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IMPROVING SCIENCE EDUCATION IN THE UNITED STATES.

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THIS PAPER SUMMARIZES THE CURRENT STATE OF SCIENCE EDUCATION IN THE UNITED STATES WITH SPECIAL EMPHASIS ON CURRICULUM DEVELOPMENT ORGANIZATIONS AND ACTIVITIES SINCE 1950. THE SEQUENCE OF TOPICS INCLUDES (1) HISTORY OF SCIENCE EDUCATION IN THE UNITED STATES, (2) RATIONALE FOR CURRICULUM CHANGE, (3) COURSE CONTENT IMPROVEMENT GROUPS AND THEIR ACTIVITIES, (4) PURPOSES AND NEED FOR SCIENCE EDUCATION, (5) CHARACTERISTICS OF SCHOOLS AND TEACHERS, (6) PRIVATE AND POLITICAL AGENCIES AND THEIR ACTIVITIES TO IMPLEMENT CURRICULUM FORM, AND (6) TRENDS AND THE OUTLOOK FOR THE FUTURE. THIS PAPER WAS PRESENTED AT THE COMMONWEALTH CONFERENCE ON THE TEACHING OF SCIENCE IN SCHOOLS (CEYLON, DECEMBER 9-21, 1963), AND IS PUBLISHED IN THE "JOURNAL OF RESEARCH IN SCIENCE TEACHING," VOLUME 1, ISSUE 4, 1963. (RS)
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*At the invitation of the Commonwealth Education Liaison Committee of the United Kingdom, Dr. Claude Gatewood and Dr. Ellsworth Obourn of the National Science Foundation and the United States Office of Education, respectively, prepared a major document describing science education in the United States for presentation at the Commonwealth Conference on the Teaching of Science in Schools. Their paper is a remarkably complete statement of the situation in the United States at the present time and as such it will be of great interest to students of science education throughout the world. The Editorial Advisory Board, in view of the unusual nature of the document and of the world-wide importance of the Ceylon Conference at which it was presented, has agreed to make it possible for this paper to be brought to the attention of science educators throughout the world. In this way, the Journal can help to fulfill one of the purposes for which it was established—that of promoting increased understanding of science education and, through this, the improvement of science teaching. Reprints will be available from the Editor, Journal of Research in Science Teaching, Department of Science Education, Florida State University, Tallahassee, Florida, at a cost of $0.50 per copy.*

# Improving Science Education in the United States

A paper presented at the
COMMONWEALTH CONFERENCE ON THE TEACHING OF SCIENCE IN SCHOOLS
Ceylon, December 9–21, 1963

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## Foreword

This paper attempts to describe science education in the United States today with special attention being given to the various facets of the "leading edge" which seem to hold the most promise. Such an attempt is, for example, to describe a bird which has been developed as a result of both planned ancestry and random mutation. Not only must one decide where in the chicken-egg-chicken cycle to begin, but there is the problem of tying in historical frame of reference information for comparison, as well as predicting the hereditary characteristics which will likely be dominant under unknown conditions.

Organization of this paper is as follows. The first section is an introduction that sets the stage, historically, for the present ferment that is effecting changes in science education. The second section describes both the methodology and the mechanics of the present curricular reforms which have originated since the early 1950's. The third section deals with the implementation of these reforms in the schools—how are ideas, even highly promising ones, put into practice in an educational "pipe-line" made up of fifty state departments of education, two million teachers and forty million students. The fourth section presents a summary of problems and trends, their probable effect on the future, and conclusions that seem to be most warranted.

The reader should bear in mind that no one, least of all the leaders of even the most praised reforms, claims to have found a panacea. As the poet Kahill Gibran said, "Say not that you have found *the* answer, but that you have found *an* answer."

Many of the projects and programs described in this paper seem to have caused change in a desirable direction; some are believed to hold promise as "an answer" to problems of science education in the United States, at least in the cultural, social, economic, and geographical environment in which they have been conceived and nurtured. They are presented here not as "the answer," but only in the hope that they might be useful as possible guidelines to those in other nations who are involved in similar curriculum reform.

It should be emphasized that, although many of the programs and projects described in this paper center around new materials and administration of reforms, it is recognized by all that in the final analysis implementation of these efforts depends upon the teacher. It will be the individual teacher in the classroom who will determine ultimately the degree of success that the current reforms have on the young people of the nation.

The present conference deals specifically with secondary school science education. Both the educational structure and the way in which reforms have developed in the United States preclude the possibility of (in this paper) completely eliminating all consideration of mathematics and engineering, although a primary emphasis on science is maintained. Reforms originating at the secondary level have, almost without exception, overlapped and generated continuing reform at the pre-secondary (elementary school) and post-secondary (college) levels, so that references to this effect and mention of some of these "second generation" reforms are also included. Due to the diversity of structures within the fifty states, the word "secondary" itself does not always mean the same thing. School structures in the United States include: 6-3-3 (elementary-junior high-senior high school); 8-4 (elementary-secondary); and to a lesser extent, 6-2-4, 7-2-3, and other local variations. Because of this variety, the term "secondary school" is not a clinically precise term, but generally refers to the last three or four years of the normal twelve-year sequence for children.

In a number of instances, only a brief sampling of descriptions of programs or projects of a given type will be included in this paper and the reader will be referred to other resource material if he wishes additional detail. Packets containing these additional resource materials will be made available to conference participants and will include a supplementary paper containing excerpts from documents too bulky for inclusion in the packet, as well as a list of additional references.

## I. Introduction

### *Historical Background*

In order to describe accurately the situation with respect to science education in the United States today, certain historical developments must be considered in order that one may understand the compelling sense of urgency felt by leading scientists which has led numbers of them to take temporary leave of their laboratories to commit themselves to the generation of new materials for science education. One striking fact is that ten Nobel Laureates are now actively involved in various projects to improve school science education in the United States, whereas during the twenty-five years preceding the 1950's, not one such distinguished person was so engaged. As it is certainly true that what is past is prologue, some knowledge of previously prevailing conditions and trends is an imperative in order to gain a clear picture of the present situation. This section, after describing the historical background, will treat the educational background, then how these factors set the stage for the current reform.

Within the memory of many senior citizens of the United States, there have been at least two major transformations in the very foundations of national society. Fifty years ago, the family farm was one of the most important institutions in the society. By and large, these farms were operated in the same way that farms had been run for a century. A third of the nation's labor pool was required on the farm, simply to raise enough food to feed the nation. Another third was required for other manual labor. Technological innovation, together with the Smith-Hughes Act,* social reform, and the labor movement, have brought sweeping changes. To a very great degree, farming is now a "big business," highly mechanized with professional management, and requiring only a twentieth of the labor pool as laborers and foremen. Tens of millions of adults who were "raised on the farm" as children must now pursue a livelihood elsewhere.

Another sweeping change that has taken place within recent decades is the arrival of what has been termed a scientific and technological revolution. At an ever-quickening pace, many of the results of research and even the specialized tools of the scientists are being translated, through technology and engineering, into the daily life of the average citizen. Materials for specialized science research and instruction of a few short years ago are now part of the technological environment of daily life. High voltage gas discharge tubes that were found only in the advanced physics laboratory now constitute the basis for a billion dollar industry employing tens of thousands as well as light the streets, homes, and businesses of millions. Many processes which were only ideas in research scientists' minds a generation ago are now commonplace, widely used and understood. Cathode ray tubes are now in the homes of fifty million television owners, most of whom probably know less about its operation than do their teen-age school children.

With the passing of each recent decade the employed number of blacksmiths and forgemen, teamsters and milliners has been halved and quartered. During these same decades a doubling of employment of lens grinders and photographic process workers, scientists and technicians has occurred. To pursue one example in detail—twenty years ago there was no television industry as such; today, five million men, women, and children depend on it for a living and it is a

* A federally subsidized program to bring modern vocational agriculture into public schools and teach future farmers better methods of farming.

multi-billion dollar industry, as common in daily life as was the wagon a half-century ago. Remembering that the average man would expect to spend three or four decades pursuing the trade or vocation for which he prepared himself as a youth, it becomes evident that frustrations of increasing intensity would develop for both individuals and society as a whole in the aforementioned circumstances.

To the average person in any nation, the world in which he lives is made up largely of his immediate surroundings, the products which he uses, the jobs at which he and his neighbors work. In the United States over half the jobs and products which exist today did not exist thirty years ago. The environmental world of the 1930's, which provided the cultural and technological environment in which that generation of the nation's young people grew up and were educated has, in the main, ceased to exist. Science and technology are with increasing swiftness causing the obsolescence of current jobs and skills and, in many instances, they are outdating current education. In recent years, for the first time in the history of the United States, a majority of the nation's young people were faced with the possibility of spending their youth acquiring an education that was simultaneously being made obsolete. It is now starkly evident that to the basically factual (reading, writing, arithmetic) education of a generation ago must be added the intellectual activity of education in basic science for all and specialized science for many.

*Educational Background*

There appears to be no record of any science offerings in the Latin Grammar Schools which dominated education in America from 1650 to 1750. The public academies which replaced them for the next hundred years offered little science *per se*. The last half of the nineteenth century witnessed the rise of "high schools"* as we know them today. Natural philosophy, chemistry, botany, and zoology were offered, but consisted primarily of memoriter learning of factual information, with little or no laboratory work. In 1872, Harvard College announced that physics and other high school sciences would be accepted for credit if the course followed a prescribed outline of content. Other colleges quickly followed suit and until the beginning of the twentieth century, high school curricula, including science, were little but college preparatory. In this period of college domination lie some roots of the troubles which plagued science education during recent decades. During this period, college professors wrote the texts and by and large gave rather close attention to the quality of school curricula, patterning them after their own courses.

In only twenty years, from 1910 to 1930, the high school population of the United States more than quadrupled. College professors became preoccupied with their own burgeoning fields of endeavor and paid less and less attention to what was going on in the schools. As secondary education for all the children (instead of only a few) approached reality, "General Science" replaced physical geography as an introduction to secondary school science, and professional pedagogists assumed responsibility for science instruction in the schools. Control was not wrested from college people but rather was assumed through default.

From 1925 until 1950, school science texts were written largely by high school teachers, often in collaboration with a professor of science or science education in a teachers' college. A dichotomy developed and became quite rigid between "respectable" scientists and science "educators." Science courses for prospective teachers were often taught in departments of education and a leading science professor would be horrified if he thought that any of his "good" students were contemplating a career as a school science teacher. Educators reacted quite naturally and for decades it was considered

* "High school" is a term commonly used in the United States to designate secondary schools.

as important that a school science teacher know *how* to teach as *what* to teach—anyone could memorize "science facts," but to know how to get children to learn in turn was of overriding importance, during these decades.

Economics demanded that textbooks be used for five, ten, or more years. An author might not have had formal rigorous college work in science for ten, twenty, or thirty years. By the time a text was put in the hands of school students, its contents usually bore little resemblance to the concepts that were occupying leading scientists of the day. Emphasis was on factual information that would allow the over-worked teacher to administer and grade tests with the least possible effort.

### *The Stage is Set for Reforms in Science Education*

By the 1950's, the stage was set; the time was ripe for reforms in science education in the United States. When Sputnik launched the Space Age in 1957, everyone was ready to do something, even if it was wrong. Parents, children, professions and politicians tried to partake of this popular new dish called Science. In order to understand the degree and type of concern evidenced in many circles in the late 1950's, it will help to bear in mind that in the United States, schools are controlled at the local and state level by quite average citizens. The degree of scientific sophistication of these citizens, whether real or imagined, thus becomes important.

Next, let us consider some of the many evidences that in recent years indicate at least public interest and, to a large degree, public support of reforms in science education.

The adult population of the United States has increased by approximately 5% in the past four years. In the same period of time, subscriptions to the magazine *Science* have increased by 45%, to *Scientific American* by 60%, to *National Geographic* by 33%. At the same time, subscriptions to two previously popular pseudo-science publications have decreased by 6% and 44%. In 1957, there were 177 inexpensive paperback books on science in print; in 1962, there were more than 900, an increase of over 400%. The educational journals published in the United States contained an average of 340 articles on science education in each year between 1948 and 1954. It is not surprising that for the four years following 1957, this yearly average rose to 535. In the nonprofessional magazines, prior to 1958, there yearly appeared a total of about twenty articles on science education. For the next four years, however, these same periodicals averaged 151 articles on science education annually, an increase of 650%.

During the past five years, membership has increased in various scientific honor and recognition societies at rates up to a hundred times the rate of increase in the adult population of the United States. Psi Chi, a psychology society, has increased its membership by 360%, Kappa Mu Epsilon (mathematics) by 32%, Alpha Pi Mu (industrial engineering) by 61%, Chi Epsilon (civil engineering) by 28%, Eta Kappa Nu (electrical engineering) by 48%, and Beta Beta Beta (biology) by 35%. One of the more conservative membership increases is that of 18% made by two chemical societies, a figure which is still three times the relative increase in the national adult population. During this same five-year period, the membership of the National Science Teachers Association has increased by 53%, evidence of a surge of professionalism among teachers of science.

