supplementary instructional materials for the three versions of BSCS High School Biology, the committee on Innovations in Laboratory Instruction was organized under the chairmanship of Addison E. Lee of the University of Texas. The first responsibility assigned this committee was that of designing a new approach to laboratory work. A major characteristic of science is the investigatory procedure used in the laboratory. It is here that much of the work of the scientist is done; where data are sought, ordered, and tested for their usefulness in clarifying hypothesis or providing answers to questions. The intellectual and observational skills demanded for careful inquiry in science are seen as having general value in any program of science teaching. With this in mind, the committee developed the concept of the "laboratory block." A "block" consists of a series of interlocking and correlated experiments on a special topic of biology. There are eleven different "blocks"; the following are illustrative: *Plant Growth and Development; Microbes: Their Growth and Interaction; Interdependence of Structure and Function.* The student works on the topic for about six weeks. In groups, and alone, he carries out a series of investigations that provide data from which he will be able to evolve biological concepts and to become acquainted with the nature of biological research.

In the "block" students are expected to read extensively and to acquire a sufficient background of information that they may enter into the investigations fully aware of what they are doing and why. They will find it necessary to master certain techniques that are necessary to conduct the required experiments. They must make careful observations, record data, and interpret the results of their observations. In the process of investigation, students seek answers to specific questions, but more important, they gain an understanding of scientific procedures and new insights into fundamental biological concepts. In other words, laboratory blocks are specifically designed to guide students to make their own discoveries and to draw their own conclusions. The major responsibility for learning lies with the student. The biological concepts have been developed through his own offorts.

Advanced Biology

There has been a growing demand for a second year or an advanced high school biology course. In considering this need, BSCS began the development of a Second Level High School Biology in the summer of 1962. Norman Abraham of Yuba City High School, California, working with other high school biology teachers and research biologists, organized a course for experimental try out during the school year 1962-63. It was thought that the primary goals of an advanced biology course should be to further the student's understanding of scientific inquiry including: the statistical analysis of data, the reading of scientific literature, and the exploration of conditions which influence the progress of scientific investigation.

It was thought by the committee that a series of BSCS Laboratory Blocks selected to form a logical sequence and interrelated by a central theme (inquiry) would meet the requirements set by the goals. Three volumes, entitled *Second Level Biology* were written to be used in conjunction with three specific laboratory blocks: *Plant Growth and Development; Animal Growth and Development; Microbes: Their Growth, Nutrition and Interaction.* The first phase of the course is devoted to discussions on: Science in Perspective, Science as Inquiry, and Science as Experimentation (includes material on experimental design and biometrics). Following this introduction are the three blocks in sequence. The concluding phase of the course consists of a further study of science as inquiry, and science as controversy. The course includes various supplementary materials such as: excerpts from historical papers, *BSCS Invitations to Enquiry,* suggestions for additional laboratory investigations, and discussion outlines to supplement the findings from the laboratory.

The committee is considering the development of other sequences of laboratory blocks that may be used for second level courses of high school biology. The nature of these courses will depend somewhat upon the reaction of teachers now using the second level course.

Although the BSCS has been concerned primarily with the preparation of biological science materials for the majority of students at the tenth grade, this was not to the neglect of the gifted student. A BSCS Committee on Gifted Students, under the chairmanship of Paul F. Brandwein, explored the development of biological materials that would be appropriate to students of exceptional ability. The committee was of the opinion "that inspired course work is not enough; we believe the creative student of high school biology needs to be under the gentle burden of independent research so that he learns that answers are not always available in textbooks. He needs to see biology not only as a body of tested knowledge but as a way of increasing man's knowledge." To implement this idea, the committee obtained from hundreds of professional biologists a prospectus for a piece of research that a very able high school student might be expected to accomplish in a reasonable period of time, perhaps a year or two. A committee of high school biology teachers, experienced in working with gifted students, reviewed and edited each prospectus for publication. Typically, a prospectus contains a note on the background of the problem, a general statement of the problem, a suggested approach to the problem and pertinent references. A precise statement of the problem, the hypothesis, and the experimental design become the responsibility of the student. Each investigation calls for imagination, originality, and frequently, the development of new techniques. Two experimental volumes, listing a total of 150 prospectuses have been published under the title of *Biological Investigations for Secondary School Students.*

The BSCS Committee on Gifted Students has prepared a bulletin describing ways of identifying gifted biology students and some promising practices of working with them. Specific suggestions are also given for introducing high school students to the art of investigation. The Bulletin is published under the title of *Teaching High School Biology: A Guide to Working with Potential Biologists.*

The Slow Learner

A Special Materials Committee, under the chairmanship of Evelyn Klinckmann, is working on instructional materials in biology for the slow or reluctant learner. Twenty to thirty per cent of the students who take high school biology have learning difficulties whether the course is BSCS biology or a conventional one. The committee plans to develop special materials for the teacher as well as for the student because it is felt that special teaching skills and approaches are probably required in teaching these students. A variety of resources are planned so that they may be geared to meet the many differences found among unsuccessful learners. The committee hopes to devise a curriculum model that will make it possible, with implementation, to teach the slow learner valid biological concepts. It is hoped that it will be possible to give these students an understanding of biology as an investigative science similar to that which we may expect of the average and above-average students.

Tests for BSCS Courses

Achievement tests for the three BSCS courses were devised by a special committee chaired by William V. Mayer. A second committee was formed to create tests for the Laboratory Blocks. This work was under the supervision of Addison E. Lee. Both committees assumed that tests should be an integral part of course instruction since tests constitute an effective way of transmitting to students and teachers alike the goals of the course. This is in addition to providing evidence that the student understands background concepts and the processes of science. BSCS tests require that the student be able to relate the facts, concepts, and theories he has learned to novel or unfamiliar situations. They also require that the student interpret data he has not worked with previously and demonstrate that he is able to use the techniques and procedures of biological inquiry in problematic situations. The entire effort of the testing committees has been to create tests that do more than inventory the student's acquaintance with isolated facts, names, and descriptions. Understanding of biological concepts and the ability to think critically about biological questions and issues is central in these tests.

Implications of BSCS for Teacher Education

With a modern biology curriculum and new instructional materials, there is now the problem of bringing about corresponding changes in the pre-service and the inservice education of teachers.

The BSCS Teacher Education Committee under the chairmanship of Paul DeHart Hurd has the following projects in progress: To acquaint high school biology teachers and those engaged in teacher preparation with the philosophy of BSCS biology. Without a thorough understanding of the philosophy and goals on which new curricular materials are based, students are likely to be taught in conventional ways with traditional results. BSCS courses need to be taught in a manner and style that complements the aims of BSCS biology. By 1963, nearly 2000 teachers will have been trained for BSCS biology. BSCS Area Consultants have been appointed in 40 states to assist teachers who wish to teach the new biology courses. A series of BSCS Teacher Education Films is in production. Experienced BSCS teachers are encouraged to take student or cadet teachers into their classes. Institute programs and conferences for high school and college biology teachers have been held in many sections of the country. The committee recognizes the need for a long and continuous program of teacher education if the new curriculum movement in biology is to be fully realized.

Teaching Facilities for BSCS Biology

Whether it concerns the teaching of high school chemistry, physics or biology, one of the most significant trends in our country today is the increased emphasis on laboratory work. Not only is there more laboratory teaching, but also the nature of the laboratory work itself is changing. There is more stress on student participation in the type of laboratory work that provides opportunity for re-discovery based upon experimental evidence. These changes require that teachers have adequate, well-equipped laboratories.

The typical high school biology laboratory is inadequate for modern science courses. School boards and parents frequently think of laboratory needs in terms of courses as they were conducted a quarter of a century ago. While they realize that science is changing rapidly, they have not had opportunities to understand the extent to which the revolution in science has altered equipment needs and costs for up-to-date high school biology courses. The result: teachers find it too much trouble or too difficult to conduct laboratory work as an experimental, investigative approach to learning. Laboratory procedure then becomes predominantly descriptive. Charts, models, and specimens become full time substitutes for the laboratory activity of the experimental biologist.

Invitations to Enquiry

One goal of BSCS biology is to convey to students that science "is more a verb than a noun," that the processes of inquiry may better represent the true nature of science than the body of knowledge it evolves. To achieve this goal the BSCS textbooks are written in a style that is true to the "science" of the topic, its development, and its status or degree of certainty. Laboratory work is designed to convey a sense of science as inquiry. Furthermore, the laboratory blocks have been designed to also serve this end. Joseph J. Schwab, Supervisor for the preparation of the BSCS Teachers Handbook, conceived the idea of specially written "invitations to enquiry" that will systematically guide the student to an understanding of the characteristics of scientific inquiry.

"Invitations to Enquiry" are designed to engage the student in one of the critical or investigative activities which constitute scientific inquiry. There are many starting points and many aims for the inquiries. Some pose a problem and ask only that the student think of an experiment to attack the problem. Other invitations introduce the idea of a controlled experiment or ask that data already collected from experiments be appropriately interpreted. Some degree of a general understanding of biology is called for but specific biological information is included in the "invitation."

More than forty of these invitations have been developed, to introduce students to the many phases of scientific inquiry at varying levels of complexity. While the "Invitations to Enquiry" were developed as an activity of the BSCS, they may be used effectively with any biology course or textbook.

BSCS Teaching Materials

Various BSCS committees have been active in preparing supplementary teaching materials as the need became apparent. Some of these materials are for use by the teacher and others by the students.

The BSCS Pamphlet Series. Each pamphlet is designed to cover a specific area of the life sciences and extends the educational program of the BSCS. Each pamphlet is approximately 32 pages in length, well-illustrated with colored, and black and white pictures. Eight pamphlets a year are being published and may be obtained on a subscription basis. The series began in the fall of 1962. Some of the titles now available are: *Cuideposts of Animals Navigation*, by Archie Carr; *Biological Clocks*, by Frank A. Brown, Jr.; and, *Courtship in Animals*, by Andrew J. Meyerriecks.

BSCS—*Technique Films.* These are short films of 2-12 minutes duration that illustrate a biological technique important for the performance of certain experiments in the BSCS Laboratory Manuals. The films are intended for use by the teacher rather than the student. Illustrative titles are as follows: *Neurospora Techniques; Removing Frog Pituitary: Paper Chromatography.*

BSCS—*Teacher's Handbook. The Teacher's Handbook for BSCS High School Biology Courses* was developed to acquaint teachers with the intent and spirit of BSCS biology, to provide useful information about supplies, and special techniques. It provides additional resource information on specific topics needed in BSCS courses such as, atomic structure, biochemistry, statistics, and selected topics from physics.

Equipment and Techniques for the Biology Teaching Laboratory. This book provides biology teachers with useful information about the biology laboratory, its facilities, equipment and use. There are sections describing the equipment and techniques for the culture micro-organisms, for physiological experiments; and for the study of plant growth. The housing of laboratory animals, light-control equipment, and the construction of simple equipment and models are among the many items described in the book.

BSCS—*Bulletin Series.* The *Bulletin Series* consists of a series of monographs on topics related to high school biology education. These are Bulletins on curriculum developments in biology, working with potential biologists in high school and (in process) one for administrators on arrangements for teaching BSCS biology.

AIBS *Film Series.* The AIBS *Film Series* is a secondary school biology course presented on film. The course consists of 120 films, organized around ten areas of biology. Outstanding biologists are used to present topics that represent their research interest. The films may be purchased singly, in groups, or as a series.

Summary

When the BSCS textbooks and teaching materials become commercially available (August, 1963), they will have been taught and evaluated by 950 specially prepared high school biology teachers and their 85,000 students in 46 states, the District of Columbia, and Puerto Rico. Translations and further experimentation is being carried on in Brazil, Colombia, Philippines, and Thailand. Teachers in Kenya, Japan, and England are studying the BSCS course for possible adaptations to schools in each of these countries. There is recognition throughout most of the countries of the world that new high school biology courses are essential to the understanding of modern developments in biology and their influence on modern life.

Chapter IV

A very important concomitant of the success of science in this century has been a misunderstanding of the proper role of science, of the sphere in which it is wholly authoritative. I am wholly in accord with the contemporary belief that the young should learn to understand the nature of science and the ways in which it has remade the world. But I think also that in learning about science, the young should cultivate those qualities of mind and that other knowledge which will allow them to make intelligent use of science in their public and private actions; that is, they should recognize science as a component of knowledge and not expect to find it in a final arbiter of all human actions. *Polykarp Kusch*

NEW DEVELOPMENTS IN HIGH SCHOOL CHEMISTRY

Editor: ROBERT E. HENZE

THE GROWING role of science and technology in shaping the political and economic development of the world demands a most serious examination of our science course offerings at all educational levels. The future requires a scientifically literate citizenry as well as an increased number of highly trained technicians, scientists and engineers.

Since the turn of the century, scientific knowledge has been increasing exponentially with major "breakthrough" in both theory and application occurring on many fronts. Chemical science has contributed significantly to this explosive development through newly discovered insights into the form and substance of our physical world. New theories, new compounds, new techniques and new applications have drastically modified much of the chemistry the present adult generation studied in school.

In a speech presented before the American Chemical Society in 1960, Glenn T. Seaborg, Nobel Laureate in chemistry, described the situation quite clearly: "Many high school students in this country get a satisfactory course in chemistry, but in many instances the high school course is pitifully low in quality and out of touch with the science as it is known to the profession. Most courses have a qualitative discussion of too many topics as a result of the accretion of new material and a stubborn reluctance to discard any material that was ever in the course. On the other hand, much important information is missing. Furthermore, there has been a movement away from the laboratory for the student."

One of the reasons for uninspiring and obsolete offerings is that it takes a considerable amount of time and talent to keep a course up to date, more than most high school teachers have been allowed to apply. Another of the reasons has been the general lack of interest and communication with high school chemistry on the part of college professors of chemistry and scientists in the chemical industries. Not enough help has come from scientists at the research frontiers. This situation has changed in recent years to the point where teachers now have a wealth of educational resource assistance available to them.

The cogent philosophy expressed in Seaborg's definition of a liberally educated man exemplifies the guiding spirit behind the scientists' growing interest in and recognition of high school science offerings: "My definition of a liberally educated person is one who is aware of the nature of his physical and social environment and of his own nature, who understands the origins of the world's social, religious, governmental, and political institutions, and the ideas upon which they are based and who, because of this knowledge, has some basis for making intelligent decisions to adjust to his environment or to change to a better one. Such a definition, I believe, means that scientific studies form an extremely important part, though not the only part, of a liberal education. An educated man of today can no more ignore science than his predecessor of the Middle Ages could ignore the Christian church of the Feudal System."

Two course content studies in chemistry are currently receiving national attention. These are the Chemical Bond Approach Project, more familiarly described as the CBA Project; and the Chemical Education Materials Study, generally known as the CHEM Study. Both of these projects receive financial support from the National Science Foundation; both involve the cooperative efforts of high school and college chemistry teachers, and provide for classroom trial and student testing. Both began after a critical examination of past courses in terms of content and philosophy. The development pattern of each of these courses is similar to that described for the course content studies in other disciplines.

Although the content and format of the CBA and CHEMS courses is different, similar guiding principles have been employed in the planning of each. Among these principles has been an attempt to identify and stress the important basic principles and concepts of chemistry and an effort to provide reasonable depth in selected areas rather than broad superficial scanning. In each of these projects a determined effort has been made to present unifying concepts and structure property relationships and to replace the "cookbook" laboratory with meaningful experimentation and student involvement in the scientific method. In the words of Charles A. Whitmer, Head of the Course Content Improvement Section of the National Science Foundation: "NSF's Course Content Improvement Program is designed to help bring scholarship of the highest order to the development of curricula, courses, and instructional materials that reflect contemporary scientific knowledge and points of view."

The fact that there are two major course content studies in chemistry suggests that there isn't any single, best way to teach chemistry. The fact that there are two projects doesn't mean that there are only two ways. Every good teacher will shape his own course even though he may be using a standard textbook or syllabus as a base. The materials devised by the CBA and CHEMS projects provide excellent starting points. Their adoption can save local schools countless dollars and hours of development time in improving their chemistry offerings. CBA and CHEMS are not intended as national courses, nor as the final word in the teaching of high school chemistry. They represent a scholarly contribution to high school chemistry on a scale not heretofore seen. They deserve the careful study and consideration of every high school chemistry teacher in the country.

The Chemical Bond Approach Project

The Chemical Bond Approach Project directed by Laurence Strong of Earlham College in Richmond, Indiana represents the cooperative effort of outstanding high school and college chemistry teachers. The idea of employing a discussion of the chemical bond as the central theme of a beginning course came out of a summer conference of chemistry teachers held in June of 1957 at Reed College in Portland, Oregon. A number of interesting concepts expressed at this conference give an indication of the rationale underlying the CBA course. Modern chemistry has developed considerable internal consistency and the process of putting details into the developing concepts is one of the more exciting parts of chemistry. The idea of using chemical bonds as a central theme was motivated by the observation that it is the chemical bond which distinguishes chemistry from related disciplines. Indeed, the making and breaking of these ties between atoms *is* chemistry.

A follow-up conference specifically devoted to the idea of using the chemical bond as the unifying theme for an introductory course was held at Wesleyan College during the summer of 1958. Continued support from the National Science Foundation permitted a six-week writing conference to be held at Reed College in the summer of 1959. The preliminary material prepared at this writing session and during the academic year of 1959-60 was used in about a dozen high schools and colleges. A second edition, revised in light of the results of the first trial year, was used in 1960-61 by 75 schools in an official evaluation program involving about 4,000 students. In 1961-62 a third revised edition had an official evaluation involving some 5,000 students in about 80 schools. On the basis of the experience of the past year, extensive revisions have been incorporated into the manuscript for the hard cover edition of text and laboratory materials scheduled to be ready in the fall of 1963. A collection of reprints from the JOURNAL OF CHEMICAL EDUCATION and the SCIENTIFIC AMERICAN magazine has been prepared for supplementary reading. A teacher's guide paralleling the text is also available.

The CBA course attempts to present modern chemistry to beginning students by emphasizing the importance of theory and experiment. The presentation is intended to give students a preliminary understanding of what chemistry is, rather than simply an encyclopedic collection of chemical reactions and laboratory techniques. Effort has been made to organize the course in a pattern which reflects the structure of the discipline itself. Since conceptual schemes play a major role in the organization of chemistry, the organization of the CBA course is based strongly on conceptual schemes. An attempt is made throughout the course to confront the student with the implications of logical arguments based on theory. A major part of this is done through the discussion of mental models, which are introduced as logical devices based on a set of convenient assumptions. Particular attention is given to three such models: structure, kinetic theory, and energy. The way in which structural models for atoms, molecules, and crystals are developed in the course is illustrative of the approach. First, electrons are assumed to behave as if they were spherical charge-clouds. Under the action of electrostatic forces, these charge-clouds arrange themselves in patterns which can be represented by arrangements of real spheres fastened together. In this way the geometrical relations that govern the packing together of spheres can be used to visualize the arrangement of electrical forces within the atoms and molecules. Experience with students indicates that this presentation in the use of geometrical analogies is quite satisfactory.

Such a charge-cloud does not, in its present development deal adequately with energy relations. To improve this aspect, a more conventional electron orbital model is introduced and developed to show energy relationships, at least qualitatively. The second model fails, however, in the description of geometrical properties. The orbital model and the charge-cloud are brought together by the introduction of the assumption that orbitals within an atom can hybridize when molecules are formed so as to produce the appropriate geometrical relationships.

Through a discussion of these two structural models, the students get some ideas of the success and limitations of each. One of the aims of the course is to have students realize that it is not proper to ask which are the right models; rather, to judge models on the basis of logical effectiveness for a particular problem. This is presumably the way in which modern scientific discussion proceeds.

The laboratory program of the CBA course is designed to develop the ability of the student to identify a problem, to design an experiment which will shed light on this problem and to carry out the technical operations of the experiment and to arrive at a conclusion through an analysis of his own data. Initially, this student is provided with assistance in all these areas. Such assistance is withdrawn gradually until finally the student is asked to perform all of these steps independently, employing ideas and techniques accumulated in the process of investigating other problems. The sequence of experiments is designed to provide the necessary background.

The laboratory program and text parallel one another in terms of topics and reinforce one another to a marked degree. The effectiveness of this dual approach to many topics has been demonstrated during the trial program. In some cases, direct use of the student's laboratory results as part of the text development has been effective, but this order of presentation is not considered essential in developing student understanding. Thus, additional freedom is given to the teacher for using the relationship of laboratory and text to best advantage in his own classroom. There is sufficient leeway in the treatment of experimentation in the text to permit conclusions which may be inconsistent with those data. Integrating the laboratory and the text in this way permits the text to be read independently and permits a flexible use of the laboratory program.

The first experiment in the laboratory section indicates the type of questioning that laboratory experience may stimulate the student to do on their own. This experiment is called "Observations" and involves "black boxes" and "mental models." When an unknown object is sealed in a closed box, it is no longer possible to determine the properties of the object through visible observation or direct handling. The total suddenly becomes a system whose composition, mode of construction, and response to external influence is not directly apparent to the outside observer. Nevertheless, procedures may be devised which will provide specific information concerning the contents of the box. Specific questions may be asked of the box. Manipulations can then be devised which will provide answers to these questions. If these manipulations are carried out and observations made, a series of assumptions can be made which will not be unsupported hypotheses for they are based on experimental evidence. However, the hypotheses must be considered tentative and subject to revision after further experimentation. From the total of questions, manipulations, and observations and assumptions, a model of the contents of the box may be proposed. This model may or may not be an actual representation of the object in the box. It is a satisfactory model, however, if it predicts the same responses to external influences that the contents of the box shows. This simple experiment exemplifies the general character of the questioning situations developed in the CBA laboratory.

The approach and content of the CBA course is quite different from that of the conventional course. Although the material is designed to be appropriate for the average chemistry student, the course puts unusual demands on the teachers, particularly the first time through. He has to look at the subject matter from a point of view which may be new to them. A teacher instituting the course for the first time should certainly have prior study time and a lighter teaching load. No unusual chemicals or equipment are required for the laboratory and therefore, the cost of conducting the CBA laboratory is not significantly different from that of conventional courses.

The Chemical Education Materials Study

The second of the two major course content projects is known as the Chemical Education Materials Study. Seaborg is general project chairman with J. Arthur Campbell of Harvey Mudd College in Claremont, California, as project director. Historically, this project stemmed from an ad hoc committee appointed by the American Chemical Society to study the need for and the possibilities of revising the chemistry course at the high school level. Alfred B. Garrett of the Ohio State University, served as chairman of this ad hoc committee. The project came into formal being late in 1959 and followed the development pattern of the other projects in the sense that outstanding high school and college chemistry teachers worked together in developing the first drafts of the material used in the text. The first meeting of the CHEM Study Steering Committee was held in January 1960. Among the broad objectives outlined for the project was to diminish the separation between scientists and teachers in the understanding of science; to stimulate and prepare those high school students whose purpose it is to continue the study of science in college as a profession; to encourage teachers to improve their teaching methods by studying courses geared to keep pace with the advancing scientific frontiers; and, to further an understanding of the importance of science in current and future human activities in those students who will not continue their study of chemistry after high school.

The specific objectives of the CHEM Study have been to develop modern and effective teaching materials for the high school chemistry course including a textbook, laboratory experiments, a teacher's guide, films, supplementary reading materials and selected teaching aids. As developed to date, the course is strongly based on experiment with the text thoroughly dependent upon and integrated with laboratory instruction. The concept of experiment is carried even to the name of the text, "Chemistry: An Experimental Science."

First drafts of the CHEMS text materials were used in 25 high schools in 1960-61. During the last academic year the course was taught to approximately 12,000 students by 158 teachers in 125 schools. Text materials have now undergone several revisions and are scheduled for hard back edition in the fall of 1963.

Introductory chapters of the text present an overview of chemistry in terms of the atomic-molecular nature of substances and develop concepts of behavior in terms of atomic theory and energy changes. The periodic table is introduced as a means of ordering chemical information. This represents the current major use of the table and how it was actually devised. The second section of the text deals with some of the most basic concepts of chemistry, again from the experimental point of view. Chapters on energy, rates, equilibrium, acids, and bases, and oxidation-reduction are tied together in terms of the mole concept, the kinetic theory and the atomic-molecular concept of behavior in matter. Matter designed for the second semester begins with a discussion of atomic and molecular structure and of structural relationships in the various states of matter together with their influence on chemical reactivity. The chemistry of carbon and selected elements are studied with particular recognition given to trends in properties as one moves through the rows and columns of the periodic table. Emphasis in these sections is on the experimental approach with the intent of utilizing the materials and ideas presented earlier to tie chemical knowledge together.

As in the case of the "black box" in the CBA Project, the CHEM Study has a very interesting experiment for the beginning laboratory session. This is an exercise in observation which students take lightly at first but rapidly recognize its significance. This first laboratory session of the CHEM Study involves the observation of a burning candle. While this may seem relatively simple, the degree of observation required is one of the keystones of scientific work, particularly experimentation. Careful observation takes concentration, alertness to detail, ingenuity and patience. It turns out that while most students mention a dozen or so items in relatively non-qualitative terms, a professional chemist's description given in the appendix of the laboratory manual lists some 53 observations, most of them in rough quantitative terms. The candle is used in several additional experiments introducing phase changes, combustion, and chemical reactions.