Increasing popularity of science youth activities in the United States reflects the desire of young people in the schools to become more closely allied with the realities of a technological society. Almost any science youth activity is assured of success if it is dedicated to the involvement of young people in the pursuit of scientific knowledge. There are literally dozens of these programs and they range from very limited activities sponsored by special interest groups to broad national programs sponsored by national groups. Some examples of these programs are: Young Engineers and Scientists of America, chartered in 1959, now has 250 chapters in thirty-six states with a membership of 7,500 school students; the Junior Engineering and Technical Society, chartered in 1950, now encompassing 100 chapters in forty-six states with a membership of 35,000; the Junior Science and Humanities Symposia program, initiated in 1959, and today involving 8,000 students participating in symposia in twenty states. The Science Clubs of America program includes a variety of science youth activities and includes over 20,000 clubs across the nation in every state. Many state academies of science sponsor junior academy programs whereby school students submit papers on individual research projects in competition for presentation to the group. In two years the school science club program sponsored by the National Science Teachers Association has grown to include over 60,000 students in 1,500 schools. A program initiated two years ago by the United States Office of Education to involve citizens with scientific backgrounds in community-centered efforts to improve school science education, is now active in twenty-five of the fifty states.

In 1958, the Educational Policies Commission of the National Education Association, largest and most powerful professional organization of teachers and administrators in the United States, issued a statement on *The Contemporary Challenge to American Education* in which it was stated:

> The public is now more fully aware that the future of nations rest in considerable measure upon progress in science and technology. There is widespread agreement that improved chances must be opened to those minds which are capable of scientific excellence. This is a matter of priority for American education.

In 1959, the President's Science Advisory Committee released a statement on *Education for the Age of Science* which called for special emphasis:

> ... to understand that the advances of science and technology need special attention to the end that (*1*) all citizens of modern society acquire reasonable understanding of these subjects, and that (*2*) those with special talents in these fields have full opportunity to develop such talents.

A mosaic of such quotations could be continued indefinitely providing evidence of an awareness on the part of the general public that can best be described in relation to a statement made a half century ago, in 1916, by Alfred North Whitehead:

> In the conditions of modern life the rule is absolute: The race which does not value trained intelligence is doomed. Not all your heroism, not all your social charm, not all your wit, not all your victories on land or sea, can move back the finger of fate. Today we maintain ourselves. Tomorrow science will have moved forward yet one more step—and there will be no appeal from the judgment which will be then pronounced on the uneducated.

During the middle and late 1950's, professional organizations, government panels and agencies, and scientists, both singly and as groups were bombarding each other and the public with statements to the effect that the "tomorrow" of which Whitehead had spoken was indeed upon us. The present concentrated concern for better education in science is part of a broad movement to enhance the quality and effectiveness of education for all students of every age in all areas of knowledge and can be best dated from about 1950. Still in its early stages, this effort is widely considered to be one that must go on indefinitely, at an increasing rate. All such reforms must consider the context: values in the society; social, economic, political changes; educational goals; the American traditions of local autonomy and control, pluralism and diversity, in education: research on learning; school and university organizations; numbers of students, teachers, schools, controlling bodies, the present and prospective content, styles of work of inquiry, interrelationships of realms of human knowledge and activity.

Accordingly, specific attempts to solve difficult problems in science education in the United States are adapted to particular viewpoints, needs, circumstances. Examination and critical assessment of the experimentation, of new curricula, courses and instructional materials are welcomed. It seems likely, however, that the tactics and approaches may be of the greatest general interest, since every country must work out its own specific solutions.

The considerable, if not yet fully adequate, effort for progress is centered around the intermeshed areas of curriculum content, preparation of teachers (both at the pre-service and in-service levels), special student opportunities, facilities and organization, and implementation of reform in individual school systems, schools and classrooms.

## II. Changing Science Curricula

### *Overview*

The current status of curriculum development in school science education is one of energetic reconstruction. The events that have been previously recounted led to a concentrated bombardment of the existing curricula by deeply concerned scientists, educators and laymen, as well as a large variety of sensation-seeking opportunists. The emergency defenses erected for protection against this onslaught have, unfortunately, become in the minds of a few the final purpose. The situation in almost all instances prior to the past ten years has been somewhat comparable to that of certain small communities in northern France. There, during the War of 1870, a few of the towns were severely damaged. Following the war, the people rebuilt using the same stone blocks. The same thing happened again with the First World War and then again with the Second World War. In each case, the building materials were either the same stones and beams, or new ones cut exactly as the old ones in order to fit the structure. Quite literally, the rebuilding in each case consisted of rearranging the rubble. Except for the addition of a few modern conveniences (e.g., electricity), the towns look exactly as they must have a century ago, and are no more defensible.

When the study of the facts of science became the end in itself, the study became indefensible. It is entirely conceivable that a person could live a whole lifetime without ever having to know that water is composed of hydrogen and oxygen, that there were once dinosaurs, that green plants contain chlorophyl, or that our solar system contains a sun and a certain number of planets. It is not conceivable that a person can live a lifetime in our modern technological society without having to gain some real understanding of inertia (e.g., in order to drive an automobile), or of objective evaluation (e.g., evaluation of incessantly contradictory advertising) or of disease prevention (e.g., general public health measures).

A focal development in the past decade is the recognition by outstanding scientists that they themselves must undertake an active role, with cooperation and help from teachers and other experts, in creating new courses and materials for science instruction in the schools as well as the colleges and universities. The task demands the attention and direct involvement of those who best know the sciences, as well as those who best understand pupils and schools.

Experience to date suggests a number of guiding principles for these endeavors, particularly the more comprehensive ones. Some of these principles are listed below. It cannot be overemphasized that this list is by no means either exhaustive or absolute, but instead, presents sometimes overlapping principles that seem to be of importance to those involved in the current reforms.

(*1*) Leadership and work by scientists of stature are essential but all elements of the educational community must contribute—teachers, administrators, psychologists, and other people with special talents bearing on the educational enterprise.

(*2*) Fundamental rethinking of content

and approach is needed. Neither the addition of bits and pieces to established programs nor the rearrangement of existing material will suffice.

(3) A prime aim is to present the sciences as systems of inquiry rather than simply as bodies of knowledge. To this end, curriculum studies lay great emphasis on having students first come to grips with phenomena through laboratory and field experience (preferably directly) but, when necessary, augmented with the range of significant phenomena that can be brought into the classroom through the use of film and television.

(4) Laboratory experiences can no longer serve merely to verify previously stated principles. Ways are sought to encourage pupils to discover ideas for themselves and to learn the sciences by developing, so far as possible, the viewpoints and modes of attack of scientists confronting problems.

(5) Curriculum content should reflect the structure itself. Program provisions for individual differences should be differences of degree, not differences in kind. There is not one science for scientists and another for laborers and mechanics. Education in science falls along a continuum, not in storage bins of varying capacities.

(6) Current assumptions on when and how to introduce or develop a topic should be scrutinized sharply by specialists experienced in both subject matter (scientists) and learning theory (psychologists and educators). One traditional practice, that of presenting facts of subject information in the same chronological order in which they were discovered historically, has in some instances seemed to be far less than desirable.

(7) No single effort or curriculum study, even by a most distinguished group, should, simply because of its existence, preclude independent consideration of the same problems by other capable groups. As has been mentioned, there is no *best* way; only (hopefully) *better* ways.

(8) Careful classroom trial of any new materials or sequences of ideas is essential. The acknowledged experts on what science a school student *should* learn are the scientists, the professional educators, and the informed electorate. The ultimate expert on what science a student *can and will* learn is the school student himself, studying that science under whatever conditions are prescribed by those in control of the situation.

Increasing support for the various facets of curriculum reform, improvement, and expansion in science education has become available from both private and public sources. These facets include fellowships, scholarships, grants for educational research and development, and other subsidies such as support of institutes, conferences and symposia. Some of these programs, such as fellowships and institutes, bear more on the implementation of reforms and will be treated in Section III of this paper. Other reforms in course content improvement and the development and utilization of equipment and aids bear more directly on the basic science education "revolution" and will be described in the following divisions of this section. With respect to course content improvement projects, it should be pointed out that while some locally conceived and financed programs create material that is unique and that will be described in this section, others are more concerned with incorporating materials into their own curriculum and will be described in Section III.

*Course Content Improvement Materials*

Within recent years there have been literally hundreds of efforts at improving science course content at all levels. These have ranged from locally conceived and executed ideas having to do with a single school's particular needs to national projects involving complete courses or sequences of courses, together with teacher-training programs, films, equipment, laboratory programs, and instructional aids. Support has come from many sources, both public and private, but the most massive support of science course content improvement projects has been furnished by the National

Science Foundation. A number of National Science Foundation-supported course content improvement projects will be described in the following pages, with emphasis on the five major secondary school projects, on which work is farthest along.* A page containing data that indicates the increasing utilization of materials produced by the five major secondary school projects supported by the Foundation is included. Following the descriptions of Foundation-supported projects, course content improvement projects receiving support from other sources will be described.

Before describing particular examples of major national reform projects which have been supported by the National Science Foundation, certain facets that are typical of all should be indicated in order to conserve time and avoid repetition. General policy is usually determined by a steering committee or advisory board made up of a number of leading scientists in pertinent fields, together with teachers, supervisors, and other appropriate scholars. Text materials are written during the summer months through the cooperative efforts of large numbers of such scientists and teachers. Revision is carried on during the school year and the following summer, based on "feed-back" from large-scale classroom trials of these materials. This compression of the normal time factor (whereby traditional commercial texts are usually revised no more than about 5% after five years of no feed-back use in schools) is a unique feature in the present course content reforms that allows project-produced school texts to be much more accurate in the light of modern scientific knowledge and much more in line with present thinking.

* Copies of *Science Course Improvement Projects*, a booklet describing over one hundred course content improvement projects at all levels which have been supported by the National Science Foundation, have been made available to conference participants. For this reason only very brief mention will be made of some of these Foundation-supported projects.

1

The Physical Science Study Committee (PSSC) was first support by the National Science Foundation in 1956. Although various reform efforts in mathematics and in some of the sciences had earlier beginnings, the PSSC physics project was the first of the major curriculum reforms to get under way on a large scale, and its work has helped to set the tone for the whole reform movement. For this reason, somewhat more detail will be included in the description of the work of the PSSC than for the other major secondary school projects which follow.

In the early stages (though not at the very beginning) these physicists found that the changes they wished to effect in high school physics were of such a fundamental nature that a fresh start was the only sensible strategy. A prime aim was to present physics as a system of inquiry rather than as a body of knowledge. To this end, they placed great emphasis on having the student come to grips with a new phenomenon first in the laboratory rather than having him use the laboratory solely for verification. Through the laboratory (using text, problems, and films) the effort is to develop in the student insofar as practicable, a viewpoint and mode of attack consistent with that of the professional physicist in his approach to physical problems. Thus, for example, he is led to explore new situations from various directions and is encouraged to develop the tools necessary for this attack; that is, facility in thinking in terms of orders of magnitude so that different hypotheses can be tested quickly without the necessity for laborious calculations in each case. The gain here is not only in speed, but in the lowering of the barriers to those intuitive intellectual leaps that are an essential part of the creative process. The student is also led to make precise calculations, but only as precise as the available data warrant, and he is encouraged to value the best answer he can get with the tools at hand in a difficult situation as much, if not more, than a very precise answer in any easy situation.

The PSSC course (as well as the courses in other disciplines that have followed it) makes a very great effort to be impeccable in its intellectual honesty, where "honesty" here has to do with a determined aversion to imprecision of thought as well as to an aversion to untruthfulness. The writers of the course feel that the fewer steps the student must take on faith the better. Such meticulousness is, of course, essential in any course designed to encourage students to think rather than simply to memorize.

The PSSC writers wish to convey to students an understanding not only of the way a physicist attacks a particular problem but also of the cumulative effects of many attacks by many scientists over long periods of time; namely, complex models to the physical world and of a few general principles. They wish also to give students some sense of the seeming inexhaustibility of nature as a subject of study and an understanding of some of the great unanswered questions that physicists are grappling with at the moment.

A third desire is to provide students with knowledge and understanding that will serve them best in future years whether they go on in technical studies or sever their formal connections with science. These aims, plus the one previously mentioned (to make as few demands as possible on the credulity of the student) forced the writers, not unwillingly, to concentrate on relatively deep development of a limited number of principal physical themes especially relevant to contemporary physics, rather than on a general coverage of physics. The determination to have the students take as little as possible for granted is manifest from the start by a discussion of the way in which we come in contact with the physical world—through the senses—and how we make measurements of time and space. (His wariness of the "obvious" is developed by such devices as discussing the fragility of Brobdingnags linearly scaled up from Gulliver.) This leads to measurements of motion involving both space and time (vectors and graphical differentiation and integration are introduced at this point).

Matter is considered next and the student is led to understand through discussion, problems, experiments, and films how we are forced to the conclusion that matter, which is to first appearance continuous, is actually "grainy" (made up of particles). The idea of a physical model as a mental construct useful in organizing our knowledge, in formulating new hypotheses, and in suggesting tests of such hypotheses is introduced and developed in connection with the molecular model of a gas. The notion of a model is carried further in a discussion of light, in which the particle model is not presented as a quaint delusion of Isaac Newton's but as a model that is quite serviceable for many purposes. The situations in which it does not seem to work are attacked from another direction after a preliminary discussion of the properties of waves in various media in which very effective use is made of the ripple tank. It is shown that the wave model succeeds in all classical situations, including those where the particle model fails.