Both the CBA and CHEMS courses return to the original concept of the laboratory as a place to experiment. No blanks are to be routinely filled in laboratory notebooks; students describe their experimental work and record their observations and conclusions on blank pages. It is important to point out in this connection that the laboratory for these courses requires an increased amount of the teacher's time. The possibility of using student teaching assistants should be explored. Such help can provide teachers more time for individual student contact and evaluation and can also provide an interesting challenge for advanced science students.

According to the project's director, the CHEMS course is really designed for seven periods a week—three single periods and two double periods. This much time is required to finish the entire text. It was written, however, so that everyone could finish the first eighteen chapters plus a selected two or three of the later chapters in the book using five periods a week. It could be a great help to the teacher, however, if one of these were a double period and three of them were single periods.

As is the case with the CBA course, no highly specialized chemicals or equipment are required to conduct the CHEMS laboratory. Balances are necessary to do quantitative experiments, but they need not be of the expensive research variety. Triple beam balances costing around $25 are adequate and generally found in most high schools. There ought to be one balance for every four students in a laboratory section. No unusual safety equipment is required. Laboratory experiments in both courses have been designed to be as safe as they possibly can be.

It is recommended that safety glasses be worn any time the student is in the laboratory.

In addition to the text and laboratory manual, the CHEM Study has developed some 24 films, an excellent teacher's guide, and a series of wall charts on such subjects as the names and formulas of common ions, the relative strength of acids and bases, and the orbitals of atoms. The CHEM Study films are designed to be shown at specific times during the course. They are intended to present things a teacher can't do, but would like to do. They represent a very significant advance in the production of meaningful educational films.

Early problems with College Entrance Examination Board examinations and certain state examinations have received attention and appear to be nearing solution through the development of special tests or different norms for CBA and CHEM Study graduates. A growing number of colleges are feeling the impact of the new courses. Most are enthusiastic and many are revising their own introductory courses or developing special sections to take advantage of the more advanced material now covered in high school.

There is not space nor is it appropriate here to go into more detail regarding each of these newly developed courses in high school chemistry. Further details can be obtained from each of the project directors, and of course, texts, laboratory manuals, and teachers' guides will soon be available from commercial publishers. Every teacher of high school chemistry should be encouraged to examine these materials and given assistance in doing so. A most important task for administrators is to see that their teachers are informed.

Other efforts to revise and update high school chemistry deserve mention. One of these is the Encyclopaedia Britannica film series, "Modern Chemistry," which consists of 160 lecture and laboratory demonstrations conducted by John F. Baxter of the University of Florida. Student and teacher manuals accompany the course which, although along more classical lines, represents a modern course in terms of both subject matter content and demonstration techniques. The course has been used in a variety of ways in different parts of the country. Film presentation can free a teacher for more discussion in depth of special topics and allow more time for laboratory preparation and participation. In some instances, the film series has been used by teachers as a source of teaching technique and lecture demonstration ideas. The filmed course can also be used by students beyond their regular classroom hours.

Other Sources and Directions

In addition to the major course content projects described above, there are and have been right along various state and local studies as well as many sources of information and ideas available to teachers concerned with the continuous revision and improvement of their courses. An example of one of these sources is the JOURNAL OF CHEMICAL EDUCATION, published by the American Chemical Society's Division of Chemical Education. This journal has been aptly described as a "living textbook of chemistry." Each month this excellent journal contains papers on both old and new concepts of chemistry and suggestions relative to the teaching of these concepts. Special features of the journal include a section on "tested demonstrations" which teachers can use effectively in illustrating principles and concepts; a "chemical instrumentation" section explaining in detail the working of new chemical research equipment; and recently added a section on "research ideas for young scientists" describing projects that students can conduct on their own. Articles on laboratory safety and the history of chemistry are of considerable interest and value at all levels of chemistry teaching.

A rapid scanning of an annual index issue of the JOURNAL OF CHEMICAL EDUCATION indicates a host of articles of interest and use to both teachers and students. For example, under apparatus, one finds such index entries as: analogue computer plug board, constant current supply, D. C. current source, float method for oxygen sensitive solutions, gas generator, heating bath, melting point apparatus, microbalance and so on.

Under the entry molecular models are listed articles on cast rubber models, molecular orbital models, tetrahedral angle layout, models of crystals, paper made models, models illustrating types of orbitals and bonding, and vibrating molecular models. Under laboratory experiments, one can find paper describing experiments involving hydrolysis, heat of precipitation, heat of reaction, turbidimetry, viscosities of mixtures, absorption isotherms and gas laws among others. These articles represent experiments, demonstrations, and methods that teachers in various schools have devised, tried with their own students and are now publishing for the benefit of other teachers. In journals of this kind, there is a wealth of information which both high school and college teachers can draw upon to improve or revise the courses they are currently teaching. In addition, the regular reading of such journals provides teachers with at least one means of avoiding the technical obsolescence which threatens every professional—scientist and teacher alike.

Excellent articles to extend textbook coverage are found in the SCIENTIFIC AMERICAN and CHEMISTRY magazines. Additional reading material of great value is rapidly becoming available in inexpensive paperback and newsletter form. Several series of monographs to assist both the student and teacher in pursuing chemistry beyond the classroom are already available. Included among these are the Physical Science Study Committee Series, the National Science Teachers Association's "Vistas of Science," the chemistry series of Prentice-Hall, the chemistry monographs of the Reinhold Publishing Company, and the monographs of Royal Institute of Chemistry. Library acquisition of these materials opens new doors to exceptionally talented science students.

Another facet of course content improvement that deserves the attention of both teachers and school administrators has to do with the teachers' professional interest and participation in the science of chemistry. This important concept has both immediate and long-range implications. Through advanced study, participation in the activities of scientific societies, attendance at local and national scientific meetings, experience in summer research jobs, and frequent contact with local scientists, teachers can pass on to their students an enthusiasm for science and an understanding of the role of science in modern life not otherwise easily obtainable.

Nearly every discussion of the new chemistry courses ends with the question—which course should be taught in my high school? Should it be the CBA course or the CHEM Study course, or perhaps a carefully revised and updated course developed regionally or locally? No absolute answer can be given. The choice should be left to the teacher after he has had a chance to become familiar with the various new materials available. Forcing a teacher to teach material he is not familiar with or enthusiastic about will probably doom the course to failure. Whatever the choice, it need not be a permanent one. As a matter of fact, if a course chosen this year is being taught five years from now in precisely the same way, it will be out of date. It makes good sense, however, to begin with one of the new courses, in toto, because they represent carefully developed and tested sequence of topics and methods of presentation. After a teacher becomes familiar with one of the new courses, and has had experience teaching it, he will be better able to determine areas which may need modification to fit special school situations.

Teachers should be encouraged to study these new courses in summer institutes whenever possible, in locally organized inservice courses, in city and county work shops, or on their own. Time and recognition should be given to teachers who try to improve science course offerings. Whether or not the teachers in our schools take advantage of the scholarship that has been focused upon the revision of the high school chemistry will depend in a large measure upon the inspiration and assistance provided by school administrators.

Chapter V

I have tried to set out in rough outline some of the many things that have occurred in the physical sciences in the last few years. These are having much bigger support than ever before. If we handle ourselves right, they can transform our lives in good ways and they can make an even greater demand for the employment of people in new vocational activities than we have ever known before. With this kind of development and understanding having the impact on the world that it does have, it is vitally important that everybody, whether he goes into science or not, ought to have some understanding of these things, simply because they are part of the world that we live in. Therefore, I would like to leave you with the thought, not just for vocational and technological training of engineers alone, but as part of the new culture of our times, it is important that good basic teaching of science occur in the schools at all levels on a much broader base and with a much larger effort than has been the case in the past.

E. U. Condon

THE CHANGING PHYSICS COURSE

Editors: MARGARET T. LLANO and WILLIAM C. KELLY

HIGH SCHOOL physics is in a time of growth and exciting change. Public interest, the profound effect of developments in physics upon the nation's economy and well-being, the rising requirements in physics for a variety of college and university degrees, and the increasing realization among educators that each citizen must know something about physics—all have contributed to a surge of activity. National enrollments in physics are increasing, curriculum-planning committees are at work, laboratory apparatus is being ordered, and new classrooms and laboratories for physics are under construction. The future holds the promise of more competent and more vital teaching of this basic science.

The present ferment in physics is attributable to a number of factors. Local school districts have moved to meet their responsibility for instruction by reviewing the present status of their physics courses, deciding in what ways physics teaching can be strengthened, and implementing these decisions. Although the supply of competent physics teachers still falls short of the demand, summer institutes and academic-year institutes supported by the National Science Foundation are helping to upgrade the preparation of inservice teachers, and national and local efforts are being directed toward increasing the effectiveness of programs of preservice education.

The competence and the enthusiasm of the teacher are most important in physics teaching, but immediately after them in importance come the content of the physics course, its spirit and philosophy, the relative emphasis on topics, the nature of the laboratory work, and the availability of time and equipment for effective teaching. Physics teachers have been greatly aided in the development of physics courses appropriate for their students by the efforts of curriculum study groups. These activities involve physicists in higher education and in industry who work closely with the schools to develop approaches to physics teaching that reflect the spirit of modern physics. The professional societies, too, are greatly interested in secondary school physics teaching and encourage in every way possible experimentation for the improvement of secondary school courses.[3] Finally, the National Defense Education Act, by its matching-funds assistance in the purchase of scientific equipment, has aided schools in obtaining the apparatus needed for teacher demonstrations and student experiments.

This report is concerned with curriculum development in physics—a never-ending process in physics as in any other subject. The present is a good time for schools to revise their physics courses because they can take advantage of the many efforts to increase the quality and the richness of the teaching resources available to the physics teacher. It is very much in the spirit in which the various curriculum groups have worked to point out that their recommendations and their products—good as these are—represent opportunities for the schools, not requirements and not prescriptions that are expected to cure every ill. The schools may well inform themselves about the new approaches to physics, try them out competently, evaluate them, and hold on to what they find out.

The Physics Course of the Physical Science Study Committee (PSSC)

The PSSC was organized at the Massachusetts Institute of Technology in 1956 under the leadership of Jerrold R. Zacharias. A group of physicists took a serious look at the secondary school physics curriculum and found that it did not represent the spirit or content of modern physics or of science generally. Out of this concern was born the Physical Science Study Committee, consisting of university pro-

[3] *Physics in Your High School.* American Institute of Physics, 335 East 45th Street, New York 17, New York, 1960.

fessors, high school instructors, industrial scientists, administrators, and other specialists from all over the country. The purpose of the group was to devise a modern course in physics and to prepare materials for it. The effort has been massively supported by grants from the National Science Foundation, the Ford Foundation, the Sloan Foundation, and the Fund for the Advancement of Education.

The PSSC program has a textbook, a laboratory manual, a teacher's guide, films, monographs, and tests. These materials have been developed over the past five years, tried out in the schools, revised, tried out again, and now, with the exception of the monographs and the films which are coming out steadily, these materials are all available through commercial sources. Complete information on the availability of these materials can be obtained from the PSSC organization which is still active and hopes to keep the course materials current.[4]

The objectives of the syllabus might be stated as threefold: first, the course should present the logical interconnections of physics at a level suitable for high school students; second, it should treat physics as a product of experiment and theory as constructed by real people in real laboratories; and, third, it should show physics as a cultural force of importance to students having diverse interests and intentions. From the very beginning the course was not intended to be solely for specialists in physics.

The pedagogical philosophy of the course is to build ideas up from very simple observations to more complex concepts, with reinforcement at each point. The films reinforce the textbook, the laboratory work reinforces the films and the textbook. There are many cross linkages among the different parts of the course so that the student's understanding is increased by every available means. One of the major things one notices is that the textbook contains less topical material than the traditional course but provides a more penetrating treatment of the material it does cover. The course leaves out virtually all technology; there is no mention of how television works, for example, although this and other technological topics are discussed in the monographs. The course is basically physics for its own sake, the study of the fundamental concepts.

The person most concerned with the development of the textbook was the late Francis Friedman of the Massachusetts Institute of Technology. The hard-cover book PHYSICS which became commercially available in 1960-61 is in four parts: Part I deals with basic notions

[4] Physical Science Study Committee, Educational Services, Inc., 164 Main Street, Watertown, Massachusetts.

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including time and its measurement, distance and its measurement, and simple kinematics—the laws of motion without reference to the action of forces on bodies. Part II gets started on the problem of the development of physics by showing that progress in physics is not unidirectional. The section includes a discussion of the nature of light, comparing the wave theory and the particle theory of light and showing how evidence supported first one and then the other. In Part III basic concepts of mechanics are introduced—for example, the concepts of energy and momentum and the conservation of these. (This is not the conventional order of topics. In the traditional course mechanics is dealt with first, and then sound, heat, electricity and magnetism, and so on.) Finally, in Part IV there is a discussion of electricity and magnetism starting from the very simple phenomena and then going into the application of those ideas to the Bohr theory of the hydrogen atom. Contrary to the impressions of some, the textbook does not attempt to explain all of relativity, quantum physics, and similar topics that the student may study later. Rather it concentrates on basic concepts, developing these in a way that will permit the student later to master the concepts of quantum and relativity physics without strenuous mental readjustment. The textbook has many questions that are novel, difficult and thought-provoking. The illustrations—photographs and line drawings—are mostly original and are effective teaching devices.

The laboratory work includes fifty-two experiments using simple apparatus. Most of the apparatus used in these experiments was developed as part of the program. The emphasis is on simplicity and clarity. Included is such apparatus as a simple stroboscope, a simple ripple tank for studying wave motion, a simple doorbell timer for studying motion, and a simple range finder. The laboratory treatment in the course is very different from the traditional course because it is quite common for the laboratory experiments to introduce a topic before the teacher has introduced it in the class. Thus the laboratory is a real learning experience. In keeping with that approach, THE LABORATORY GUIDE was prepared. This manual tries to avoid the "cookbook" approach. It is an exploratory, open-ended program of laboratory work. The teacher expects the student to keep a laboratory notebook in somewhat the same way that a scientist would. One of the aims of the laboratory work is to promote an understanding of theory and to give the student some insight into the meaning of evidence. An attempt is made to forestall the development of the attitude that an experiment is a success if it comes out "right."

A school in Fort Pierce, Florida, reported that with the PSSC course it was possible to have a laboratory two nights a week, from 7-10 p.m. The laboratory was set up and, according to the instructor, the students flock to it. Some stay the full three hours; he has never had anybody who did not complete the laboratory work.

The films for the course are extensive and effectively supplement the course. There are fifty-three of them, averaging about twenty-five minutes in length. Some are used to present to the student phenomena that would be difficult to set up or to reproduce in the laboratory or on the demonstration bench—such as the film on "The Pressure of Light." Others are used to reinforce understanding of a very fundamental concept by bringing to bear on it some more elaborate apparatus that would not be available in the school. Still others serve as summaries or introductions to certain parts of the course. The films usually show the physicists themselves and enable the students to make firsthand observations of the physicist and his work. In addition to the course films, there are also a few films intended to aid the teacher; they indicate the various techniques that the teacher can use in carrying out certain demonstrations or certain laboratory experiments.

Another element of the course is a series of monographs, the SCIENCE STUDY SERIES. There are thirty in print and more to come. These pocket-size, inexpensive booklets are not textbooks. They were developed to provide outside reading for the student who may want to take a little further some idea that was presented first in the course or to explore a corollary topic that for lack of time could not be discussed in the classroom. Tests were developed specifically for the course by the Educational Testing Service in cooperation with the PSSC. They were designed to place greater emphasis upon the application of principles than upon recall of information.

To carry forward the PSSC program, teacher preparation has been of great importance. A very detailed book, the TEACHERS RESOURCE BOOK AND GUIDE, was developed. It is in four volumes and well organized. The book is a careful analysis of the text and problems. It serves as a very useful aid for the teacher. In addition to this guide, PSSC has worked closely with colleges and universities in offering institutes for teachers who want to study more science and mathematics and who are at the same time interested in the PSSC approach to the teaching of physics. Last year there were twenty-two summer institutes, and currently, nineteen inservice institutes, all sponsored by the National Science Foundation. Although special training is desirable and undoubtedly smoothes the way for teachers using the PSSC course, it should be noted that the course is not something mysterious. A teacher with twenty to thirty hours of college credit in physics at a satisfactory level should be able to teach the PSSC course or any other kind of high school physics. However, the PSSC course is challenging—rewarding, but not easy—for teachers and students.

There are various reports as to how long it takes to give the PSSC course. Some schools stretch it out to three semesters. More often it is given as a one-year course, but the teachers do not attempt to cover in the year the entire course content that the PSSC includes.

How effective has the PSSC program been? One measure might be the adoption of the program. In 1957-58, the first year in which the course was being developed and only mimeographed materials were available, eight schools and 300 students were involved. In 1962-63 the course was being used by 2,500-3,000 teachers and approximately 125,000 students. By comparison, it has been estimated that currently about 400,000 students study physics, in all types of programs, including the PSSC course, in secondary schools. Some states have made a major effort to introduce the course widely. In Florida, for example, PSSC physics is taken by 85 per cent of all students who take high school physics.

How effective is the PSSC program for the college-capable student? Very early in the development of this course it was found that the College Entrance Examinaton Board test—one directed toward a traditional college physics program—was not suitable for testing students in the PSSC course. Students from the PSSC course did not do very well on the test. The CEEB then offered two tests for several years, one of which was especially designed for the PSSC course. Just recently CEEB announced that it has a test that is believed to be suitable for both courses. The test was administered for the first time in the spring of 1962, but the results have not yet been announced.

There have been some attempts to test PSSC students against control groups to see how well they do. But again conventional tests have been used, and these are designed for the standard college course. On such tests some PSSC students have been found not to do very well, but in view of the differing objectives and content of the PSSC approach and the traditional approach, the results are inconclusive.

It should be pointed out that some colleges and universities have individually studied the preparation of students coming to them from the PSSC course and from the standard high school course. In the words of one of the recent reports that the committee has put out, "The PSSC students are more likely to have a better understanding of the fundamentals of physics, although this is not always the case." Until more data are available, one will have to reserve judgment. What about the effectiveness of the PSSC course for students who will probably not go to college? One rather standard phenomenon that has been noted in the testing programs—in both chemistry and physics—is that there has been a declining correlation between performance in the experimental course and the aptitude tests that had been taken. It looks as if these new courses are bringing out interests or are motivating students who had not shown up with high aptitudes before, and vice versa. In one school in Florida the teacher reported that from his experience in teaching traditional physics over a number of years and from his experience of four years of PSSC, they had fifty per cent fewer dropouts in PSSC than in the traditional physics course.

One interesting thing is that the PSSC course, because of its unconventional order of topics may appeal more to the girls, a group who are not very highly represented in high school physics. The reason seems to be that the girls feel at a disadvantage in most physics courses because of mechanics, which comes up early. In the PSSC course they get into some rather general notions first and then into optics which they can handle on more or less equal terms with the boys. They seem to thrive on this, according to some school reports.

How do students and parents react to the course? The PSSC course does not reward rote memory, but emphasizes the ability to reason. Some parents are upset and some students are frustrated because those who have been accustomed to making an "A" in a science course now bring home a "B" or even a "C." Others report great enthusiasm for the course.

What about the attitude of the teacher? This is all-important because the preparation of the teacher and his enthusiasm are central to any effort to improve teaching. The evidence is that some teachers—usually those who have attended an institute—are giving the course very enthusiastically. Some who approach it reluctantly at the start become converted to it after a while. Some have used it and have given it up. Many have been influenced by it in some way or other. Many have not heard of the course; correcting this is an important problem of teacher education.

There have been some questions raised regarding the content of the course. Should nothing be left to the teacher in those areas in which each minute step in the reasoning is exposed in detail, and everything to the teacher in areas that are not discussed? Should the teaching of omitted topics, such as an introduction to nuclear physics, be left to social studies and the chemistry classes? Can the teacher properly present a true picture of physics in our world without some attempt to associate it with related social, historical, and technological developments? Each school must answer these questions for itself.

The PSSC course is a total program. As one participant phrased it: "The PSSC course is more than a textbook. It is a coordinated set of resources for teaching secondary school physics." This makes it particularly important that the various materials be available to the teacher—textbooks, laboratory equipment, films, and guides. More important, the school district must have a teacher who is willing to carry out the work. The first year for the teacher can be a strenuous one. It is here that the administrator can encourage the teacher to have a creative attitude toward the program and perhaps can assist him to attend an institute specifically oriented toward the course.

In summary, the PSSC course has met its objectives to a considerable degree. Whether these are the proper objectives for a high school physics course is now up to individual schools and—for the college-capable students—to colleges to decide. The materials for the PSSC program are readily available. There is ample opportunity for schools to experiment with this new approach. Even with other approaches to high school physics teaching, the excellent PSSC materials—the laboratory apparatus, the films, and the monographs—are worthy of consideration for supplementary use.

One other aspect of the PSSC course should be mentioned here. It is the "Advanced Topics" program. The committee has already produced some experimental chapters and laboratory experiments for a course that goes beyond the usual PSSC course. This is being prepared in individual chapters. Such an advanced program would usually be offered in the twelfth grade.

The Film-Television Course

Another new approach to the teaching of high school physics is the film course. These films were recorded in 1956-57 by Harvey F. White of the University of California in a project that was supported by a grant from the Fund for the Advancement of Education. There was little time for advanced planning and preparation for these films since they were televised over the Educational Television Network in Pittsburgh as a regular school course at the same time the films were made. In spite of that, the films came out very well. They have been used rather extensively by educational televison networks and in film teaching.

The latest bulletin on the use of these films from the distributor[5] lists about 400 educational units that have used them. "Units" refers to school systems as well as to single high schools. More than 50,000 students have used the physics and/or the chemistry films that were developed shortly thereafter. Major experiments in the use of the physics films, directly or via television, were carried out in Nebraska; Aspen, Colorado; Chicago; Washington County, Maryland; Wisconsin; Pittsburgh; Atlanta; and, Beaufort, South Carolina.

The philosophy and objectives of the program that led to these physics films included the following: 1) The films should provide means of giving a physics course where a qualified physics teacher is not available; 2) the films should enable some schools to release qualified teachers for duties other than conventional classroom teaching—discussion with students, working with them on projects, guiding outside reading, and so on; 3) the films would follow a conventional order of topics, but with rather more rigor than the standard high-school physics course; 4) the films were to emphasize demonstrations and take advantage of closeups made possible by films; and, 5) there should be an attempt to provide a so-called laboratory experience on film. The distributor states that the films have had a further purpose of facilitating the learning of greater amounts of information.

The course consists of 162 thirty-minute films in a five-day weekly schedule. There are lecture demonstrations for three days each week and laboratory sessions for two days. Professor White, assisted occasionally by his laboratory aide, is the film teacher. A typical lecture demonstration consists of discussion, blackboard work, apparatus use, and then the blackboard again. In a typical laboratory experiment the procedure is described by the film teacher, the apparatus is demonstrated, the data are taken, and the students are expected to work out the results of the data. The order of topics in the course is standard. The division of time is standard. The course covers the following: mechanics, properties of matter, heat, sound, light, electricity and magnetism, atomic physics, electronics, quantum optics, and nuclear physics.

How effective is the film course? An evaluation was carried out in 1957-58 by the American Association of Physics Teachers and the American Institute of Physics under the direction of Grant Gale of Grinnel College, Iowa. One test administered to students was the Dunning Physics Test which places rather heavy emphasis upon the recall of information. It was found that there was a negligible dif-

[5] Encyclopaedia Britannica Films, Inc., Wilmette, Illinois.

ference between the performance of students who had taken the film course and those who had taken conventional courses so far as this text could determine.

There is much to be said, however, about preferences of students and teachers. The evaluation revealed that the students have some preference for conventional instruction compared to the film kind or the film by television instruction. The teachers in this particular survey turned out to be less receptive to the use of films than the students.

There are mechanical and organizational problems involved in using films or film by television. These must be recognized. They involve arranging satisfactory scheduling, technical transmission, and the distribution of films to the schools.

It would seem, however, that the films can alleviate the teacher shortage to some extent by providing a teacher substitute—as far as information presentation is concerned. Once again, one must decide what the objectives of the physics course are. If the objectives include an emphasis on a greater rate of communication of information, films or television use of films are a possibility worthy of consideration for high school physics teaching. Mention should be made of the opportunity for supplementary use of the Harvey White films. Originally the films were only available as a complete set. Now, groups of the films are separately available. This offers interesting possibilities for a school to obtain films of, for example, a modern physics demonstration which may be difficult to set up.

Advanced Placement Physics

Another program in high school physics teaching is the Advanced Placement Program.[6] This is not new, but it represents a course that is undergoing a continual experimentation. It is a college level course given in high school to enable the school to enrich its program and the able student to accelerate. It uses a college-grade textbook and laboratory apparatus of the kind used in colleges and universities in the introductory course. There is a three-hour examination given each May by the College Entrance Examination Board to students who take this course. In 1959, 500 physics students took this test.

The group that sponsors the program recommends that the teacher have adequate preparation for giving the course. It requires a teacher with superior preparation and teaching ability. He must be ready

[6] *Advanced Placement Program,* College Entrance Examination Board, 425 W. 117 Street, New York 27, New York.

to accept the philosophy of this kind of course which is somewhat different from that of the usual high school physics course. It is recommended that the student be very definitely superior in reading ability, that his general academic record be good, that he previously has taken the first course in physics, and that his extracurricular load be low enough to allow him to do justice to this kind of a course. The recommendations to the school include these: that there be at least one double period and possibly two double periods for laboratory work, that there be three or four additional class periods for recitation and discussion work, that apparatus and textbooks be provided in adequate quantities. It is noteworthy that in this kind of a course there is close contact between the high school program and that of the college program.