Next, attention is turned to the causes of motion. With use of the essentially frictionless dry ice puck, other simple laboratory devices, and flash photography, the student is led to develop his intuition concerning the relationship of forces to motion and then the conservation of momentum and energy. After a treatment of electricity and magnetism, again approached through experimental observation, the student brings together his work in these subjects with his previous work on measurement, motion, the particulate nature of matter, light, waves, forces, the conservation principles, and physical model-making to look more closely at the atom. Filmed experiments on scattering of alpha particles by a gold foil lead into a discussion of the Rutherford model of the atom with its highly concentrated positively charged nucleus. The student is then led, here with liberal use of filmed experiments and demonstrations, to see how classical theory alone is unable to explain the frequency threshold of the photoelectric effect and how this phenomenon and others such as the existence of discrete spectral lines and the diffraction of electrons lead to a new model that unifies our view of matter and radiation. The fundamental break in going from classical to quantum theory is made clear, but so too is the way physicists proceeded from one to the other and how much the language and models of one were carried over into the other.

The PSSC course now consists of a textbook, a set of some fifty-five films carefully integrated with the text, a series of paperback monographs (described below), special laboratory experiments, inexpensive apparatus kits, a laboratory guide, special tests, and a rather comprehensive teacher's guide. PSSC is currently engaged in producing more films and monographs, in further research on testing, in the creation of a course in advanced topics for advanced-standing high school students and for liberal arts colleges, and in exploring the possibility of presenting selected material at an earlier level in the junior high school. Approximately one-fourth of the high school students in the United States who are enrolled in physics are taking the PSSC course.

Through a separate monograph series, the PSSC encourages students to explore paths branching off from the main course. Thus, students who wish can pursue technological interests in such monographs as *The Physics of Television*, *The Origin of Radar*, and *Heat Engines*. Some thirty of these monographs are now in existence and a like number of additional ones are under consideration, including ones covering such topics as the telephone, the electron tube, and synthetic polymers. The present close relationship of technology to physics is such that subjects such as masers cannot be said to belong exclusively in either category. Discussions are being held at the present time that may lead to the formation of a new group or groups to develop alternative approaches to high school physics. One direction that has had some discussion is a course in which the student is led into good physics through modern technology rather than as in the PSSC course previously described.

2

The Biological Sciences Curriculum Study (BSCS) was started in 1959 and is by far the most massive reform project concerned with secondary school biology. To date, more than 2,000 persons have contributed to the work of the BSCS. General policy for the BSCS is set by a twenty-seven member Steering Committee of biologists, biology teachers, supervisors, and other specialists.

The central BSCS effort has been preparation of three complete general biology courses for secondary schools which are called the Blue, Yellow, and Green Versions. Whereas traditional textbooks have all emphasized the organ and tissue phase of biology, the Blue Version emphasizes molecular biology, the Yellow Version deals mostly with the cellular level, and the Green Version emphasizes population-community ecology. Each version includes text, laboratory manuals, tests, and teachers' materials. In addition to these materials, the BSCS is involved in the production of: (*1*) *laboratory* blocks—each supplementary block requires a six-week period of class time during which the class devotes itself to a single problem-area in biology. A series of twelve blocks is planned, of which ten are now in experimental editions; (*2*) *biological investigations*—two volumes of biological investigations have been prepared for use by the more creative science students; (*3*) *second-level course*—a course to follow any of the versions of BSCS biology has been developed. It uses three laboratory blocks, with additional materials to tie the blocks together, and to stress the inquiry and controversy of science; (*4*) *pamphlet series*—discourses on various biology subjects are being issued currently. These pamphlets are suitable for the teacher, the motivated student, and the layman; (*5*) *bulletin series*—monographs on topics related to high school biology education are being issued periodically. Bulletin Number 1, *Biological Education in American Secondary Schools—1890–1960*, was prepared as a background for the writers of the BSCS High School Biology materials. Bulletin Number 2, *Teaching High School Biology—A Guide to Working with Potential Biologists*, is also available. Bulletin Number 3, in preparation, is addressed to administrators, and concerns administrative arrangements for teaching BSCS biology; (*6*) *films*—the BSCS has three film programs: a series of ten brief techniques films to assist the teacher in mastering new laboratory techniques, a series of brief "single-concept" films to supplement one version of BSCS biology in the classroom, and a series of "thematic films" for teacher-training purposes which is planned for future production to illustrate possible ways of teaching to convey the framework and basic themes in BSCS biology. In addition, the BSCS publishes a newsletter which is made available to program participants and other interested persons.

3

The Chemical Bond Approach Project (CBAP) is the older of the two major secondary school projects involved with this discipline. Among chemists the initial need for reform was perhaps a little less serious because a number of university chemists over the years have attempted to aid schools through the *Journal of Chemical Education*, by helping to review courses, and by other means. Nevertheless, in the summer of 1957, a group of chemists from colleges and secondary schools were encouraged by the American Chemical Society to look into the problem of improving secondary school courses in this subject. Out of this came the suggestion for a course which would stress fundamental principles, with chemical bonding as a central theme. A little pilot work the following year, a conference the following summer, and expanded school experimentation led to a 1959 writing conference at Reed College (Oregon) at which the CBAP put together a first version of textbook and laboratory program. After trials and revisions each year, a definitive, hardback version is available this year for use by secondary school students in the United States. Materials other than text and laboratory manual produced by the CBAP include a teacher's guide, special achievement tests for use with the course, a collection of supplementary readings for CBAP students from the *Journal of Chemical Education*, another collection from *Scientific American*, a chart of atomic and ionic radii, and a periodic newsletter concerned with project developments.

4

The Chemical Education Material Study (CHEMS), has conducted a project of somewhat greater magnitude than the one described above. The text, laboratory manual, teacher's guide, and motion pictures emphasize heavily the experimental approach to chemistry and the importance of laboratory work. This experimental emphasis has been used to develop the major concepts, such as dynamic equilibrium, rates and mechanisms of reactions, chemical bonding, structural ideas, and the systematics of chemistry in terms of the periodic table. The course tries to present chemistry from the point of view of a person intimately involved in the profession of chemistry, but in terms both interesting to and comprehensible by typical beginning students. Also produced by this group are some special wall charts and pieces of equipment for use with the other materials. Current films deal with kinetics of reactions, catalysis, equilibrium, ionization energy, vibration of molecules, molecular spectroscopy, synthesis of an organic compound, mechanics of an organic reaction, gases and how they combine, and chemical families. A number of additional films are also in various stages of planning or production.

5

In secondary school mathematics, a number of projects are under way. The School Mathematics Study Group (SMSG), the largest of the mathematics reform groups, has produced over a hundred volumes for school use since its inception in 1958. Most of the books are for use as tests in regular courses in grades 7–12 although a series of books for student and teacher use in grades 1–6 have also been produced. Nearly two million students are currently using materials produced by the SMSG. Another project, the Survey of Recent East European Literature in School and College Mathematics Project is accumulating a library of mathematics textbooks, books, periodicals, pamphlets, resourse materials, and syllibi that may be used at all levels from elementary through college. The major function of this group is the translation and adaptation of some of the best materials from East European sources. Another project, the University of Illinois Committee of School Mathematics, has been at work for over ten years. Support for continuation of its work has recently been given by the National Science Foundation. Materials have been produced for grades 9 through 12 and developmental work involves course materials for grades 7 and 8. In addition to specific course content improvement projects in mathematics, the National Science Foundation has supported a number of regional conferences to acquaint school administrators with a new curricula and the problems of conversion or adaptation involving these new materials.

Number of Students Using Materials Produced by Major Course Content Improvement Projects

| School year | 1958–59 | 1959–60 | 1960–61 | 1961–62 | 1962–63 | 1963–64 |
|---|---|---|---|---|---|---|
| School Mathematics Study Group | — | 23,000 | 173,000[a] | 626,000 | 1,222,000 | 1,801,000 |
| Physical Science Study Committee | 11,000 | 22,500 | 44,000[a] | 75,000 | 125,000 | 200,000 |
| Chemical Bond Approach Project | — | 800 | 4,000 | 10,000 | 18,000 | 25,000–30,000[a] |
| Chemical Education Material Study | — | — | 1,200 | 11,500 | 45,000 | 105,000[a] |
| Biological Science Curriculum Study | — | — | 14,000 | 52,000 | 95,000 | 250,000–300,000[a] |

[a] First year commercial editions became generally available.

The earth scientists have thus far undertaken somewhat more modest efforts, partly because they feel that their first step should be to prepare materials to be used in other science courses rather than to create specific geology, earth sciences, or meteorology courses. Earth science courses in the secondary schools of the nation had steadily declined in popularity for several decades prior to the recent renaissance in school science course content but have been the subject of several recent projects. With support from the National Science Foundation, the American Geological Institute has sponsored the generation of *The Geology and Earth Sciences Sourcebook for Elementary and Secondary Schools.* Other projects are involved in the production of (*1*) a comprehensive series of motion pictures, filmstrips, and slides on meteorology; (*2*) a series of monographs on such topics as satellites, planetary atmosphere, jetstream phenomena and climatology; and (*3*) a series of narrated filmstrips on oceanography.

The secondary school social sciences curricula are being explored by a number of projects, including: (*1*) a film series on archaeological salvage in the United States; (*2*) development of annotated bibliographies, tapes, films, museum facilities and other resources, by the Anthropology Curriculum Study Project; (*3*) the Study of Fundamental Processes in Education Project to explore promising directions for research in basic educational processes in the sciences; (*4*) regional conferences to acquaint school administrators with the new science curricula and their implications for school education.

Elementary school science and mathematics projects have derived from two major sources: (*1*) a downward extension of secondary school projects (secondary school projects, after initial development of materials are often further extended to develop improved materials for pre-secondary school use), and (*2*) independently conceived ideas for improving elementary school science. Efforts of Foundation-supported elementary school projects in mathematics range from the production of a film series for elementary school teacher education to the writing of texts for use by both students and teachers. One project is developing earth science materials for junior high school use, another is working on basic science for the first three grades in elementary schools. The PSSC project is developing materials for use in pre-high school grades. The Geometry Project is a large-scale experiment on the teaching of geometry in elementary schools, working primarily at the fourth- and fifth-grade levels. A television course developed by mathematicians at the University of Wisconsin has been kinescoped and made available for other educational television stations in the nation. One project is developing materials related to a program of algebra, arithmetic, and mathematical physics intended as a supplement to, rather than a replacement for, a standard arithmetic program. One elementary school project is involved in experimentation in finding how the learning experience should be planned so that a secure connection is achieved between the pupils' preconceptions of common-sense attitudes and the concepts that embody the modern scientific point of view. Coordinated science and mathematics for grades 1–9 is the goal of one project recently supported. Materials for the first three grades have been developed which emphasize the use of graph paper in order that the students will have a geometrical model of the real number system. Another project has produced student and teacher text and laboratory materials on astronomy and gravitation for elementary school use. Several other projects are in the early stages of the generation of materials for the whole of the elementary school science curriculum, including texts, graphic material, apparatus, and teacher-training programs.

National Science Foundation support of college and university course content improvement projects encompass both restricted and broadly conceived projects. As numbers of secondary level projects were initiated, various groups of college people became concerned that college science courses might not be sufficiently sophisticated to challenge the students coming from those shcools offering these "modernized" courses. Further, as numbers of college projects were initiated within specific disciplines, the scientific community became concerned with broadening bases of operation and a number of college "commissions" for specific scientific disciplines were initiated with the financial support of the Foundation. The first of these, the Commission on College Physics (CCP), was established in 1959 by the American Association of Physics Teachers, and is an independent *ad hoc* group of seventeen prominent physicists. The Commission of College Physics is dedicated to the improvement of undergraduate instruction in physics and, in this capacity, it collects information about physics teaching and experiments for its improvement, distributes this information to those whose activities may be affected by it, encourages new developments in course content, laboratory apparatus, and teaching aids. Approximately ten such college-level groups under varying titles have been instituted within recent years and include such areas of concern as chemistry, biology, geology, agriculture, and anthropology.

Social sciences at the college level are being studied by a number of groups including: (*1*) the Educational Resources in Anthropology Project, which has arranged the compilation of basic reference and test volumes for college use; (*2*) the Visual Anthropology—Motion Pictures as Applied to Research and Teaching Project, which is currently producing a number of films, mostly on primitive societies; (*3*) two projects concerned with the production of films on the cultures of the American Indian; (*4*) a broad study of the undergraduate curriculum in psychology; (*5*) a project created to produce a series of films on scientific developments in psychology; (*6*) a conference to explore the nature and purpose of undergraduate science for the non-science major.

College-level course content improvement projects in biology, supported by the National Science Foundation, include: (*1*) the development of a source book of laboratory exercises in plant pathology; (*2*) the compilation of a book of selected and tested laboratory experiments in general physiology; (*3*) a series of short films on microbiology; (*4*) the writing and revision of a new one-year course to serve as an introduction to modern biology; (*5*) a project working toward the development of a course in laboratory methodology and instrumentation; (*6*) two studies dealing with wood science and technology, one concerned with a survey of existing material and the other with the production of a film on wood-moisture relations; (*7*) a series of films on the life sciences; (*8*) a television course entitled *The New Biology;* (*9*) the development of a laboratory manual on experiments in elementary human physiology; and (*10*) films on developmental anatomy, plant science, and predatory-prey relationships.

Chemical education projects at the college level include: (*1*) supplementary teaching aids for introductory chemistry, (*2*) an experimental laboratory course in organic chemistry, (*3*) films for general introductory college chemistry, (*4*) two projects concerned with new approaches to the teaching and analytical chemistry, and (*5*) several conferences on the undergraduate training of chemists as well as the development of a chemistry course for non-science majors.

The college training of engineers has, as one might suspect, been the subject of numerous conferences which have been concerned with different aspects of aeronautical, ceramic, chemical, civil, electrical, materials, fluid, mechanical, sanitary, and solid mechanics engineering. Although projects are in varying stages of operation, a typical group of projects in a specific field of engineering might be concerned either singly or collectively with texts, laboratory work, films, and general undergraduate or graduate education with respect to that field.

College mathematics has been the subject of concern for over a dozen different course content improvement project efforts that range from such problems as the production of films or courses for the education of mathematics teachers to a coordinated program for mathematics and physics majors. The Committee on the Undergraduate Program in Mathematics has been particularly active in conducting surveys, publishing informational materials, the encouraging mathematicians to conduct specific projects. Computer applications in the atmospheric sciences at the college level have been studied by one project. A source book and text materials are planned for production by 1964.

College physics, like college mathematics, has been approached by a number of projects. Individual projects are concerned with a variety of facets of physics education and include the development of new approaches to introductory physics, including laboratory guides as well as special laboratory tests. Films and tests for different levels are being produced by several different groups.

It should be mentioned here that institutes (discussed in Section III of this paper) have influenced college curricula to some extent. As science teachers attended regular college classes (after having attended specialized institutes) they began to clamor for equally stimulating courses through the regular college curricula. Groups of professors on many campuses have responded with locally produced courses modeled after typical institutes.

In addition to the National Science Foundation, other federal agencies have supported, to a lesser extent, the development of science course content materials or materials useful in course content improvement. This support has ranged from the development of entire courses to the writing of supplementary material as aids for use by science instructors and students. The United States Office of Education is concerned with public education in its broadest sense. Under its Cooperative Research Division, a number of projects have been supported which deal with learning theory, science instruction, and the dissemination of information about studies conducted under the aegis of various groups and agencies. Consultative services to state and local educational systems are provided for either specific or general efforts at improving science instruction at the school level. The United States Office of Education also administers two programs for the support of state and local efforts to improve science education. The programs provide primarily for equipment acquisition but include provisions for support of supervisory personnel who make work toward the development of improved course content materials. The Atomic Energy Commission has, partly through the University Relations Division of its Oak Ridge Institute of Nuclear Studies (ORINS), done much to advance nuclear education, particularly at the college and university level. A few projects, however, have been supported which bear directly on secondary school atomic and nuclear science education.

Although federal agencies have afforded the most massive financial support for course content improvement in recent years, a number of public and private agencies have also been active in this area, sometimes in joint enterprises. A few of these activities will be described below. These agencies include private foundations, commercial enterprises, and state and local educational systems. Many of these agencies have also supported massive programs of implementation of reforms which will be discussed in Section III of this paper.

1

The Continental Classroom has presented television courses on a national network. These lessons have constituted full-year courses in chemistry, physics, biology, mathematics, and social science, directed primarily at school teachers. Academic credit was obtained through cooperation of colleges and universities across the nation. Some of these courses were later modified and filmed for use at the secondary school level as a cooperative effort by several agencies. An example is the chemistry course, consisting of a series of 160 filmed lessons. The film series was produced by Encyclopedia Britannica Films, Inc., through the support of the Foundation for the Advancement of Education and under the supervision of a committee appointed by the American Chemical Society.

2

The Ball State Teachers College Experimental Program is one example of an effort conducted essentially with no outside support that has been involved in production of course content improvement materials. Four new texts have been written which attempt to present mathematics as a structure in which the interrelationships between concepts become apparent. Experimental drafts of additional texts are being used this year at the Ball State Laboratory School, and it is expected that these will be published in 1963 and 1964, completing the series in grades 7 through 12.

3

The Ford Foundation has probably given as much support to the improvement of education in the sciences as any other private foundation but its support typifies much of the support given by others. Grants which have been made include: (*1*) one to the California Institute of Technology to update its course in college physics and initiate a new two-year required sequence of studies presenting a synthesis of modern and classical concepts, (*2*) a number of grants to support the initiation of school and college educational television stations, (*3*) grants for research in teacher education and the design of improved courses for teachers and students, (*4*) grants for comprehensive school improvement, including science education.

4

The development of programed instruction and the use of accompanying utilization devices or teaching machines has grown phenomenally in recent years. In 1960, there were forty companies with teaching machines on the market; in 1961, there were seventy. In February of 1962, there were 122 sequences of programed materials available for school use; by September of 1962, there were 187, with 440 being planned for future use. These materials range from brief, programed instructions on the use of the slide rule to complete courses involving thousands of frames. Machines developed for use with programs range from simple, twenty-dollar paper-roll tin boxes to complex closed-circuit television systems costing thousands of dollars which utilize computer-like devices to record answers and select appropriate alternative questions. Many devices and programs are now in various stages of testing and exploratory use. The direction their use will take will probably not begin to be clear for some years to come.

*Science Instructional Equipment*

In recent years, there literally has been an explosion in the field or science instructional equipment, particularly for the lower grades. Federal and private agencies, commercial enterprises, and private contributors have jointly and individually become involved in the development and generation of newly expanded laboratory and other instructional equipment.

As noted above, the Unites States Office of Education administers a program which provides for federal grants to state educational agencies to aid local educational groups to acquire laboratory or other special equipment for science and mathematics teaching in public schools. Over sixty million dollars are channeled annually through this program in the form of grants requiring state or local agencies to match the Federal funds on a dollar-for-dollar basis. The United States Office of Education also administers a national program for the utilization of government surplus commodities in science education.

Many of the pieces of equipment, movies, and supplementary resources which were originally developed by National Science Foundation-supported secondary school projects are used in traditional courses as aids. In addition, the Foundation's Science Teaching Equipment Development Program has made over one hundred fifty grants to scientists, engineers and mathematicians for the development of new instructional aids and equipment to be used at all levels. These projects range in scope from the design of a simple meter to the creation of computer systems and, in subject matter, from secondary school anthropometry to college zoology.

The National Science Foundation, in addition to its program of support for the development of prototypes of new equipment, supports a program of grants to colleges and university science departments for the purchase of undergraduate instructional equipment. These grants are limited to $25,000 for a single department and are made available on a matching basis. Plans are to make yearly grants totalling approximately twenty-five million dollars in this program.

The Atomic Energy Commission administers federal funds for a variety of efforts including the Oak Ridge Institute of Nuclear Studies. ORINS is administered through an affiliation of thirty-six colleges and universities and supports many educational projects in addition to the graduate studies program whereby students work and learn in the Oak Ridge National Laboratories. ORINS also supports a National Museum for Atomic Energy and a number of smaller mobile museum and laboratory units which are scheduled for appearances in schools and colleges across the nation.

With the advent of greatly increased support for the purchase of instructional equipment, there has been a corresponding change in commercial companies producing the equipment. Although some produce poorly designed and constructed equipment and sell it to uninformed school people, there is a greater diversity of good, reliable and useful instructional materials than ever before. Many large national companies that had previously not produced equipment for the educational market have entered the field through new subsidiaries.

Science museums have increased greatly in number in recent years. They range from highly technical ones for use in graduate instruction to small town or school museums where students' science projects are displayed. Outdoor museums, or living laboratories, are being utilized by many schools in the form of a small tract of land where flora and fauna are carefully preserved in their natural state for study and observation by students. A number of cities have built combination planetarium-science museums for use in conjunction with school work, both during and after regular school hours.

In many communities, a single industry is the predominant factor in community economics and employs most of the students who complete their education in the local schools. In such instances, many of these industries have furnished museums, displays and supplementary educational material which reflect the scientific applications pertinent to their particular businesses.

*Science Instructional Aids*

In many cases it is difficult to distinguish between aids and instructional equipment and course content materials. To supplement a regular course, many students and teachers may use certain books or pieces of apparatus which have been taken from another comprehensive course to sequences of courses. On the other hand, some complete courses have been developed by utilizing a large array of materials that, individually, were orginally designed to be used primarily as aids.

Commercial enterprises in the science-based industries have been producing free aids for science teachers in increasing quantities in recent years. Many have realized that their continued growth in a technological society depends largely on the scientific literacy of the average citizen.

Thus, a large life insurance company provides extensive free health education materials for school use, a large steel producer gives science teachers free demonstration and display kits and charts showing how steel is made, and a large manufacturer of agricultural chemicals provides free sets of booklets on agricultural chemistry. This practice has become so widespread that one enterprising group formed a successful educational service company which has no product except a yearly-revised book listing and describing free materials which are available to school teachers. Although some of the free materials made available by commercial agencies are poorly disguised advertising, many are excellent and constitute a real aid for the science teacher.

The greatly increased commercial production of equipment as a manufacturing enterprise was mentioned in the preceding portion of this paper. Such material, of course, includes all kinds of apparatus throughout the spectrum from science instructional equipment to ancillary aids. One heartening aspect of this commercial expansion is that, much more often than in previous years, successful teachers' ingenuity is the source of ideas for new devices as opposed to their being the product of a commercial design specialist.

Many industrial concerns, aware of their inability to give adequate aid directly, support the work of science educators in colleges, universities and professional organizations toward the development of supplemental aids for teachers. Through its Science Manpower Project, Columbia University, in association with some sixty teacher-training institutions and with financial support from some thirty leading industries and foundations of industries has produced and distributed monographs to guide teachers and administrators in the work of establishing substantial programs in elementary science, junior high science, biology, physics, and chemistry. The National Science Teachers Association, with the support of both government and industry, produced several series of supplemental books and pamphlets, which are made available at low cost to science teachers.

Although educational television programs have been mentioned previously, additional information should be included here. Many programs broadcast for us as regular course content improvement sequences are utilized on a part-time basis by teachers who want to show a particular lesson or program as supplemental to regular classroom work. In addition, more and more commercial sponsors are supporting Saturday and Sunday prime-time showing of productions intended for adult viewing on current science topics. Even Captain Kangaroo, a commercially sponsored, six-day-a-week early morning program, frequently includes a carefully planned daily lesson in science aimed at young children.

One remarkable development of the past ten years is the rapid growth in the numbers of college- and university-sponsored science education centers. Where ten years ago there were very likely less than a half dozen in the nation, there are now probably over thirty, and the number is still growing. A typical center might involve a science museum, science curriculum materials library, equipment and aids displays, regularly scheduled workshops for in-service science teachers and visits to the center by groups of students and teachers. The center would also constitute a regular part of the physical materials utilized in the preparation of preservice teachers. Some, at large state universities, receive support primarily through the state fiscal agency; others receive substantial support from nearby industries or private foundations, as well as from federal agencies. Some have a staff which regularly spends a portion of its time conducting in-service classes for science and mathematics teachers in nearby communities.

*The Extension of Activty*

In a way, this section on changing science curricula has dealt with the invention, development and testing of "ammunition" for use in the revolution in science education in the United States. No such mass of materials can be thought of as being successful to any great degree unless they are, after the research and development stage, widely utilized at the local level in schools across the nation. Such utilization may vary from outright adoption of the entire program to subtle or indirect effects on existing programs, and may involve students, teachers, administrators and even politicians at varying levels.

The following section will, at the other end of the spectrum, deal with the implementation of reform in the schools. Overlapping cannot be completely eliminated, and in fact in many instances is essential in order to portray cooperative aspects of the various forces involved in the reform movement.

## III. Implementation of Reform in Schools

The immediate test of reform in science teaching will be the extent to which it modifies and improves the factors which affect the learning of science by young people. The ultimate test will be the contribution that science makes to the advancement of civilization once these young people have become the producers and consumers of their generation.

This section of the paper will discuss the methods, processes, devices, and other means through which the resources for reform in science teaching discussed in Section II are being introduced into school programs. The discussion will be developed under the following sub-headings:

Overview
Programs for Implementing Reform
Programs to Prepare Personnel for Reform: The Institutes
Implementing Reforms in Aids to Instruction

*Overview*

During the century 1840–1940, science—either directly or through related technology—brought about a revolution in circumstances and conditions of living in man's relationship to nature and to the universe. Since 1940, the rate of change has been explosive. The mind of man has penetrated the nucleus of the cell and the nucleus of the atom, and man himself has loosened the bonds of gravitation and entered space.

The vistas of the conceptual sweep of modern science have been caught in the following quotation from Dr. Warren Weaver of the Alfred P. Sloane Foundation:

> ...we are just in the process of gaining a scientific picture of the total ascent of life. By far more vast and significant than the Darwinian view, this modern evolutionary doctrine begins with the elementary particles of the nuclear physicist and moves through the whole range of the atomic and molecular world up to the nucleic acids which, in their capacity to reproduce pattern and to pass on coded information, seem capable of forming the primitive basis for a living organism. From this point it is conceivable to move on to the gene, the chromosome, the cell, and ultimately human life. Whether or not man is the present climax of this ascent is itself now under question: we have radar-listening devices, directed at inconceivably distant parts of the cosmos, seeking to determine whether there are other and possibly more advanced beings there, trying to communicate with earth-bound man.
>
> When the sights are set as high as this, the view transcends all the compartments of science. This is not, in any exclusive sense, physics or biology or chemistry or astronomy. This is the whole of science, engaged with a problem of majestic dimensions.
>
> The sweep and the depth of such a view of matter, man, and the universe fairly suggest what science really is—not a trivial business of tricky hardware,

not the phony bubbling retorts of the advertisements, not strange men with white coats or beards, but the response, at once poetic and analytical, of man's creative mind to the challenge of the mystery of matter and life.

This then is an age of science and of technology. In many nations, the social and the cultural milieu are now influenced, if not largely determined, by forces whose causal elements are rooted in science and technology. Science is deeply involved with many of the major political, social, and economic issues facing the nations of the world today. Among these are: the expanding population; water and food for the world; dangerous pollution of air, soil, water, and plants from pesticides, nuclear fallout and chemical wastes; the control of weather; the conservation of natural resources, and many others. Nations aspiring to the well-being which science has brought to the more advanced nations, may, in the years ahead, face these and other science-related issues of even greater complexity.