As a step toward advanced placement in college—one of the objectives of this program—the Advanced Placement Physics course has had a rather limited success. There may be two reasons for this. One is the problem of mathematics. Until recently the mathematics programs of the schools have not included calculus in the senior year. As a result the student who can pass the Advanced Placement course in physics finds himself in the situation where he cannot advance beyond that point in college physics very readily because the higher level work in college requires calculus as a prerequisite. With the improved and expanded mathematics programs of the schools, there may be a return of interest in the physics Advanced Placement Program. Beyond that, there is another reason why many students who have taken the Advanced Placement test have not asked to be advanced in their college programs. The explanation is that some students conservatively prefer to take the introductory college course again in college in order to improve their grades.

As an enrichment for a high school program, the Advanced Placement Program is excellent for schools prepared to give work at this level. It gives the superior teacher a chance to use his talents and his knowledge of physics to the utmost. It provides a real challenge to the better student.

Other Resources in Curriculum Revision

The process of curriculum revision is a continuing one. One study group is already planning a physics course that stresses the historical development of the concepts of physics and relates physics discoveries to their cultural and social setting. Another approach under discussion is a physics course with some stress on the relation of physics to the growth of technology. We can also expect to see more of the interdisciplinary approach. For example, a physics-chemistry combination course of two years duration is probably not out of the question. Some groups are thinking about this. This would be a course that would take advantage of common topics in physics and chemistry and would strengthen the linkage between these two disciplines in the mind of the student.

The scientific journals provide many resources for course content improvement. In addition to *The Science Teacher*,[7] two physics journals are of specific interest here—the *American Journal of Physics*[8] and *The Physics Teacher*.[9] Among the articles and notes published in these journals are ones dealing with the objectives of physics teaching; reports on new courses; new demonstrations and experiments; reviews of textbooks, apparatus, and films; and similar topics. Meetings of national organizations, such as the National Science Teachers Association and the American Association of Physics Teachers, furnish other opportunities. Finally, schools should become acquainted with their Regional Counselor in Physics, whose assignment it is to arrange upon request for consultation between physicists and the schools concerning curricular changes.[10]

Apparatus makers, film distributors, and publishers also provide information about their products that is helpful to curriculum planners. Discounting proprietary enthusiasm properly, the schools can use the catalogs and other announcements to advantage in implementing their curricular plans. Of special interest in this connection is the *Purchase Guide*, prepared by the Council of Chief State School Officers.[11] The *Guide* provides great assistance in interpreting requirements and evaluating the uses of scientific apparatus.

The new physics curricula that the times require will make greater demands on the teacher and on the student. There will be a richer variety of materials available. The schools will have more of a choice of materials for presenting courses with different objectives. Certainly there will be a continuation of the school and college cooperation that has produced the curriculum developments discussed in these meetings. Physicists and their societies are ready and eager to contribute their services in the cause of better physics education.

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[7] National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington 36, D. C.

[8] American Association of Physics Teachers, 335 E. 45 Street, New York 17, N.Y.

[9] *The Physics Teacher*, 1201 Sixteenth Street, N.W., Washington 36, D. C.

[10] The Regional Counselor Program, 335 East 45 Street, New York 17, New York.

[11] The publisher of the *Guide* is Ginn & Company, Statler Building, Boston 17, Massachusetts.

Chapter VI

If there is one feature of science on which we all should be able to agree, it is that science is never the same for long. In one dimension of change, the content of science is always altering in detail, with the result that textbooks have a way of going out of date just about the time we come to view them as tried, true, and reliable.

Furthermore, the estimation, by students and experts alike, of what is important in pure and applied science is continually shifting. Why else has enrollment in engineering been falling off in our colleges around the country during the past few years?

There is no fundamental gulf between the theoretical and the practical, the pure and the applied, and the overwhelming demonstration of this is before our very eyes in today's rapidly changing science—changes that have come about so subtly and swiftly that we Americans don't even know we've produced a new science superior to the old. I refer to modern scientific research and engineering development, a new synthesis of the old technical, "Doer" tradition with the old scientific "Thinker" tradition. *Thomas M. Smith*

THE SCIENCE MANPOWER PROJECT'S K-12 SCIENCE PROGRAM

Editor: WILLARD J. JACOBSON

IN THE EARLY fifties several critical trends were becoming increasingly apparent to the discerning student of American science education. New information and knowledge in the sciences was accumulating at a geometric rate. In fact, new fields of science have been opened up. These developments in the sciences were not being incorporated into school science programs with sufficient rapidity. Since the thirties, there had been considerable interest in elementary school science, and increasingly effective science programs for children were being developed. But, there was little recognition of the inevitable impact of this profound development in science programs for junior and senior high schools. Although whole new sciences were being developed and the possibilties for school science programs were many and varied, many of the K-12 science programs were replete with interest-deadening repetition. Finally, a careful study of educational and population statistics yielded predictions of a sharply growing need for personnel well-educated in the sciences to man our highly sophisticated industries, shoulder the awesome responsibilities of our governmental agencies in this and other lands, staff our programs of research and development in new and exotic fields, and meet the desperate needs of our schools and colleges for teachers of science who satisfy the criterion of excellence. Such were the considerations that led to the organization of the Science Manpower Project.

A major undertaking of the Science Manpower Project has been to develop an effective K-12 science program. Undoubtedly, this is one of the most challenging tasks facing the science educator. This K-12 science program must help prepare children and young people for the world of today and tomorrow. In some way the program must deal with all aspects of science, the new as well as the traditional. It must be devoid of interest-deadening repetition, and yet it must help youngsters to build on their previous science experiences. Most importantly, the science experiences that our children and young people have must help them to grow and develop in the direction of defensible goals that have clearly defined meanings. It is little wonder that the K-12 science program is a tantalizing challenge to the science educator.

To augment the K-12 science program the Science Manpower Project has sponsored a limited amount of research and developed several teacher resource monographs. Of special importance have been Allen's studies of the attitudes toward science of high school seniors. One-tenth of the high school seniors in the public high schools of New Jersey were studied. Some of these students were restudied two years later to see what had happened to them and to see if any change in attitude had taken place. The teacher resource monographs deal with areas essential to the K-12 science program but for which there were few materials available.

The K-12 science program of the Science Manpower Project is intended for use by local school systems. It is not the "final word." Instead, this program can be used by teachers and curriculum committees as they plan the programs that will best suit the children and young people in their schools. We have suggested goals which we hope will have meaning to everyone and with which many will agree, criteria which should be considered, program characteristics which seem desirable, and a prototype program described in some detail which can be used as a reference by teachers and curriculum planners. It is hoped that these materials will improve the quality of our K-12 science programs.

Goals for a K-12 Science Program

Goals indicate directions. Teachers and curriculum planners must have some concept of the directions in which they hope that pupils and students will develop. As in science, our statements of goals should have operational meanings; i.e., they should have meanings in terms of our day-to-day work in teaching science. The following are among the goals of the Science Manpower Project K-12 science program with concrete examples to give them operational significance.

1. *To develop a better understanding of the natural, physical world.* This has always been one of the most important objectives of science teaching. We want our youngsters to develop a weltanschauung: a picture of the world in which they live, and a rational idea of their place in this world. This goal becomes critically important in this age when our knowledge of the world appears to be increasing geometrically. We are members of the animal kingdom—a recognition of this fact has led to great advances in medicine, human physiology, nutrition and other health sciences. We live in a very vast universe—a recognition of the vastness of the universe has challenged our imagination and opened new worlds for exploration. The development of a view of the world in which we live consistent with the pictures emerging from investigations in a wide range of sciences is essential for optimum intellectual growth.

All of our science activities should contribute to the achievement of this goal. One example from the Science Manpower Project's program is the study of the two leading hypotheses concerning the formation of the universe: the evolutionary or "big bang" hypothesis, and the steady state or continuous creation hypothesis. What are some of the "facts" that any theory of the formation of the universe has to explain? How do these two hypotheses deal with these "facts?" What are some of the possible ways that we might test these hypotheses? This is one example, from among many, of an area of study that will help young people to develop a more adequate picture of the universe in which they live, and begin to build a concept of the manner in which scientists deal with hypotheses.

2. *To help young people gain some understanding of the methods used in the sciences.* The methods used in the sciences are among the most powerful intellectual tools man has developed, and some of these methods can be used to deal with questions and problems that children and young people recognize. In the scientific approach, suggested answers of proposals for action are subjected to empirical, experiential tests. For example, a few years ago statements could be

found in newspapers and journals to the effect that the deerfly can travel at speeds of more than 700 miles per hour, although this speed approaches the speed of sound in air. When subjected to an empirical test, the speed of the deerfly was found to be much less than 700 miles per hour. In science, an attempt also is made to have the findings of one person checked by others. For example, when it was reported that Hahn and Strassman had found that U-235 fissioned into elements near the middle of the periodic table, American scientists did not wait for the meeting to close before they set out for their laboratories to check this report. The experiment in which all variables but one are controlled, is another important tool in the sciences. As young people engage in various kinds of science activities, it is extremely important that they understand the methods employed.

In a recent laboratory experience, some students were sprouting seeds by placing them on wet blotting paper between two pieces of glass. They were trying to find out whether or not it made any difference which end of the seed was down. After the experiment had been completed, one of the students asked, "What would happen if a full-grown plant were turned upside down?" The teacher countered with the question, "How could we find out?" Their immediate response was, "Try it!" However, the teacher hesitated and asked, "After trying it, how would you know whether or not turning a plant upside down had made a difference?" They suggested a control, i.e., growing another plant right-side-up. Also, before "trying it," the teacher asked them to suggest hypotheses as to what would happen if they tried growing a plant upside down. After carrying out the experiment, the students were asked to check textbooks, tradebooks, pamphlets and journals to see if they could find other accounts of this experiment, and to see whether or not their results were consistent with those obtained by others. What could have been only a prosaic science activity became a rather interesting demonstration of some of the methods used in the sciences.

3. *To learn more about their bodies and how to take care of them.* A great deal has been learned about the human body: how it functions, and how to achieve optimum health. This knowledge has been developed in such fields as physiology, pathology, immunology, chemotherapy, nutrition, and public health. It has helped us to increase the average life expectancy about twenty years in the last half century. However, health is more than the mere absence of disease. Instead it is a state in which each individual can operate at his optimum effectiveness. Few individuals have attained this state of optimum health. The study of the human body and how it works is

especially important for the early adolescent, for he is at a stage when profound and sometimes mystifyng changes are taking place in his body.

Many students have studied the effects of various kinds of diets upon growth and development. These studies are usually made with white rats. The laboratory rat has much the same nutritional requirements as humans and the effects of nutritional deprivation are seen about 30 times as fast in white rats as in human beings. The studies usually take the form of controlled experiments, in which some rats are given an adequate diet, while others are fed a diet deficient in some nutrient. Students learn how to set up a controlled experiment, make observations, secure and record data, arrange and interpret data, and discover that "what you eat makes a difference."

4. *To learn what it is like to work and study in science.* Guidance has always been seen as an important dimension of the junior high school program. Much of the basic work in guidance would be done in such areas of the curriculum as science, industrial arts, social studies, mathematics and English. Students should begin to acquire an understanding of what it is like to work in occupations and professions related to science, in preparation for the day when they will decide their life work. They should also begin to become aware of the kinds of preparation they will need for various occupations and professions. In the senior high school, they will begin to make choices among subjects in the school program. Since the basic courses in science and mathematics are often prerequisites to more advanced study, it is essential that students keep the doors to future opportunities open.

Guidance is an important feature in the Science Manpower Project's *Modern Junior High School Science.*[12] In each unit of the program some attention is devoted to the nature of the work in scientific occupations and professions related to the subject matter of the unit. Field trips to factories, laboratories, farms, and governmental agencies are encouraged, and scientists and engineers are often invited to contribute as a class studies various phases of science. In the final unit of the three-year science program there is serious consideration of science in the future, and the opportunities that young people have in the scientific enterprises.

5. *To prepare for effective citizenship.* In our democracy, citizens and their elected representatives have to make decisions concerning conservation of natural resources, agricultural policy, transportation, communication, atomic energy, public health, national defense, space

[12] Fischler, Abraham S., *Modern Junior High School Science.* New York: Bureau of Publications, Teachers College, Columbia University, 1961.

exploration, industrial development, air and water pollution, and education. Science and technology are involved in almost all decisions in these areas, and, if these decisions are to be intelligent ones, citizens will have to know some basic science and technology and have the background to study and resolve these issues. For many future citizens the K-12 science program provides the last opportunity they will have for an organized study of the wide range of the sciences. The responsibility for the future effectiveness of the democratic way of life that must be shouldered by the overburdened teachers of science is indeed impressive.