### 1. Broad Purposes of Education in Science

The reform movement to improve the teaching of science in the schools of the Unites States has grown out of a deepening awareness on the part of many people of the basic role of science and technology in the present and future welfare and security of the free world. To safeguard these for the future, quality education in the sciences becomes imperative and mandatory.

To summarize, it would seem that the following purposes guide and motivate all phases of the reform movement in science teaching in the United States:

(*a*) To provide an education in science for all citizens that will insure a level of scientific literacy commensurate with the demands placed on the society by science and technology.

(*b*) To provide specialized education in science for those who will constitute the creative scientific and engineering manpower for the future.

(*c*) To provide full educational opportunities for the pursuit of science as a humane endeavor in a society in which it plays a significant role.

The movement to improve the teaching of science in the schools of the United States has been charted largely in terms of the broad purposes stated above. Implementation has been directed toward providing a supply or excellently educated scientists, engineers, technicians, and retrained workers, as well as toward raising the level of scientific literacy of all citizens.

### 2. The Public Understanding of Science

The public understanding of what science is, how it operates, and the circumstances which make it prosper, has become increasingly important as its influence in the lives of people has increased. As has been pointed out previously, science has become so heavily involved with major political and social issues of the day that for a citizen or his representative in government to vote with wisdom, there must be some understanding of science and the scientific enterprise. The citizen must understand science so that he can "use" its processes of inquiry, methods, and attitudes to help him make intelligent decisions in all aspects if living. In short, science needs to become more of a way of life with all people.

In recent years in the United States, the major source of financial support for science has passed from private foundations and industry to governmental agencies both state and federal. The ultimate control of these agencies lies in the hands of the citizen and his elected representative. Thus, for another vital reason, the citizen's understanding of science must be secured and nurtured.

The need for public understanding of the motives and purposes of the scientific endeavor has been pointed out by C. P. Snow in his book, *The Two Cultures and the*

*Scientific Revolution.* A serious gulf has opened between the intellectual outlook of some of the scientists and the outlooks, beliefs, attitudes, and activities of such other segments of our culture as creative artists, humanists, educators, ministers, and others. On the other hand, many scientists and humanists are deeply sensitive to and concerned with the cultural impact of science and the maintenance of balance in all programs of education. The basic reason for understanding among these people has been well stated by Dr. Warren Weaver:

> All citizens would be given a richer inner life if they could have a chance to appreciate the true nature of science and the scientific attitude.
>
> For science is not technology, it is not gadgetry, it is not some mysterious cult, it is not a great mechanical monster. Science is an adventure of the human spirit. It is an essentially artistic enterprise, stimulated largely by curiosity, served largely by disciplined imagination, and based largely on faith in the reasonableness, order, and beauty of the universe of which man is a part.

### 3. Providing Science Manpower

The basic elements upon which estimates of the scientific manpower needs of the United States are based lie well within the scope of our national welfare and security. The United States, like the nations of western Europe, has sustained an economic progress that is based on the unprecedented rate of growth of scientific research and development since World War II. This progress has occurred in the face of an expanding population, increased competition in world trade, and higher living standards, all of which have demanded further developments. During this transition to a technologically based society, the scientifically literate as well as the scientifically illiterate have called for advancement in the field of medicine. Problems in chronic disease, disability, mental health, aging, and environmental health have been and will continue to receive increased attention.

The world has witnessed apprehensively the extensive and sophisticated research and development for military purposes. Further demands on the science manpower pool of resources have been made by the complex nature of space exploration and the advances in the uses of atomic energy.

Educational institutions in the United States have felt a shortage of qualified instructors in certain fields of science and engineering due to the attractive salaries available from industry. This problem is becoming acute as the postwar population bulge enters college. It was not long ago that management in industry and government relied mainly on people trained, or with experience, in business, law, or finance. Today, with developments in science and technology changing the shape of industry and government, and with the policies of industry and government affecting the course of science and technology, management has demanded its share of people trained in science and engineering. These problems, among others, have brought about national challenges; challenges that create urgent and accelerating requirements for a scientific and technical manpower. Further information on manpower needs is contained in the supplementary paper distributed to conference participants.

### 4. Elements Basic to Reform in Education

The structure of the educational enterprise in the United States is complex and often difficult to understand for people outside the country. Since an understanding of the responsibility, the structure, and the operation of public education is so basic to understanding any reform movements, a quotation has been taken from a 1960 U. S. Office of Education publication entitled *Education in the United States of America* and included in the supplementary paper distributed to conference participants. (If the reader is not familiar with the structure of education in the United States he may wish to stop at this point and refer to this paper.)

Rather than one national ministry of education in the United States, there are, in essence, fifty ministries of education. Although each state has the responsibility for providing educational opportunities and facilities for its citizens, many regional and national organizations have some direct influence on the actual educational programs.

It would seem that by having fifty autonomous state departments of education there would be a great diversity of educational facilities, programs, and opportunities. True, there are differences but they are more regional than state in nature and are more in degree than in kind. The striking aspect of the fifty educational systems of the United States is their similarity.

Some of the reasons of this similarity may be: (*a*) the great mobility of the people, (*b*) the efficient communications and mass media systems, (*c*) the similarity of the commercial textbooks that are used by the schools, (*d*) the likeness of the higher educational institutions that train the public administrators and teachers, and (*e*) the lack of great cultural and social differences among all the people of the United States.

Contrary to the idea (that some people have to operate under a single ministry of education at the national level) that such division of control of education in the United States is ineffective and results in a poor educational system, is the fact that such a diverse system is best suited for our pluralistic society. Modern innovations, based on research, can be inplemented without gaining federal approval. Regional geographic differences can be considered by an individual state in planning its program. And, the educational goals of the school system include not only state and regional goals, but also national and individual goals.

This diverse system of educational programs, controlled by the States, is felt to be a strong factor for continued progress in education in the United States.

### *Programs for Implementing Reform*

The multiplicity and variety of patterns in the programs which have been utilized for implementing reform in school science have made some compromise necessary in the organization of this portion of the paper. The many programs of reform are presented under categories of supporting agencies and organizations.

Some compromise with available space in the paper has also been made necessary because of the numbers of these programs. Programs of major importance from the following agencies are discussed: the federal government; state and local school systems; professional organizations; private foundations; colleges and universities; industry, and miscellaneous programs.

The broad areas of providing personnel for reform, institutes, and reform in aids to teaching are so specialized and involved that for purposes of clarity, each has been treated in a separate part at the end of this section.

1. Statistical Factors Related to Reform

**(a) School Districts and Types of Schools.** The matter of effecting reform in education is not only inhibited by the very nature of the structure of the total educational enterprise in the United States, but also by such factors as the large number of local school districts, the variety of size and type of secondary schools, and the prodigious numbers of young people who must be accommodated.

Despite a steady trend toward consolidation of small school districts, estimates made in 1961–62 indicate that there are still about 35,000 public school districts in the United States. Within these 35,500 school districts, there were about 25,000 public high schools. Of these 25,000 secondary schools nearly 9,500 had enrollments under 200 pupils: nearly 15,000 had enrollments between 200 and 2,499 pupils, and about 200 had enrollments of over 2,500.

The median size high school in the United States in 1958–59 was reported as enrolling 278 students. This same report indicated that:

The number of extremely small secondary schools (1–199 pupils) has been declining steadily; the number of extremely large secondary schools (enrolling 2,500 or more pupils) has remained about stationary at less than one percent of the total. At the same time, the number of schools of a more desirable size (200–2499 pupils) has increased sharply.[1]

It is interesting to note and of considerable importance in implementing reform measures in the public schools, that as late as five years ago 39.1% of all secondary schools in the United States had enrollments of 100 to 199 pupils.

**(b) Teaching Loads of Science Teachers.** The factor of teaching load of science teachers is probably influential in the implementation of reforms in science teaching. In the fall of 1961, there were 103,666 science teachers in public secondary schools (grades 7–12) in the United States who were teaching one or more science classes per day. These were distributed as follows among the various types of high schools: 24.4% were in junior high schools; 37.2% in junior-senior high schools; 9.9% in senior high schools; and 28.5% in regular four-year high schools.

Junior-senior high schools had the largest number of full-time science teachers. Of the 64,951 full-time science teachers in the fall of 1961: 26.2% were in junior high schools; 34.3% in junior-senior high schools; 12.6% in senior high schools; and 26.9% in four-year high schools.

Junior-senior high schools also had the largest number of teachers with two or three science classes a day. Of the 23,334 teachers in that category: 21.6% were in junior high schools; 38.0% in junior-senior high schools; 6.8% in senior high schools; and 33.7% in four-year high schools.

In fact, junior-senior high schools led in all categories of number of classes per day—partly, no doubt, because they included both upper and lower levels of pupils. Of the 15,381 teachers who were teaching only one class: 20.9% were in junior high schools; 48.1% in junior-senior high schools; 3.5% in senior high schools; and 27.5% in four-year high schools.

Judging by the percentage of teachers in each type of high school who were new to the schools in which they were teaching, turnover among science teachers was greatest in the four-year and smallest in the senior high schools.

Inexperienced science teachers were least likely to be found in senior high schools, where only one in fourteen was inexperienced. In each of the other three types of schools, the ratio was about one in eight.

Teachers who were teaching both mathematics and science appeared most often in the junior-senior high school, where approximately one in four was teaching in both fields. At the other end of the scale was the senior high school, where the ratio was only one in nine.[2]

### 2. Resources Available for Reform in School Science

Any attempt to implement reform would be futile without excellent resources with which to work. The production of the resources by the various curriculum improvement groups supported by the National Science Foundation has been discussed earlier. Such other material and personnel resources as have been made available through government agencies, professional organizations, private foundations, science-based industries, and others will be discussed in some detail in a later section of the paper. At this point, resources are mentioned only as one of the essential factors in the implementation of reform in school science programs.

### 3. Emphasis on Quality and Excellence

In implementing reform in science education in the United States, there has been a strong emphasis on reform to get a product of excellence from the secondary schools. This emphasis has necessitated first a re-examination of some of the elements that constitute quality and then an attempt to find the weaknesses in the traditional materials and procedures which failed to reach the newly defined standards of quality and excellence.

There seems to be fairly general agreement among the scientists and school personnel who have produced the new resources for reform that the older view of merely purveying information *about* science is no longer acceptable. There is evidence to indicate that today the widely accepted view that science at all levels must be learned firsthand, and that its *process* element is as important as its *product* element. It seems reasonable to believe that to reach the level of quality and excellence desired, the pupil must have continuous opportunity in the classroom to practice the intellectual skills associated with the various processes of inquiry in order to conceptualize the content of science.

The growing concern of those responsible for producing new resources for reform in science teaching with an emphasis on the process element of education has resulted in an elevation of laboratory or practical work to a new level of importance in science teaching. Some of the older recipe-following procedures formerly used in laboratory teaching have given way to a newer emphasis on open-ended problems whereby the student goes into the science laboratory with a problem which challenges his interest perhaps more than verifying the specific heat of lead or the coefficient of linear expansion of brass as in an earlier day.

Few directions are given the student. He is expected to propose reasonable hypotheses and then proceed to design and carry out a controlled experiment to test his belief. As this investigation develops, the teacher may ask the student to state the assumptions which lie back of any inferences he has made and perhaps to repeat the experiment under other suggested conditions. The results of the experiment may be inconclusive and may lead to further experimentation.

Without further elaboration on classroom techniques, it is evident that such an emphasis on firsthand experimental work demands that laboratory time be flexible. It is also evident that if time is to be provided to propose and test hypotheses, to go perhaps down a blind alley to a dead end and then back out to take a fresh look and make a new approach, the old ground-to-be-covered concept has to be modified, or more time provided for the laboratory study of science.

Both of these elements are involved in reform in science teaching in the United States. In a very few places, the specialized sciences in the high school have been given increased time. In one city, classes in biology, chemistry, and physics now have two class hours per day or ten hours per week. In the majority of science classes, the time factor has been met by teaching fewer science concepts in greater depth.

### 4. The Role of the Teacher in Implementing Reform

The reform movement in science in the United States was confronted at the outset with the problem of up-dating and improving the background preparation of the teachers of secondary science. In 1953, some of the first supplementary training programs for secondary school science teachers were started with support by the National Science Foundation. This endeavor, easily one of the most important factors in the implementation of reform in school science, and other efforts to improve the quality of science teaching, are so indispensable that they will be discussed in greater detail later.

Today, as never before in the United States, education is being overwhelmed with new aids to instruction. Teaching by television, by programed learning, by teaching machine, and a myriad of audiovisual devices has flooded the educational market. As long as these newer devices and techniques are kept in their proper and subsidiary role of means to the end of education rather than being elevated to the priority of ends, many of them are useful to trained and resourceful teachers.

It is important to note that such aids to instruction are important in the implementation of reform in science teaching only as they aid the teacher. The teacher remains the dominant and essential element in bringing about reform in science teaching.

5. Local Action—the Key to Reform

United States Commissioner of Education Francis Keppel remarked in a recent address:

> We must recognize first of all that the quality of education depends upon what happens to individual students in individual classrooms, and that the actual improvement of our schools is initiated and supported through local action and as a result of individual attitudes. At the same time, we must recognize that the educational enterprise is a public trust and a public responsibility, and that the answer to finding ways to finance its improvement lies in concerted public action. In private institutions as well as in public ones, this concerted action is a composite of individual concern, individual effort, and individual action.

Reform movements which have made lasting impact on public education in the United States usually have been closely associated with the local schools. The production of courses of study in science is one example.

Practically every state in the United States has produced a course of study or study guide for each of the high school sciences. Many also have courses of study for the junior high school and for the elementary schools. In many school districts of a state, especially those comprising small towns and rural areas, the state course of study in science is used as a guide to instruction.

On the other hand, in urban and suburban areas and in consolidated school districts it is common practice to use local courses of study or curriculum guides in science and other fields. These guides are usually prepared by selected teachers working as a committee with a local supervisor or curriculum consultant. In such cases, the state guide may be used as a model or the endeavor may be carried out quite independently.

The various curriculum improvement programs in science and mathematics which have been developed in recent years with support from the National Science Foundation have been concerned about involving science teachers and supervisors from the various subject matter areas in the original writing, as well as in subsequent revisions.

While models and guide lines for various reform movements may be produced by groups of experts, such endeavors make an impact only as they are accepted by local school administrators, supervisors, and teachers, finally modifying the day-to-day classroom activities of the teacher.

6. Starting Action Programs of Reform at the Local Level

The discussions of this section up to this point have dealt with some of the important elements involved in the implementation of reform in science teaching. With many fine resources available, with better trained teachers in the schools, there are still formidable problems which must be overcome before a reform movement can take root and flourish at the local level.

One such element is inertia, a resistance to change. Often this is a fear of the new or a fear of costs on the part of the local board of education; fears which may be reflected in the reactions of the school superintendent and the school principals. Before a reform movement can be initiated in any school district in the United States, the superintendent and the board of education must approve the project and then it must be accepted by the school principals and the teachers.

The National Science Foundation in 1962 provided more than one hundred thousand dollars for the purpose of holding nine regional conferences over the United States for school administrators. The purpose of these conferences was to acquaint these school men with the new curriculum materials in secondary school science. Each of these conferences lasted two days. They were addressed by some of the scientists who had worked in the production of the new courses, by science education specialists, and by teachers who had taught the various courses. These conferences were greatly appreciated by the superintendents, many of whom returned to their local areas and encouraged others to become acquainted with these new developments.

Lasting improvement in science teaching requires a broad acceptance among the parents and other people of a community, and must also be concerned with all aspects of the science program, rather than with just one aspect of reform. Instituting a new and improved course in chemistry will not be worthwhile unless the teacher has had his science background updated and improved to the point where he can teach the course effectively to students. The teacher, even though updated, will not be able to do the job unless he has adequate facilities, equipment, materials, and other aids.

The crux of the problem of getting reform programs initiated at the local level is to find ways of catalyzing all of the available resources, both material and personnel, into a long-range plan of action. One such plan is discussed later in this paper (the STEPS program) along with others which have proved to be most effective.

### 7. Long-Range Planning Essential to Reform

The experience of the past few years with improving science teaching in the United States has indicated that if the purposes of scientific manpower and public understanding of science are to be fully met, spasmodic efforts at reform are unsatisfactory. With the accelerated pace of the discovery of new knowledge moving forward exponentially, it becomes imperative that long-range plans be made. These plans must include continuing programs for the revision and updating of course materials as well as for the periodic updating of teaching personnel, classroom and laboratory techniques, and aids to instruction. Unless long-range planning is effected and continuous updating is built into the budgets of school districts, it will only be a very short span of time until much of what we now have and know will become obsolete.

In this section, some of the essential factors in the implementation of reform in science teaching have been discussed. In the next section, which constitutes the body of Part III, the great number and variety of patterns and programs used for carrying out reform programs will be discussed.

### 8. Programs Supported by the Federal Government

Most of the departments and several of the independent agencies of the federal government support programs which in one way or another promote the better teaching of science and implement reform in the schools. In some agencies the program consists only in the production of science-related bulletins while in others the program may be one that projects more directly into the classroom. Space limitations preclude the mention of all programs. Those selected are unique in the implementation of reform in the school science program.

**(a) The National Science Foundation.** This agency supports a wide variety of programs in secondary school science including such fields as anthropology, biology, chemistry, earth sciences, mathematics, meteorology, and physics. The programs in these fields vary widely. Some of particular interest are encouraged through the following sections of the National Science Foundation:

(*1*) The Fellowship Section is responsible for the administration of support to graduate students, teachers, and advanced scholars in science, mathematics, and engineering according to plans designed to meet the education needs of individuals. Additional information about fellowships and other supplemental training programs for secondary school teachers is given later in this section.

(*2*) The Institutes Section is responsible for the administration of programs of group study, primarily for teachers of science, mathematics, and engineering directed toward the improvement of science education. These programs are discussed in greater detail in a later part of the paper.

(*3*) The Special Projects in Science Education Section (SPISE) is responsible for experimental testing and development of promising new ideas for improving instruction in science and increasing the understanding of science, mathematics and engineering on the part of young people. Activities include:

- Programs for Secondary School Students
  - Summer Science Training for Secondary School Students
  - Cooperative College-School Science
  - State Academies of Science
  - Holiday Science Lectures
  - Visiting Scientists (Secondary Schools)
  - Supplementary Science Projects for Students
  - Research Participation and Scientific Activities for Teachers
  - Research Participation for College and High School Teachers
  - Supplementary Training for Science Teachers
  - Visiting Scientist Lecture Programs
- Undergraduate Science Education Programs
  - Undergraduate Research Participation and Independent Study
  - Undergraduate Instructional Scientific Equipment
  - Specialized Advanced Science Education Projects
  - Advanced Science Seminars
  - Inter-institutional Associations
  - Public Understanding of Science
  - Science Education Developmental Projects

(*4*) The Course Content Improvement Section projects were discussed in some detail in Part II of this paper.

**(b) The U. S. Department of Health, Education, and Welfare.**

(*1*) The United States Office of Education under the National Defense Education Act provides money on a matching fund basis to provide science consultants in each state department of education. Prior to the enactment of this law in 1958, there were fewer than five state level science supervisors. At present there are more than seventy-five. Under this Act, money is provided to schools on a matching fund basis for minor remodeling of science laboratories and for the purchase of equipment. Funds are also supplied for producing films and other aids to instruction.

(*2*) The STEPS Program (Science Teaching—Exploring for Excellence—Program Steps) is also supported by the U. S. Office of Education. The main purpose of this program is to assist state and local school systems and colleges to organize and utilize available resources in a continuing program for improving science teaching. This program is discussed in detail later in this section.

(*3*) The National Institutes of Health make grants of money to professional organizations for a variety of projects directed toward improving science teaching in the schools. Among these are such projects as film production, awards programs, grants for teacher and student research. These institutes also maintain a program of summer employment in laboratories for high school students with career interests in science.

**(c) The National Aeronautics and Space Administration.** Commonly referred to as NASA, this agency of the Government provides funds for a variety of programs which aid reform in science teaching. Among these are conferences of state supervisors of science, in-service institutes for teachers of elementary science, production of films and the preparation of paperback books on space-related topics. NASA also supports a program which includes about thirty-five "spacemobile" units over much of the nation. These units consist of two lecturers and a truck-load of equipment to demonstrate space science principles. These programs are presented to school assemblies, science classes, and other audiences.

**(d) The Atomic Energy Commission.** This agency contributes to school reform in science through the following types of programs: institutes for science teachers in radiation biology supported jointly with the National Science Foundation; the conducting of institutes in nuclear science for teachers; the provision of traveling museums; the production of films; and, the preparation and distribution of publications on atomic energy. In addition, the Oak Ridge Institute of Nuclear Studies is administered through an affiliation of thirty-six colleges and universities and supports many educational projects in addition to the graduate studies program whereby students work and learn in the Oak Ridge National Laboratories. ORINS also supports a National Museum for Atomic Energy and a number of smaller mobile museum and laboratory units which are scheduled for appearance in schools and colleges across the nation.

## 9. Programs Supported by State and Local School Systems

Many states and many more local school systems in the United States have initiated and supported programs which have aided reform in science teaching. Because of space limitations, it has been necessary to select a few representative endeavors in a few states and a few local areas.

**(a) State Departments of Education.**

(*1*) *Colorado.* A mobile and fully equipped classroom for in-service science institutes for elementary teachers has been used for several years.

(*2*) *Florida.* Under the leadership of The Florida State University and with support from the National Science Foundation, 280 high school physics teachers were retrained in P.S.S.C. physics in one school year through in-service institutes held in all parts of the state. Ninety percent of the pupils studying physics in the state are enrolled in P.S.S.C. The State Department of Education cooperates with the United States Office of Education in supporting four STEPS projects over the state.

(*3*) *Georgia.* The State Department of Education with assistance from the National Defense Education Act supports one senior supervisor of science and four regional supervisors. Each of these has one region of the state in which he serves as a resource person to upgrade science teaching at all levels. Each regional supervisor has a station wagon in which he carries many aids to teachers. This state also has a program of Science Youth Congresses in cooperation with the U. S. Office of Education.

(*4*) *Indiana.* The State Department of Education has completed a state-wide organization for a comprehensive STEPS progam in cooperation with state universities, regional colleges, and selected local school systems. A program of Science Youth Congresses is being developed in cooperation with the U. S. Office of Education.

(*5*) *Maine.* The National Aeronautics and Space Agency is supporting a state-wide program of upgrading elementary school teachers of science. In cooperation with the State Department of Education and four regional colleges, in-service institutes are being held in each of the four regions as the first step in a state-wide STEPS program. The institutes are conducted by qualified secondary school teachers in the areas of earth-space, biological and physical science.

(*6*) *Missouri.* With funds from the National Defense Education Act, the State Department of Education has employed several consultants in science and mathematics who go about the state on planned schedules conducting in-service institutes in these subjects.

(7) *Oklahoma.* The State University in cooperation with twelve regional colleges in seven adjacent states, is planning a program of institutes for upgrading teachers of elementary and junior high school science. The institutes, to be taught by secondary school science teachers, will be the second phase of the long-range program of improvement.

(8) *Pennsylvania.* Under leadership from the State Department of Education and in cooperation with well-qualified scientists, this state has produced a complete course of study in earth science as well as some unique curriculum materials for elementary science. Presently a long-range program of local curriculum improvement is bieng initiated as a part of a STEPS program in cooperation with the U. S. Office of Education.

**(b) Local School Systems.**

(1) *Baltimore County, Maryland.* This county school system, under the leadership of a science supervisor, has prepared some modern curriculum guides for various high school science courses. The guides are prepared by committees of teachers, tried out, and then revised. The teachers also engage in building a considerable portion of the equipment to be used for the course.

(2) *New York City.* This is one of the largest school districts in the nation in terms of students enrolled and numbers of teachers employed. Significant progress has been made under the leadership of a Director of Science with several area supervisors for elementary, junior high and senior high school levels. Among several specialized high schools in the city is the Bronx High School of Science, one of the finest in the country. The facilities, equipment, and materials of this school are distinctive and the instruction in all subjects at a level much above the average in secondary schools over the nation. New York City has produced local curriculum guides in the typical science courses of outstanding quality and has produced unique guides in some highly specialized areas such as nuclear energy.

(3) *Portland, Oregon.* Under the leadership of a city supervisor of science, Portland has developed a course of study in elementary and junior high school science. The program is enriched through the use made of a city-owned science museum, zoological garden, and arboretum. These facilities are on adjacent parcels of land readily accessible for field excursions.

### 10. Programs Supported by Professional Organizations

In the United States, there are many professional scientific organizations and societies. The largest and parent body of many of the organizations is the American Association for the Advancement of Science which has a current membership of over 80,000. The professional scientific organizations are increasing in number as new specialties emerge.

Many of the professional scientific organizations support educational programs and maintain an education officer to carry out the program. These organizations, together with several professional societies related specifically to science teaching, are important factors in implementing change in school science programs.

While it is not possible to detail here the program of each organization, representative aspects of some of the principal ones related to the purposes of this paper can be outlined. "Aids and Sources for the Science Teacher," a booklet distributed to conference participants, contains similar information about a number of additional organizations.

**(a) The American Association for the Advancement of Science.** This Association maintains a secretary for science and mathematics teaching as well as a standing committee on the teaching of these two subjects. The following types of activities are sponsored: (1) nationwide science teaching improvement programs, (2) cooperative programs with states to raise teacher certification standards in science and mathematics, (3) experimental programs to improve course content in science and mathematics, (4) a program to set standards of college requirements for different types of teachers of science and mathematics, (5) nationwide programs to inform school administrators of new source materials in science and mathematics, and (6) conferences in cooperation with teacher education agencies to promote the upgrading of courses for science and mathematics teachers.

**(b) The National Research Council–National Academy of Science.** This is a nongovernmental agency which is advisory to the Federal Government. It carries out the following activities: (1) administers programs and publishes reports for the improvement of various phases of science teaching, such as the laboratory, (2) conducts conferences of specialized groups on broad issues of education, such as teaching and learning, (3) promotes research in pure and applied science, (4) publishes materials on the organization of science and scientific research over the world, (5) sponsors the production of aids to science teaching from programs such as the International Geophysical Year, (6) maintains an advisory board on education made up largely of scientists, (7) administers funds from various sources to promote improvements in science education, and, (8) stimulates improvement in educational television and audio-visual aids.

**(c) The National Science Teachers Association.** This Association is affiliated with the American Association for the Advancement of Science and the National Educational Association. Such activities are carried on as: (1) the publication of magazines for elementary and secondary school teachers of science, (2) a packet service of professional and industrial publications to science teachers, (3) conducting nationwide youth activities programs, (4) holding conferences on problems and issues, (5) sponsoring projects for curriculum improvement, and (6) sponsoring the publication of paperback books on science.