Perhaps one of the best ways to prepare for effective citizenship is to have experience in studying, analyzing and suggesting solutions for current community, regional, state, national, and international problems related to science and technology. In the Science Manpower Project's program for example, problems of the conservation of biological resources are considered at the community level, problems relating to energy sources are among the regional problems studied, and the control of nuclear energy is considered as an example of a national and international problem. In the study of these problems, the methods of study and analysis are emphasized, for as times goes on, the nature of the problems will change, but it will always be helpful to seek all pertinent information, to know how to use expert judgment, and to consider with respect differing and often controversial opinions.

The Science Manpower Project's K-12 Program

It is clear that a variety of approaches to effective science programs are possible. Communities, student groups, and teachers vary in a multitude of ways. This is why the program sponsored by the Science Manpower Project is primarily a guide to the development of the programs at the local level. At the same time, however, it is believed to have several important characteristics which should be represented in any local program modeled upon it. These characteristics are as follows:

1. *Content from a wide range of sciences is included.* Biology, chemistry, and physics are the traditional sciences of the schools. But, today, it becomes virtually impossible to ignore the potential contributions of astronomy, geology, astronautics, oceanography, and meteorology, or the subsciences of physiology, biochemistry, biophysics, genetics and nutrition. The range of our scientific knowledge is being extended, and it is high time that we recognize the fact in the design of science education programs.

2. *The science program is articulated.* One of the faults of too many K-12 science programs is that there is too much obvious repetition. At the same time, important areas of science are ignored. The Science Manpower Project's K-12 science program is an example of the broad spiral approach to curriculum planning. Similar areas of science are considered every third or fourth year rather than every year, and each time an area is included in the program an attempt is made to use a fresh, new approach at a more sophisticated level.

3. *A depth approach is used.* Areas of science are developed in greater depth than in most previous courses of study so that students can obtain a better understanding of the subject matter. The depth approach also makes it possible to give greater attention to method. Many of the areas of science should be developed through the use of the problem approach with emphasis on problem solving methods used in science.

4. *There is an emphasis on the broad generalizations of science.* Areas of science have been analyzed to identify the most important ideas or generalizations. Science activities are planned to help students develop clearer and more sophisticated concepts of these important generalizations.

5. *Science is considered as a human enterprise.* Scientific enterprise is not a separate entity devoid of relationships with other activities, nor are the various sciences unrelated to one another. Instead, the sciences represent an important kind of human activity, and there are many interrelationships among them. In the Science Manpower Project's Programs for the junior and senior high school, the year's work in science is developed around a unifying theme or a small number of unifying concepts that serve to emphasize these interrelationships. The emphasis upon ways of working and methods of investigation also help students to develop a concept of science as a human enterprise.

6. *The guidance function of science education is stressed.* In this age of science and technology, all students should learn something about studying and working in the area of the sciences. Many of them may find their life occupations in the scientific enterprise. Basic to any school's guidance program is the instruction in subject-matter fields. The Science Manpower Project's program, and especially the junior high school segment, is designed to provide the kinds of experiences that provide essential background for an effective guidance program.

7. *A variety of approaches to teaching is encouraged.* There is no one best way of teaching science. In fact, good teachers will use a

variety of approaches: laboratory experimentation, demonstrations, field work, project work, library research, lectures, and class discussions. They will also use a variety of teaching and learning materials: tradebooks and textbooks, films and filmstrips, radio and television, magazines, and mimeographed materials. The question is not, "What methods and materials are best for teaching science?" Instead, *the basic question* is: "What methods and materials are best to achieve a particular objective at a particular time with a particular group of young people?" In teaching the Science Manpower Project's K-12 science program the enterprising teacher will be able to utilize the wide variety of teaching methods and materials that are now available.

Science for the elementary school. A two-dimensional program of elementary school science is suggested in *Modern Elementary School Science.*[13] In the flexible dimension of the program, children have a wide variety of experiences related to the questions they ask, to other subjects in the curriculum, to timely concerns in the community, and to special science projects that they may undertake. In the planned dimension of the program, high quality experiences developed in depth are planned in each of six major areas of science. This elementary school science program can be taught by the classroom teacher. However, it is suggested that more effective experiences can be developed by a classroom teacher—science consultant teaching team.

The Flexible Dimension of the Elementary School Science Program

In this phase of the program we are primarily concerned with the needs and interests of children as expressed through their questions and interests. Since the purpose of the elementary school is to help children achieve optimum intellectual, social, and physical growth and development, this phase of the science program will almost always be closely related to work in non-science areas of the curriculum. Excellent science experiences are often developed as part of a broader study. The flexible dimension also makes it possible to meet the wide range of individual differences in ability and interest among children in most elementary schools.

The following are approaches to the flexible dimension of elementary school science:

[13] Jacobson, Willard J. and Tannenbaum, Harold E., *Modern Elementary School Science*, New York: Bureau of Publications, Teachers College, Columbia University, 1961.

1. Science experiences developed from children's questions.
2. Science experiences developed as a part of a broad area of study.
3. Science experiences related to other subjects.
4. Science experiences to meet individual differences.

See Jacobson and Tannenbaum [14] for a distribution of materials from six areas of science:—The Earth on which We Live; Healthy Living through Science; The Earth in Space; Machines, Materials, and Energy; The Physical Environment; and The Biological Environment.

The Junior High School Science Program

An effective junior high school science sequence is a key factor in the development of a superior science program for all school levels. The science courses in grades 7, 8, and 9 represent the last opportunity to study the broad range of the sciences. They obviously must be structured in terms of what pupils have learned in elementary science, and they must prepare students for their science studies in senior high school. Moreover, the junior high school science courses have an important relationship to guidance. It is at the junior high school level that many young people make their initial career decisions.

See Fischler [15] for a recommended pattern for the three general science courses of the junior high school: Seventh Grade—*The Environment and Human Needs;* Eighth Grade—*Use and Control of Energy;* and, Ninth Grade—*Frontiers of Science.*

The biology course is normally available to students in the tenth grade. In many schools it is elected by a majority of the students. In view of the fact that the program of the Science Manpower Project calls for a considerable amount of biological instruction in the junior high school, it should be no surprise that the course pattern proposed for biology omits a number of familiar, but elementary topics.

For biology Stone [16] recommends content under six areas as follows:—Chemical and Physical Aspects of Life; Structure and Function of Living Things; Intra—and Interdependencies of Life; Reproduction; Genetics; and, Changing Things.

[14] Ibid., p. 43.

[15] Fischler, Op. Cit.

[16] Stone, Dorothy F., *Modern High School Biology,* New York: Bureau of Publications, Teachers College, Columbia University, 1959, Chapter 3.

The Program in Physics

Notable additions have also been made to our knowledge of physics in the past two decades, and they should obviously be recognized in the senior high school course. This has been done in the course proposed by members of the Science Manpower Project. Again, this is made possible by the fact that elementary concepts of physical science are dealt with in the program of the junior high school. A brief outline of course content in the Science Manpower Project's proposal[17] is as follows:

1. Foundations of Mechanics: classical mechanics, Newtonian formulation of classical mechanics, applications of principles, and basic assumptions of classical mechanics.

2. Wave Motion: types of motion, dimensions of wave motions, similarity of wave types, principle of superposition, resonance, and diffraction.

3. Heat Energy: kinetic theory, equivalence of mechanical and heat energy, statistical development of kinetic theory, thermo-dynamics, radiant heat energy, and discrepancies in the physical theory of heat.

4. The Nature and Propagation of Light: wave theory, interpretation of light phenomena, optical technology, and sources of light energy.

5. Electricity, Magnetism, and Electronics: charge, field, electrical phenomena, basic electrical devices, and analysis and synthesis of secondary devices.

6. Nuclear Energy: atoms and elements, atomic structure, atomic particles and electrical charges, nuclear stability and radioactive decay, and radiation detection and control.

The Program in Chemistry

Like biology and physics, chemistry has made significant advances in recent years, and the time has obviously come to recognize the new knowledge in student programs. It is now possible to organize a chemistry course in terms of a unifying theme or basic concept. As pointed out by Pierce,[18] such unifying themes included (a) energy transformations, (b) atomic structure, (c) chemical equilibrium, and (d) the chemical bond. The course pattern sponsored by the Science Manpower Project[19] has three main themes, and various subdivisions.

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[17] Science Manpower Project, *Modern High School Physics*, New York: Bureau of Publications, Teachers College, Columbia University, 1959, Chapter 2.

[18] Pierce, Edward F., *Modern High School Chemistry*, New York: Bureau of Publications, Teachers College, Columbia University, 1960, p. 12.

[19] Ibid., Chapter 3.

1. Science, Matter and Energy: scientific methods, properties of matter, energy and energy changes, characteristics of gases and liquids, and the solid state.

2. Atomic and Molecular Structure: structure of the atom, the atomic nucleus, frontiers of atomic energy, periodic classification, the periodic groups, chemical combination and molecular structure, atomic and molecular weights, and chemical quantities.

3. Chemical Dynamics and Equilibrium: chemical equations, energy of reactions, oxidation and reduction, chemical equilibrium, the nature of solutions, the colloidal state, electrochemistry, acids and bases, the carbon compounds, and an introduction to biochemistry.

Summary

The foregoing analysis of the Science Manpower Project's articulated program of science education is by no means complete. For details, the reader is referred to the various monographs of the Science Manpower Project. The program assumes that science instruction will be provided for *all* young people through the years of the elementary school and the junior high school. In the senior high school it is recommended that the three first-line courses be biology, physics, and chemistry. It is recommended that the following courses be mandated:[20]

1. For all students: a course in biology and a course in physical science.
2. For the college preparatory group: a course in biology and a course in physics and/or chemistry.
3. No special mandates for students having special science interests and aptitudes. They should have as rich a science offering as possible.

[20] Fitzpatrick, Frederick L., (ed.) *Policies for Science Education.* New York: Bureau of Publications, Teachers College, Columbia University, 1960, pp. 205-206.

Chapter VII

What is unique about us relative to all other organisms on the earth is the nervous system. It is highly developed beyond that of any other organism that has ever evolved on earth. And this makes us different from all other organisms. We are aware of our own existence; we can remember things; we are capable of rational thought; we can reason; we can put information into our nervous system, rearrange it, get it out again; this makes possible the evolution of language, spoken and written; and this in turn makes possible the development of a culture—a culture consisting of religion, language, literature, art, music, technology, science, etc. This is information that we add to our systems after the DNA is translated. We store it, we add to it, and we communicate it.

This is our principal business in education—this adding to and communicating the information stored in our nervous systems. Science, research and scholarship of all kinds add to the sum total of this knowledge in significant ways. It is accumulated in the minds of people who put it down on paper, record it in other ways, and transmit it to contemporaries and to the next generation. That is human culture. And science is part of it.

George Wells Beadle

ELEMENTARY AND JUNIOR HIGH SCHOOL SCIENCE

Editor: Ellsworth S. Obourn

The past few years have witnessed an unprecedented round of activity in curriculum revision in science. A majority of these efforts have been directed toward the later years of the high school in the specialized sciences. Several of these projects will be discussed in subsequent chapters.

This report will have rather wide distribution among school administrators and its authors would be remiss if some note were not taken of the efforts toward curriculum revision in science now going forward at the junior high school and elementary school levels. If these efforts culminate in the kinds of the products now available for the specialized sciences, they will have a profound impact on the junior high and elementary school curriculums in the decade ahead.

Even before the curriculum efforts in the specialized sciences were underway, forces were at work changing the pattern and sequence of science offerings in the junior high school. Due to a variety of causes many science educators, as early as 1950, began to question the wisdom of devoting 9 years of a 12-year science sequence to general science. This questioning gradually gave way to experimentation with other offerings than general science at the ninth grade level. The result of this movement has been a trend that is rapidly making the ninth grade a year of specialized science.

Among the specialized offerings currently being tried at the ninth grade level are biology, earth science, integrated physics and chemistry, and physical science. Some reasonable arguments can be found both for and against each of these sciences as an offering at the ninth grade level. The important thing for purposes of this report is not what science is being offered; but that there is currently experimentation in making the science offerings at the ninth grade level specialized rather than general.

No other level of the curriculum in science is in such a state of flux and uncertainty as the junior high school. Dissatisfaction and unrest are also visible in the elementary school science program.

Current Curriculum Efforts

Although the main purpose of the regional conferences was to acquaint school administrators with the newer curriculum materials in science for the senior high school, it was deemed important to examine briefly certain of the current efforts at the junior high and elementary school levels. A selected group of these efforts will be summarized briefly with the hope that any desiring further information will consult the references provided in the footnotes.