**(d) National Association for Research in Science Teaching.** This group carries out such activities as: (1) preparing and publishing, in cooperation with the United States Office of Education, a biennial survey and analysis of science education research, (2) publishing a journal devoted to research in science education, (3) stimulating and encouraging centers for science education research, and (4) sponsoring and carrying out the production of ten-year digests of research in science teaching.

**(e) The Association for the Education of Teachers of Science.** This Association seeks to: (1) raise professional standards for science teachers, (2) promote improvement in teacher education in science, (3) improve methods and techniques of teacher education, (4) promote research on aspects of science teacher education, and (5) cooperate with other national and international groups interested in teacher education in science.

### 11. Programs Supported by Private Foundations

In the United States several philanthropic foundations have been established for the purpose of making grants to promote public welfare in a variety of ways. The support of educational programs is one of the channels through which money is distributed. The programs of some of these private foundations have been effective in promoting reform in school science programs.

(a) *The Carnegie Foundation* has made money available for such programs as: (1) The Commission on Mathematics at the University of Illinois, (2) work at the University of Maryland on secondary school mathematics, (3) the carrying out of learning studies in science and mathematics at Princeton University, (4) the Science Teaching Improvement Program (STIP) for six years under the American

Association for the Advancement of Science, and, (*5*) the development of courses in physical science for secondary schools at Harvard University.

(b) *The Ford Foundation*, in addition to grants for materials referred to in Section II, has made a number of grants-to-aid in the implementation of reform in science teaching such as: (*1*) grants to public school systems to install experimental educational television equipment and programs, (*2*) grants to a selected nation to establish a science high school and inaugurate a program to train scientific manpower for the future, (*3*) grants to more than forty colleges and universities to establish fifty-year Master of Arts in Teaching programs to improve teacher education in all areas of the curriculum.

(c) *Other foundations.* There are a number of other private philanthropic foundations which in one way or another have supported programs that have been directed toward reform in science teaching. Among these are the Cottrell Foundation, which has made grants to small liberal arts colleges for the purchase of science equipment, and the Mott Foundation which has done much in the support of science teaching in the public schools of Flint, Mich.

12. Programs of Colleges and Universities

Many public and private colleges in the United States have provided leadership, consultative services, and action programs which have greatly implemented reform in school science programs. There is a movement throughout the country toward establishing science teaching centers in colleges and universities which is unique.

**(a) The Advanced Placement Program.** This program is operated by the College Entrance Examination Board. It has the following basic purposes: (*1*) to encourage secondary schools to offer college-level courses for their best students, (*2*) to provide course descriptions for the use of teachers, (*3*) to prepare and administer examinations based on the course, (*4*) to encourage colleges to give advanced placement to successful candidates. Established in 1956 when 104 high schools prepared 1229 students who took 2199 examinations, and went to 130 colleges, the program has expanded so that in 1961, 1126 schools prepared 13,283 students who took 17,603 examinations, with 617 colleges cooperating.

**(b) The Science Manpower Project.** Many industrial concerns, aware of their inability to give adequate aid directly to colleges and universities, often support programs established by science educators and professional organizations. One such example is the Science Manpower Project at Columbia University, in New York City. Under the leadership of the science education department at that institution, with the collaboration of some sixty teacher education institutions and financial support from more than thirty industries, a program has been established to improve the teaching of secondary school science. Studies have been carried out and several monographs have been prepared.

**(c) The Master of Arts in Teaching.** More than six years ago the Ford Foundation made grants of money to forty colleges and universities to establish this program in the interest of reformed teacher education. Universities and colleges have begun to assert leadership in setting standards for teachers and working cooperatively with school systems attempting to develop higher standards of achievement.

At present, the Ford Foundation programs are largely five-year programs for preservice education of teachers. A typical prospective teacher pursues a liberal art course to the baccalaureate degree. In the fifth year, some graduate work is taken in addition to courses in education. In some colleges and universities the prospective teacher of perhaps two, replace a permanent teacher in a cooperating school system. This teacher is then free to pursue graduate work or to assume other responsibilities in the school system.

When MAT graduates go into a school system, they serve as sources of new ideas for teaching methods and subject matter. They also serve as liaison between the colleges and the school system thus bringing about a desirable closer relation between the academic fraternity and the public school systems. The MAT program of the Ford Foundation is representative of a very broad and active movement in many colleges and universities across the country to improve the preservice education of teachers in all fields.

**(d) The Science Teaching Center Movement.** The rapid increase in the number of science teaching centers has been mentioned in Section II of this paper. A few selected centers will be mentioned to illustrate the different ways in which various centers implement the current program:

*Ohio State University.* This is one of the oldest centers. Here both undergraduate and graduate students pursuing advanced degrees have courses, seminars, and institutes designed for their specific needs. Facilities, equipment, materials, and publications have been provided for the teacher to become familiar with all of the practical aspects of teaching. In this and other centers much is being done to improve research in science teaching. At Ohio State, some progress has been made in getting special subject matter courses for teacher similar to premedical and pre-engineering courses.

*Michigan State University.* This is one of the first to be established. This center has the responsibility for all special education courses in science for the University, as well as a new design for the graduate program. This center is one that gives wide service to the public schools of the state.

*The University of Texas.* This center is one of the newer centers but is growing very rapidly. Three basic purposes motivate the program: (*1*) research in science education, (*2*) preparation of teachers, (*3*) services to teachers in the field. One of the significant contributions made is in the area of curriculum development. The Director of the Center has been deeply involved with the BSCS curriculum improvement program and has prepared a considerable amount of laboratory material at the Center.

*The University of Maryland.* The University of Maryland set up a science teaching center as a source of materials on course content, laboratory equipment, and testing for the teaching and training of science teachers. The teaching center provides information about new course content developments in science teaching for a science teaching commission of the American Association for the Advancement of Science and reviews new science materials for the National Science Teachers Association. A program of field services is also provided.

Other centers which have made significant contributions toward reform in secondary school science are Oregon State University, Florida State University, Stanford University, Cornell University, Columbia University, Harvard University, New York University, and many more.

### 13. Regional Planning for Improving Science Teaching

In a few places rather large regional plans are being developed for the improvement of education in general and science education in particular. Factors motivating such movements are the similarity of types of schools, the likeness of problems, and reduced costs from cooperative efforts. These endeavors are in some cases initiated by a group of state departments of education banding together and in other cases by some major university in a region providing cooperative leadership with several state departments of education, a satellite group of small colleges, and secondary school personnel from the region.

Several state departments of education in the Rocky Mountain area of the United States have formed a regional planning and administrative group with a director and headquarters in Denver, Colo. They will seek to improve teaching in all areas of the curriculum.

Another group of colleges, local communities, and state departments of education from seven states have begun planning a long-range improvement in the teaching of science in the elementary school under the leadership provided at Oklahoma State University. This project has been described previously in this paper.

The Florida State University in serving as the hub of a project involving colleges and local schools in the southern part of the United States. The purpose of this project is to upgrade the teaching of science in the junior high schools.

14. Programs Supported by Industry

Industry, and especially science-based industry, supports many programs which are effective in implementing reform in school science programs in the United States. The National Science Teachers Association maintains a Business–Industry Section which works closely with other phases of the Association in promoting improvement. A selected group of programs supported by industry will be mentioned. Some science-based industries located in communities where the industry employs mayn from the area have supported programs in which a scientist from the industrial plant teaches part- or full-time in the science department of the local school.

**(a) The Shell Companies Foundation Program.** Over the decade 1953–1963 this foundation has contributed nearly $6.5 millions of dollars for the improvement of education through such programs as: (*1*) *Fellowships*—college and university fellowships, (*2*) *Grants*—college and university graduate teaching, research activities in broad and undesignated areas, (*3*) *Assistance*—furthers the professional development of college teachers and supports undesignated general needs of the participating institutions, (*4*) *Merit Fellowships*—summer fellowships for in-service high school teachers and supervisors of science and mathematics, (*5*) *Merit Residence*—twelve months of special-graduate level study to key teaching-improvement leaders in high school science and mathematics, (*6*) *Merit Scholarship*—four-year college scholarships for future high school science and mathematics teachers, (*7*) *Merit Fifth-year Scholarship*—a fifth year of academic training for Shell and National Merit Scholars.

**(b) The Manufacturing Chemists' Association.** The aid-to-education program of the MCA, trade organization of the chemical industry, is now in its eighth year. Although many firms have substantial activities of their own, the MCA program is a concerted effort, supported from regular Association dues. The work is executed by a full-time staff with guidance from the more than twenty industry leaders contributing to the Education Activities Committee. MCA's primary objective in this field is to inspire students especially talented in science and mathematics to follow science as a career in industry, government, or education. To accomplish this, the Association has worked with educators to prepare several guidance booklets and to produce supplementary aids to the teaching of chemistry at the elementary, junior high and senior high school levels.

**(c) Scientific Apparatus Manufacturers Association.** Programs for implementing reform in science teaching are supported by this trade association and also many of its members have individual educational programs which they carry out in the schools. Recently a grant made by the Science Facilities Section of the Association has enabled a committee from the National Science Teachers Association to carry out a two-year study on new laboratory facilities for schools.

(d) **Other Programs Supported by Industry.** It would be almost impossible to list every industry or trade association which has a program related to the improvement of school science programs. A few others will be mentioned as typical: the Westinghouse Manufacturing Company annually supports a nationwide science talent search and makes awards of scholarships to the winners; General Motors, Ford, and General Electric Companies furnish bulletins for school use as well as carry on other activities for helping science teaching. More specific examples will be given in Part 17 of this Section.

15. Programs for Youth Activities in Science

In Section I, brief mention was made of the recent growth of science youth activities in order to indicate the increasing concerns which help set the stage for the current reform in science education. The science youth activities movement is now an accepted, significant, and growing part of science education in the United States and includes many programs sponsored and supported by a variety of sources. This increasing popularity of science youth activities in the United States reflects the desire of young people in the schools to become more closely allied with the realities of a technological society. Many of the activities provide extra-curricular pursuits in science for large numbers of students who would not otherwise be able to engage in such activity.

The following brief descriptions of some of the national science youth organizations indicate the extent of the movement as well as the variety of activities involved. A pamphlet giving information on a number of other science youth activities has been distributed to conference participants.

(a) **The National Science Youth Programs.** Sponsored by Science Service, Inc., a private foundation in Washington, D. C., these programs include a variety of science youth activities. Science Clubs of America, consisting of more than 20,000 clubs in senior and junior high schools and even elementary schools, with a total membership of over half a million boys and girls, was organized in 1941. This organization is dedicated to the development of science interest and talent in the youth of the world. Club sponsors, who may be any teacher or other adult working with a group of young people in science activities, may affiliate at no charge with Science Clubs of America and receive free educational aids and low cost materials through Science Service's "Things of Science" program. The National Science Fair-International is the culminating event of the 10–15,000 science fairs which are held each spring in many secondary schools in the United States as well as the schools of a number of other nations. The Science Talent Search for the Westinghouse Science Scholarships was inaugurated by Science Service in 1942 to discover those high school seniors whose scientific skill, talent, and ability indicate potential creative originality. This competition is open to any senior of any accredited high school within the continental United States. As part of its National Science Youth Program, Science Service develops and internationally distributes experimental kits, books, and pamphlets promoting scientific experimentation and provides basic and background information in all fields of science.

(b) **The Junior Academy of Science Programs.** It has been mentioned that many state academies of science sponsor junior academy of science programs for those students interested in science and mathematics. Participation in individual research and presentation of papers on this research constitute the principal activity of this organization. The project or paper presentations represent the student's scientific investigation and are entered into competition with the work of his peers.

(c) **The Future Scientists of America.** This student science club organization is sponsored by the National Science

Teachers Association and features the following activities for its members: (*1*) local science club members receive from the national offices program suggestions, guidance material, and a national publication, (*2*) an awards program is designed to encourage individual student investigations and careful reports on the work, (*3*) science congresses are held to provide an opportunity for the student to present orally a report on his scientific investigation before his peers, (*4*) the Vistas of Science publications is a series of paperback books intended for use as enrichment literature for the junior and senior high school student. They provide the average or above average student with current scientific information not readily available through other sources. Other materials available for the club members are booklets and reports on careers in science teaching, suggested student projects, and periodical science magazines.

(d) **Mu Alpha Theta.** This mathematics society for high school and junior college students was started under the sponsorship of the Mathematics Association of America in 1956 to develop sound scholarship in the subject and promote enjoyment of mathematics. Among the more successful activities of this club are mathematics seminars held periodically throughout the country. Entrance requirements for individuals and their schools are very high. There are currently 800 chapters with a membership of over 50,000 school students. The periodical, *The Mathematics Log*, is furnished the members. It is designed to foster continued interest in mathematics with timely articles and problems.

(e) **Science Youth Congresses.** The U. S. Office of Education provides financial assistance to the states to expand and improve worthwhile science youth activities through its administration of Public Law 875. This program provides a means of encouraging activities of the various science youth organizations. The activity is culminated with an area or state-wide meeting of secondary school students interested in science and mathematics, together with their sponsoring teachers. At regional Congresses the following types of student activities are carried out: the science fair, presentation of papers, seminars, and meetings of science club officers.