Several separate curriculum efforts, pertaining to elementary school science, are being undertaken currently by various groups, in addition to that of the Science Manpower Project reported in Chapter VI. These are listed, and for purposes of illustration, one or more selected examples are cited.

1. *Inservice education for teachers.* Inservice education of one kind or another for teachers of science has been practiced for some time by colleges, universities, and school systems. One example is that of the State Office of Public Instruction for Illinois. For three years this Office sponsored science workshops for elementary teachers and junior high school science teachers. Curriculum planning was the subject of concern in these workshops and the suggestion was made that local school systems adopt similar inservice workshops.[21] The

[21] *Inservice Institutes for Elementary School Teachers and Supervisors of Science and Mathematics.* National Science Foundation, Washington, D. C., September, 1962.

National Science Foundation has also made funds available to colleges for institutes for elementary science supervisors and teachers.[22]

2. *The use of specialists in teaching science.* The American Association for the Advancement of Science has been active for a number of years in endeavors directed toward science teaching improvement. About two years ago, the AAAS initiated a major experiment using specialists for teaching science to fifth and sixth grade students. Four major school systems were involved.[23] The results were favorable enough to encourage the AAAS to undertake a pilot study in 1961-2 as preparation for a larger study in the belief that special teachers may be particularly helpful in a period in which new course materials are being introduced.[24]

3. *Production of special content units.* Innovation in course content at the elementary level are being developed at the University of Illinois and the University of California at Berkeley, and at other institutions. The Illinois program is in astronomy and the course content is being developed cooperatively by astronomers and science educators. The course is being tried out in selected elementary schools.

The California program, drawing university scientists from several fields, is developing course outlines of "units" for elementary schools. The scientists involved in writing the courses have also become involved in teaching them and in some cases the regular classroom teachers acted as observers and consultants.[25]

4. *Guide in a special area.* The Manufacturing Chemists' Association has prepared a publication entitled, *Matter, Energy and Change.*[26] This publication contains directions and explanations for experiments and activities in the area of chemical and physical change suitable for elementary grades. It indicates an interest as well as an effort on the part of a group of scientists to assist in improving the science curriculum.

5. *A commission on science instruction.* The American Associa-

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[22] Weigand, James, "Improving Elementary Science Through Inservice Workshops." *Elementary School Science Bulletin,* National Science Teachers Association, Washington, D. C., February, 1962, p. 5.

[23] *Science Education News.* American Association for the Advancement of Science, Washington, D. C., March, 1962, p. 3.

[24] Gibb, E. Glenadine and Matala, Dorothy C., "Study on the Use of Special Teachers of Science and Mathematics in Grades 5 and 6." *School Science and Mathematics,* November, 1962, pp. 565-585.

[25] Karplus, Robert, "Beginning a Study of Elementary School Science," *The American Journal of Physics,* January 1962, pp. 1-9.

[26] Milgrom, Harry, *Matter, Energy and Change,* Explorations in Chemistry for Elementary School Children. Manufacturing Chemists' Association, Inc., Washington, D. C., 1960.

tion for the Advancement of Science has a newly formed Commission on Science Instruction in Elementary and Junior High School. The AAAS hopes, through this commission, to improve course content by encouraging scientists and educators in all fields to assist in designing and implementing the use of course material, and to work in cooperation with the large number of groups who are preparing science curricula over the nation.

During the summer of 1962, the AAAS held two ten-day conferences where scientists and teachers met to make general plans for course content improvement in elementary and junior high school science. These conferences were held at Cornell University and the University of Wisconsin. A recommendation that came from both of these conferences was to urge the newly formed Commission on Science Instruction to encourage the development of several science curriculums based on different logically sound approaches.

6. *Summer science institutes and inservice institutes.* The National Science Foundation has provided financial assistance for many efforts that have bearing on the elementary and junior high school science programs, besides those previously mentioned. A limited number of Summer Institutes for elementary supervisors of science and classroom teachers are supported each summer. A few inservice institutes offered during the school year, are also supported.

7. *Television.* Television is being used for science instruction in many schools and school systems; for example, Lincoln and 34 other school systems in Nebraska, and Des Moines, Iowa, and nearby county schools.[27]

In some schools where science has not been particularly strong, the television courses have in essence become the science curriculum. In other schools the television is supplemental, or for enrichment.

Television is also used to present inservice programs for teachers, either in conjunction with the TV courses for the pupils or independent of such courses.

8. *Other practices in elementary school science.* Without elaboration, mention should be made that some schools are using one or more of the following: team teaching in science; one or more teachers who teach only science; and the use of resource teachers, coordinators, or consultants.

An excellent article summarizing another very promising experiment in a new approach to elementary science has appeared in *Science Edu-*

[27] NDEA Study Project for Television Library Service. OE-2-16-015-Title VII *Great Plains Regional Instructional Television Library.* University of Nebraska, Lincoln, Nebraska.

cation News.[28] This endeavor is being carried out under the auspices of Educational Services, Inc. More information about this venture may be obtained by writing to Elementary Science Study, 108 Water Street, Watertown, Massachusetts.

In 1958, the National Science Teachers Association and Oregon State College cosponsored the West Coast Summer Conference for teachers of junior high school science. This conference considered numerous aspects of junior high school science, with considerable emphasis being given to the curriculum.[29]

Reference is made to this meeting because it is one of the very few national meetings that has considered specifically the junior high school science program. Many science educators, and others, view the junior high school as perhaps the most critical area, the one that needs a great amount of attention, if the K-12 concept of science education is to be promulgated. Herbert A. Smith, a past president of the National Science Teachers Association, has written, "One must apparently conclude that the junior high school is still the stepchild of American education frequently discriminated against in faculty and in housing. After 50 years, it looks as though we ought to get around to taking this branch of the public school system into the family." [30] Smith goes on to indicate that junior high school teaching is not looked upon as a career, that teacher education institutions rarely provide for preparing junior high school personnel, and that the general idea that "anyone can teach general science in grades 7, 8, and 9" still prevails.

The above reference is used to point up the great need for action at the junior high school level. Fortunately there are many excellent junior high school science programs across the land.

Since 1958, there have been some decided efforts to do something about the junior high school science curriculum, and the preparation of teachers. In June, 1961, there was a report of three regional conferences held under the auspices of the AAAS which considered the rather broad topic, *Science Teaching in the Elementary and Junior High Schools*.[31] Some of the common agreements reached in these conferences were: science should be a basic part of the general education for all students at the elementary and junior high levels; new in-

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[28] *Science Education News*, American Association for the Advancement of Science, Washington, D. C., 20005. October 1962, pp. 4-5.

[29] Bryan, J. Ned, *Science in the Junior High School*, National Science Teachers Association, Washington, D. C., 1959.

[30] Smith, Herbert A., "Some Implications of Research for the Training of the Junior High School Science Teacher." *Science Education*, February, 1960, p. 37.

[31] *Science Teaching in Elementary and Junior High Schools*, (AAAS report of three conferences). *Science* June 23, 1961, p. 2019.

structional materials must be prepared; preparation of the new materials will require the combined efforts of scientists, teachers, specialists in learning theory and in teacher preparation.

The Science Manpower Project, previously mentioned, has also prepared a monograph entitled, *Modern Junior High School Science; a recommended sequence of courses.*[32] This guide presents a three year sequence in science for grades 7, 8, and 9, making it possible to consider the subject matter materials in reasonable depth, to engage in experimentation, and to explore individual and group interests. The recommended sequence could be adapted to various school programs.

There has been considerable discussion, and some action, about subject area placement in the junior high school. Several schools have tried or are trying biology in the ninth grade. Several thousand junior high school students in the San Francisco Bay area are taking chemistry via television.[33] As reported in Chapter II, another effort in subject area placement has been that of a group of scientists and educators, under the auspices of the American Geological Institute, who have been working with geology and earth science curriculum plans.

Quite a number of summer institutes, sponsored by NSF, offer courses in earth science or include earth science among the courses. Several of the summer institutes are for junior high school science teachers only, and other institutes include junior high school science teachers.

Television is being used as an instructional tool in some school systems for junior high science, as in the case of the San Francisco Bay area previously mentioned. The same reference indicates that several junior high schools receive science lessons through the Southwestern Indiana TV Council.

K-9 Science Curriculum Trends

In an excellent paper given at a conference of State Supervisors of Science held at the U. S. Office of Education in 1962, Philip G. Johnson [34] of Cornell University summarized the directions of change in elementary and junior high school science under the following rather provocative headings. His paper covered these topics:

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[32] Fischler, Op. Cit.

[33] *Science Education News,* op. cit. October 1962, p. 4.

[34] Johnson, Philip G., *National Developments in Science Curriculum in Elementary and Junior High Schools.* Paper presented at the June 1962 Conference for State Supervisors of Science, U.S.O.E. Washington, D. C. Published in part *School Life,* October 1962. Complete text will appear in U.S.O.E. report.

1. From much subject matter to less.
2. From one problem-solving method to many relatively unstructured instructional methods.
3. From much use of one textbook in a series to the use of many books.
4. From emphasis on accumulating knowledge to an emphasis on how to find and create knowledge.
5. From facts and factual concepts to skill in inquiry as teaching goals.
6. From teacher selected concepts as teaching goals to concepts as they arise in confirming and rejecting hypotheses.
7. From the terms "elementary science" and "general science" to "science."
8. From reliance on qualitative observation to stress on making and recording quantitative observations.
9. From films that stress a body of knowledge to films that report one or a series of experiments.
10. From science experiences as preparation for secondary school science to experiences for the basic education of all pupils.
11. From science as something to be learned from books to something that grows out of a series of experiments.
12. From a program based on topics, limited concepts and experiments to one based on a more fundamental frame of reference.
13. From great attention to uses of science including technology to more attention to science.
14. From science built on a limited understanding of mathematics to science built on mathematics.

There is little doubt that at present each of these fourteen trends is present in the areas of elementary and junior high school science. Which ones, if any, will prove to be the dominant factors in determining the curriculum of the future for grades K-9, is at present quite unpredictable.

The strong emphasis placed on the learning of science not only as content but also as a process of inquiry which is evident in each of the major curriculum efforts in the specialized areas must become a dominant concern in any curriculum changes in the lower level. If we are to produce an excellently trained science manpower for the future, and a scientifically informed citizenry to support an expanding scientific endeavor, we must have strong elementary and junior high school programs in science. Rather than only teaching about science, these programs must begin the teaching of science as inquiry at the earliest levels.

Chapter VIII

I think that this meeting is of very considerable importance in American education because you not only are leaders in curriculum and instruction but you also have opportunity and responsibility for creating the climate under which new views of instruction can begin to be made effective.

It seems to me that the National Science Foundation and other groups which are associated both in this conference and in the curriculum revision programs have made contributions of such significance to the development of education in this country that they cannot yet be fully assessed. If one examines the work of the various curriculum committees, he sees philosophic assumptions operating even though they often are not made explicit. Among these assumptions is a view of man as an animal that seeks experience, as an active inquirer and learner, rather than one who is constantly trying to retreat from tension-producing situations to the quiescence of the womb. This is very notable, I think, in these curriculum studies.

With regard to a theory of knowledge, the curriculum studies are grounded in a view that rejects the notion of specific items of information to be learned and the view that extension of knowledge occurs through a simple process of accretion. In the proposed organizations of the curriculum, all pretense of covering the field of knowledge is abandoned, and reliance is placed instead on apprehension of a system of basic concepts and their logical consequences. These concepts serve, not only as a structure for holding related bits of knowledge, but also as perspectives through which to view phenomena—perspectives moreover that are recognized as partial and temporary in nature and, therefore, to be supplemented and/or replaced in time by other perspectives.

It seems to me that the studies also incorporate a methodology for learning that is akin to the methodology for the discovery of truth. This means that the methodology of instruction in each field partakes of the strategies of inquiry which have proved fruitful in that field. *Francis S. Chase*

THE ADMINISTRATOR AND THE NEW SCIENCE CURRICULA

Editors: Kenneth W. Lund and Henry M. Gunn

"THE DOGMAS of the quiet past are inadequate to the stormy present, as our case is new we must think anew and act anew." These words were spoken by the narrator on the first Telstar program in the summer of 1962. They were used to highlight the great changes that a new technology was making possible by linking together Europe, Africa and North America in direct visual communication.

These words were first used by Abraham Lincoln one hundred years earlier. This is a reminder that change is always present and that the response to it must be intelligent in order to utilize its full import in the educational enterprise.

Change always brings a special challenge to the administrator. It is safe to say that his attitude toward change will have a powerful effect on the direction curricular change will take. It is the administrator who encourages teachers who have the desire to innovate. He gives them equipment, materials, encouragement, and protection during their first faltering steps in a new approach. He helps set the climate that places all of the needed resources at the call of those who will strive for instructional excellence.

It is a great opportunity for administrators to gather in these regional conferences and to hear the full story of these exciting new curricula. In a real sense we have been called together to study our first responsibility as educational administrators—providing instructional leadership. No task is more important, and our success in this venture will have a great effect on the lives of our students and the success of our country.

Changes are taking place in the science curriculum, especially in physics, chemistry, biology, and the earth sciences. The national space program, the rapid change in technology, and the increasing emphasis on scientific research all indicate the need for change and improvement. Since the National Defense Education Act, the National Science Foundation, the American Association for the Advancement of Science, and other agencies and organizations are all available to provide leadership and financing, the question for the administrator seems to be how best to use these sources in improving the science program or how to effect improvement when the resources are not immediately available. A set of administrative guidelines concerning the new curricula are here offered to administrators.

Motivation of Personnel

There is only one way to be a great administrator—that is to have great personnel. It is *people* who change and improve curricula, not organizations or programs. Usually one has the leavening influence of two or three individuals who are self-motivated to improve whatever programs they are responsible for. The excitement they feel for the subject they teach is catching. The students catch it and other teachers catch it. One of the main advantages of the new programs is the excitement of the first few teachers exposed to them, which, under proper conditions, spreads to other teachers in the system. On the other hand, one of the problems of the new programs is that when they cease to be new we find ourselves right back where we started when we were teaching the so-called traditional programs. How to motivate, how to keep excitement at a high pitch, how to keep this leavening influence at work is one of the most perplexing and one of the most challenging tasks in school administration. Unless one is able to do this, one is defeated almost before the program begins. Fortunately, the matter of motivation is less of a problem than it once was. Speakers and films on the new curricula are available, the public is interested and excited, and there is a ferment at work. In fact, one may even find that the task of governing enthusiasms, once developed, is more complex than creating the interest at the start.

Planning

Success with any of the new programs demands long-range planning that considers and includes the schools' personnel. Answers to many questions must be found. What sciences are to be improved first? At what grade level should a new program begin? Which school should start the program, or should all schools start at once? Which teachers should be involved, the enthusiastic teachers, the new teachers, or only those who have obtained status? How much experimentation should be allowed individual teachers?

PSSC started with materials at the upper grades in the high school. This new approach through problem solving in the learning of science was entirely new for many science classes. Students had been taught to learn tables and formulas by rote and to use the data in the solution of problems already set up in a text. The idea of the child discovering problems for himself and using the scientific approach to solve them was new. A new method had to be mastered along with the new program. If science had been taught in this new way in the elementary grades and consistently in the science program throughout, the task would have been easier for the Physical Science Study Committee, or so many instructors believe. Science teaching is beginning to change now, and the methodology of the new program is being used in the introduction to science in the earlier grades and consistently upward.

Fortunately, the new programs did not explode onto the national scene all at one time. The PSSC program was followed by the CHEM Study and the CBA and later by the BSCS. This was a good national approach and one that has helped schools in introducing the new curricula. One must be careful not to ask too much of the teachers, pupils or parents. It is better to proceed slowly and soundly than quickly and chaotically.

In general, planning should involve pilot programs in local districts if the districts are large enough to include several schools. The psychological problems involved in selecting the school and the teachers to start the programs can become complex but are familiar to all school administrators who have been in the profession for even a short time.

Capitalizing upon the creativity of the individual teacher is, or can be, a severe problem, and it is probably the heart of the whole matter. The creative teachers are the ones who make the new programs go. They must be sincere, interested, creative people who will find and develop ideas. The smart administrator allows creativity to flourish and stimulates it by giving it recognition and by allowing real experimentation to occur. Basic to the new programs are the people concerned, and they must be allowed to try new things, to experiment with new ideas, and to seek new directions.

There is a grave danger, of course. How is the crackpot avoided? Every child involved in the development of new programs is a guinea pig. The reason these children have been subjugated to that position is that the new programs have borne the earmarks of respectability. The greatest minds in science, in psychology, and in education have been associated with those programs to which school administrators have been willing to expose children. But how is the experimentation which is not really experimentation avoided? There is probably no final answer, but one possible answer is to appoint a curriculum committee to look at experimentation, to approve it and give it some guidance, or to reject it. The superintendent ought not to have to pass on the individual teacher's request for permission to experiment. It is far better for the plan to be submitted to a group of colleagues and peers who can properly appraise its worth and properly reject it if necessary.

Communication with the General Public

How is acceptance from the general public obtained in changing from a traditional program familiar to all, to a new program with new content and new methodology? Perhaps the best way is to involve the public in the change. Not everybody can be involved, but at least a segment of the public can be brought in to discuss the new concepts, the new ideas, the background of the program, what the goals and objectives are, what evaluation will be needed, and the reasons for instigating the change. Mass media should also be involved—the press, radio, TV, and whatever other means are available for communicating with the public at large.

Those in the community who are apt to be informed about and sympathetic to the new programs should be asked to help. Chemists, biologists, physicists, geologists, medical doctors, engineers, and many of the lay people in the community will be helpful in communicating the major goals of new programs. They will understand that it is necessary to create an appreciation for science and an understanding of its scientific methods.

Inservice Education

This should be an on-going program that is well organized and well established with resource people who understand what they are doing. If resource people are not available they must be brought in from the outside. Adequate funds must be provided to carry on the program. Only failure will result if improvement in science offerings is left solely to the staff. Plan through free time, summer sessions, and other means to reduce the burden placed upon teachers.

Inservice education also involves the complex problems of organization at the elementary school level. Shall science in the elementary school be the responsibility of teachers in self-contained classrooms only or shall specialists be used? In general, it is probably preferable to use the specialist in the intermediate grades. Rather than bringing in a person who rotates from school to school a staff teacher can be used who can change off with other teachers. This requires interdepartmental planning between teachers—a wholesome process at any level of instruction and keeps costs down.

Articulation

The administrator must be concerned with *all* students, a fact which compounds the problem of articulation. Questions for which answers must be found are directly related to the community and involve its resources and general goals. If the new programs are for the academically talented and gifted students, how is proper continuity provided? When does biology for college entrance credit begin? When shall advanced biology be given? When shall chemistry be introduced? When shall college chemistry be offered? How about physics? What shall the science program be for the non-college bound student? Should he have an understanding and appreciation of the sciences and the scientific method? Shall there be one, two, or three lanes, and what shall be offered for courses in each of these lanes? You perhaps will have other questions to add to the list for articulation is basic but complex.

Materials: Production and Storage

The necessity for new materials and for a place to store them must not be overlooked. Ripple tanks, stroboscopes, electronic measuring tubes, and other such devices are an integral part of the new curricula. Some, but not all, of the materials available for the traditional programs will be useful. It has been estimated that the materials necessary for the PSSC program will represent about one-fifth the cost of materials for the traditional program. On the other hand, materials for an elementary science program may be double the present costs. More than anything else, this reflects the paucity of materials usually available at the elementary level for the teaching of science.

The methodology of the new curricula is based heavily on the student's experimenting on his own to discover new ideas and to gain a feeling for the methods of science. To skimp on materials would be to negate the whole approach. Some of the programs offer inexpensive materials that the pupils can assemble. Provided the time and a minimum of raw materials, most teachers who are truly excited about the new programs can construct the necessary materials themselves. In some cases the industrial arts and home economics departments will cooperate in constructing desirable devices. The purchase, the production, and the storage of materials is very much a part of implementing the new programs.

Costs

The cost of installing new programs in science will vary widely according to the scope and ambitions of the school's plans. In one district $100,000 is budgeted for research, or about one per cent of the budget. For curriculum development beyond the cost normally expended, about $75,000 is budgeted. Two per cent of the district's budget ought, then, to be the amount suggested to the School Board as not unreasonable for introducing the new curricula.

As mentioned earlier, the per-pupil cost in the elementary schools for materials runs somewhat higher than for traditional programs. The largest cost, however, in introducing new programs will be for inservice training but quite likely the greatest rewards will also be reflected here.

Evaluation

How does one know that what is being done is worthwhile? This is the question the administrator is constantly called upon to answer to his Board and to his community. Moreover, if it is worth doing, how well is it being done? One answer is that the method itself is worth the doing. Another answer comes from the colleges, which report that the students arriving in the freshman classes are far better prepared and often able to omit some of the standard freshman courses. This, of course, only answers the question for the academically talented and leaves unanswered the question of how well the majority of students, the non-college bound, are doing in high school science. Evaluation is not easy. Is it content that is of concern? Is it interest in science? Is it knowledge of the processes of science and scientific inquiry?

A Balanced Program

Administrators in their zeal for improving science programs must reflect on the matter of balance among the humanities and the sciences. They must ask themselves: Why science in the general education of youth? What is the relation of science to the improvement of man? Science increases man's store of knowledge, and that it is exciting, but how does it increase his understanding for a more peaceful and better world? The administrator must not become overwhelmed with science. It must be put in its proper perspective so far as a total program for the education of all youth is concerned. Science seeks truth; it is not truth itself. The knowledge, the understanding and the appreciation of science must be related to the goals of free men and directed toward peace and good will. It must have its own place in a well-balanced program.

Appendix

SOURCES OF INFORMATION

A reading list has not been included in this document because of the increasing volume of materials produced by the studies described. Schools interested in exploring the use of the new science curricula should write for current information to:

BIOLOGY

American Institute of Biological Sciences, 2000 P Street, N. W., Washington, D. C.

Biological Sciences Curriculum Study, University of Colorado, Boulder, Colorado

CHEMISTRY

Chemical Bond Approach Project, Earlham College, Richmond, Indiana

Chemical Education Materials Study, University of California, Lawrence Hall of Science, Wing B, Gayley Road, Berkeley 4, California

American Chemical Society, 1155—Sixteenth Street, N.W., Washington 6, D. C.

EARTH SCIENCE

American Geological Institute, 2101 Constitution Avenue, N. W., Washington, D. C.

PHYSICS

American Institute of Physics, 335 East 45th Street, New York 17, New York

Physical Science Study Committee, Educational Services, Inc., 164 Main Street, Watertown, Massachusetts

SCIENCE MANPOWER PROJECT

Bureau of Publications, Teachers College, Columbia University, New York 27, New York

GENERAL INFORMATION

John R. Mayor, Director of Education, American Association for the Advancement of Science, 1515 Massachusetts Avenue, N.W., Washington, D. C. 20005

Ellsworth S. Obourn, Specialist for Science, U. S. Office of Education, U. S. Department of Health, Education, and Welfare, Washington 25, D. C.

Richard E. Paulson, Program Director, Course Content Improvement Section, National Science Foundation, 1730 K Street, N.W., Room A4-443, Washington, D. C.

SCHEDULE

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Director: WILLIAM P. VIALL, American Association for the Advancement of Science, Washington, D. C.

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Earth Science: Harold Dinsmore, Farragut High School, Iowa: David B. Kitts, Associate Professor of Geology and the History of Science, University of Oklahoma, Norman, Oklahoma: William H. Matthews III, Professor of Geology, Lamar State College of Technology, Beaumont, Texas: Richard A. Smith, Department of Met. and Physical Science, San Jose State College, California: John L. Snyder, Director of Education, American Geological Institute, Washington 25, D. C.: Robert C. Stephenson, Executive Director, American Geological Institute, Washington 25, D. C.: Leo A. Thomas, Professor of Geology, Iowa State University, Ames, Iowa: Willard Gates, Manhasset High School, Long Island, New York.

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Henry M. Gunn, Professor of Education, San Jose State College, San Jose, California: Robert E. Henze, Director, Membership Affairs, American Chemical Society, Washington 6, D. C.: Paul DeHart Hurd, Professor, School of Education, Stanford University, Palo Alto, California: Willard J. Jacobson, Professor of

Natural Sciences, Teachers College, Columbia University, New York 27, New York: W. C. KELLY, Director, Education and Manpower, American Institute of Physics, 335 East 45 Street, New York 17, New York: MARGARET T. LLANO, American Institute of Physics, 335 East 45 Street, New York 17, New York: KENNETH W. LUND, Vice President, and Editor-in-Chief, Scott-Foresman and Company, Chicago, Illinois: J. STANLEY MARSHALL, Head, Department of Science Education, Florida State University, Tallahassee, Florida: ELLSWORTH S. OBOURN, Specialist for Science, U. S. Office of Education, U. S. Department of Health, Education and Welfare, Washington 25, D. C.: and, ROBERT C. STEPHENSON, Executive Director, American Geological Institute, Washington 25, D. C.

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OTHER PUBLICATIONS

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Secondary School Science and Mathematics Teachers: Characteristics and Service Loads, NASDTEC-AAAS Studies. Order from Superintendent of Documents, Government Printing Office, Washington 25, D. C., (Catalog No. NS 1.2:T 22/2), 35 cents, 1963.