(f) **National Science Foundation.** The Special Projects in Science Education Section (SPISE) at the National Science Foundation is primarily concerned with designing, operating and evaluating new ideas in science education. Many of the activities supported in this section are designed primarily for identifying and accelerating the scholarly development of the Nation's future scientists. A brief description of these activities follows: (*1*) *Summer Science Training Program* (*SSTP*) —academically talented students are provided the opportunity to gain experience beyond the offerings of the normal secondary school curriculum through the Summer Science Training Program. The primary purpose of this program is to bring the high-ability student into direct contact with the college teacher and the research scientist. Programs provide for either special courses in depth or opportunities to participate as a team member in on-going research project. (*2*) *Cooperative College–School Program*—the primary objective of this program is to assist in the improvement of secondary school offerings in science and mathematics through joint projects on the part of higher educational institutions and secondary schools. Two main types of projects are supported under this program. Some provide for instructors for talented students and capable teachers and are directed toward the improvement of secondary school instruction—particularly for superior science and mathematics students. Others are concerned with planning the introduction of improved science and mathematics programs into school systems. (*3*) *Holiday Science Lectures*—this program provides for a series of science lectures by eminent scientists in various cities. Attendance is by invitation extended only to outstanding students in the area and to a small number of their teachers. (*4*) *State Academies of Science Program*—under this program, state and local academies of science, as well as other scientific organizations, conduct programs specifically aimed at providing the nation's youth with opportunities to come in contact with competent scientists. Among the activities supported in this program are visits by scientists to high school and college student groups, and encouragement of scholarly projects in which the students themselves participate.

*Programs to Prepare Personnel for Reform: The Institutes*

Although the word "institute" is used in a number of ways, it has in recent years come to have a special meaning to almost all those concerned with science education in the United States. Because institutes are such a unique development and powerful force in science education reform in the United States, they are being treated here as a separate topic. By far the most widely known of these programs in the United States are the summer institutes supported by the National Science Foundation. Some institute support has also come from other federal agencies and private foundations. Also, there are now other kinds of institutes being conducted, but almost all of them have most of the following characteristics.

The summer institute is similar to a regular summer session on a college or university campus in that it is four to twelve weeks long. It is conducted on a college or university campus or associated educational facility and is usually taught largely by the regular staff of the college with augmentation permitted from visiting faculty. There are, however, marked differences between college and university summer sessions and summer institutes.

A science teacher attending a regular summer session would take courses of his choice—content, methodology, cultural, or other offerings. These courses are the regular summer offerings of the college (and vary in quality from material of little value to very rigorous work in the disciplines). Enrollment is open to teachers who can afford the tuition and who are interested in attending to acquire credit.

A typical National Science Foundation-supported summer institute in science usually develops in the following way:

(*1*) In response to an announcement of program support by the Foundation, college or university scientists make application nearly a year in advance for the support of the institute. This application is in the form of a detailed proposal which includes: (*a*) a statement of educational objectives, (*b*) an outline, in some detail, of course content, (*c*) personnel involved, (*d*) level and subject matter to be covered, (*e*) participant selection procedures, (*f*) estimated numbers of participants to be selected, and (*g*) estimated cost. The proposal is signed by the president of the institution and a person designated to act as the institute director. This indicates that the institution has accepted responsibility of sponsorship which includes the maintenance of academic standards and fiscal responsibility.

(*2*) Proposals received by the date established by the Foundation are read and evaluated by several scientists. Proposals are evaluated by scientists with competence in the fields with which the institute is concerned. Those judged meritorious are considered for support.

(*3*) Proposals are supported as funds permit. The grants are made to the sponsoring institution to be administered by the scientists previously designated as directors.

(*4*) Participants are selected by the individual institute directors using general guidelines from the Foundation. Interested teachers make application to the institution offering the institute. A teacher may apply to more than one institution.

(*5*) Grants are intended to cover concomitant expenses of the institute, including stipends for costs of living of the participants.

Institutes are designed to fit more nearly the specific needs of the participants than is possible in the usual college session. Thus, one institute may be for secondary school physics teachers who wish to become familiar with modern atomic physics or the PSSC course; another may be structured for biology teachers who have been out of school for many years and who wish to be updated in radiation biology and modern biochemistry. Others may be concerned with such areas as earth science for elementary school teachers.

Institutes supported by the National Science Foundation may be categorized in a number of ways which are described below. (A statistical summary of the growth of the various types of institutes programs is included in this portion of the paper to indicate their growth during the past ten years.)

### 1. The School Level at Which the Participants Teach

Three levels of education are the basis for designing and describing institutes programs: (*a*) college teacher programs, (*b*) secondary school teacher programs, and (*c*) elementary school personnel programs. These levels are respectfully, post-high school, grades 7 through 12, and 1 through 6.

### 2. The Type of Institute Offered

There are four kinds of institutes when categorized in this way:

**(a) Academic-Year Institutes.** These are full-time training activities meeting during the long academic session from late September to late May or early June. Many have accompanying summer sessions, either before or after the long sessions. These activities frequently make provision for the awarding of a master's degree which reflects the emphasis on scientific or mathematical course content. Teachers can be selected by the director from all parts of the United States.

**(b) In-Service Institutes.** These are part-time training programs meeting once or twice a week in the evenings or on Saturdays. The participants continue to discharge their full-time professional teaching duties. Selection of teachers to attend is limited to the locale in which the institute is held.

In some areas of the western part of the United States, a locale may be defined by a radius of 150 miles (approximately 240 kilometers). Many colleges have off-campus facilities which are used to make these institutes available to more teachers.

**(c) Summer Institutes.** These are full-time training programs held during the summer period and vary from four to twelve weeks in length. Selection of participants can be made from all parts of the United States. These institutes are generally of two types: (*1*) unitary, in which essentially the same content is repeated to a different group each summer, and (*2*) sequential, in which the content is varied each year in accordance with an overall objective. A teacher may be selected to take the entire sequence. Many of the sequential programs provide for the awarding of a master's degree upon successful completion.

**(d) Conferences.** These are group activities of short duration held during the summer or at some other convenient time. Generally, they are more limited in scope than institutes with respect to topics discussed and more specialized in the selection of participants.

As has been mentioned previously, the National Science Foundation has provided much of the support for institute programs in the United States. The Atomic Energy Commission has also supported a limited number of summer institutes in radiation biology, nuclear science, and related fields in collaboration with the Foundation. Recently the National Aeronautics and Space Administration has announced support of additional institutes in areas of interest to that agency. The U. S. Office of Education, under provisions of the National Defense Education Act, has also supported

Statistical Summary of the Growth of National Science Foundation Supported Institutes Programs, 1953–63

| | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Secondary | | | | | | |
| Summer | | | | | | | | | | |
| Institutes supported | 1 | 6 | 18 | 91 | 121 | 327 | 353 | 333 | 421 | 423 |
| Applications received | 250 | 600 | 2,100 | 20,000 | 25,000 | 83,500 | 140,371 | 171,719 | 185,700 | 190,000 |
| Individual applicants | 100 | 192 | 672 | 6,400 | 8,000 | 26,720 | 42,081 | 55,249 | 64,000 | 65,000 |
| Participants | 26 | 126 | 750 | 4,800 | 6,200 | 17,000 | 17,350 | 17,962 | 20,469 | 20,750 |
| Academic Year | | | | | | | | | | |
| Institutes supported | | | 2 | 16 | 19 | 32 | 33 | 42 | 52 | 56 |
| Applications received | | | 600 | 5,000 | 6,500 | 9,500 | 14,467 | 14,875 | 16,200 | 16,500 |
| Individual applicants | | | 156 | 1,300 | 1,690 | 2,470 | 3,713 | 3,988 | 4,290 | 5,000 |
| Participants | | | 100 | 782 | 932 | 1,533 | 1,491 | 1,494 | 1,725 | 1,755 |
| In-Service | | | | | | | | | | |
| Institutes supported | | | 2 | 21 | 85 | 184 | 191 | 253 | 285 | 267 |
| Applications received | | | 150 | 900 | 3,400 | 9,000 | 10,011 | 14,225 | 16,281 | 16,600 |
| Individual applicants | | | 138 | 828 | 3,128 | 8,280 | 9,210 | 13,127 | 14,979 | 15,500 |
| Participants | | | 90 | 635 | 3,000 | 8,725 | 9,026 | 10,984 | 13,652 | 13,423 |
| | | | | Elementary | | | | | | |
| Summer | | | | | | | | | | |
| Institutes supported | | | | | | 12 | 15 | 19 | 21 | 33 |
| Applications received | | | | | | 3,165 | 9,008 | 14,305 | 14,977 | 14,150 |
| Individual applicants | | | | | | 570 | 1,621 | 2,643 | 2,800 | 4,000 |
| Participants | | | | | | 515 | 552 | 555 | 712 | 1,036 |
| In-service | | | | | | | | | | |
| Institutes supported | | | | | | 11 | 13 | 35 | 35 | 45 |
| Applications received | | | | | | 499 | 612 | 1,560 | 1,864 | 4,895 |
| Individual applicants | | | | | | 299 | 367 | 935 | 1,118 | 1,750 |
| Participants | | | | | | 350 | 405 | 866 | 1,060 | 1,403 |

institutes for a number of years in foreign languages and in counseling and guidance.

Prior to the advent of support by the National Science Foundation, industries supported a limited number of summer institutes for science teachers in the United States. As early as 1945, the General Electric Company supported institute-type programs. The Westinghouse Manufacturing Company supported an institute at the Massachusetts Institute of Technology for several years. The Shell Oil Companies Foundation has supported summer institutes at Stanford and Cornell Universities for many years.

The imposing job of implementing reform in science education that has been accomplished by science institutes cannot be overstated. It is probable that the institute, as it has become known in the last ten years, will continue to be a powerful force in continuing the reform movements by providing an excellent means of both updating teachers and keeping scientists in close contact with school science education. It is estimated that more than 50,000 secondary school science and mathematics teachers have been affected by these activities to date, and it is hoped that eventually all science and mathematics teachers will be reached as the United States continues to work at basic methods of improving its education.

*Implementing Reforms in Aids to Instruction*

In each of the sections of this paper, mention has been made repeatedly of the fundamental role played by the laboratory in the current science education reform movement. In the course-content improvement projects, in the new films of scientists at work, in the programs involving new laboratory equipment, the emphasis has been on the deep involvement of students in the process of scientific inquiry. So it is with many of the ancillary aids to science instruction which have come on the scene within recent years. From toys for pre-school children and elementary school science kits to corallary reading material for high school students and free materials from industry, the emphasis is more and more on having the user become actively involved in the process of inquiry. Whereas many free booklets or corallary reading material previously gave the reader factual information about science, many are now "how-to-do-it" guides for individual activity or experimentation. The following descriptions by no means includes all of even the most wide-spread programs but instead give a sampling of the variety of aids involved and their implementation.

1. The National Defense Education Act

The U. S. Office of Education administers a program which provides for federal grants to state educational agencies for the purpose of aiding local educational groups in acquiring laboratory or other special equipment for the teaching of science and mathematics. Over sixty million dollars are channeled annually through this program in the form of grants to state or local agencies. To be awarded these grants, the state or local agencies must match the federal funds on a dollar-for-dollar basis. The U. S. Office of Education also administers a national program for the utilization of government surplus commodities in science education.

State and local schools and colleges, by initiating and implementing action to utilize the resources provided by NDEA and other agencies, improve science teaching in our schools. Such a course of action is the essence of one endeavor through which the specialists for science at the U. S. Office of Education are seeking to stimulate local action. This has come to be known as the STEPS idea. (Science Teaching—Exploring for Excellence—Program Steps.)

The main purpose of the STEPS program is to assist state and local schools and colleges in organizing and planning to utilize effectively all the resources available to them in a continuing program for the improvement of science teaching. Through projects within the states, the STEPS program aims to demonstrate how: (*a*) local, state, federal, and other agencies can work cooperatively to improve science teaching, (*b*) available resources can be identified and used effectively by focusing them on the immediate local target, (*c*) local initiative, leadership, and support can be stimulated to constructive action for a continuing program to improve science teaching.

Because STEPS is primarily a *way* of working with existing resources, it does not require, initially, any major commitments of funds and personnel. Participating schools would ordinarily be expected to provide financial support to the extent provided for any locally organized program of improvement. The STEPS program is essentially a local effort and is initiated by a mutual agreement between the state department of education and the school administration of any area that wishes to become a pilot project center. One of the earliest organization steps is to select a local advisory committee and project director who will assume the responsibility for carrying out the rest of the program steps over an extended period of time.

2. Aids from Industrial Sources

Many science-related industrial firms produce and distribute educational materials and teaching aids which are either supplied free or at a nominal cost. This topic has been described earlier in the paper and will not be treated further at this point.

The specialized industries that manufacture or sell scientific apparatus and supplies to schools provide detailed catalogues and guides for the use of their equipment. Several provide pamphlets that show students how to conduct experiments and carry out investigations. One of these, a distributor of biological supplies, not only has a detailed catalogue, but also supplies leaflets on various subjects that include activities designed for students in biology classes. A manufacturer of microscopes publishes a booklet that gives much up-to-date information to the student that he might not be able to get from his textbook.

The toy selections of department stores in the United States have a large array of science toys and kits. A child can buy anything from an ant farm to an advanced chemistry set from a local department store. Many of the commercial educational science kits include textbooks or other printed matter that are suitable for classroom use, particularly on the elementary and junior high school levels. These toys and kits, when implemented properly, provide opportunities for younger students to actively participate in science.

Among the many other instructional aids that are being implemented in the science classroom and laboratory are: television, programed instruction, mobile science laboratories (charts or tables), and classroom science kits.

Television is being used in several ways as an aid to instruction. Not all uses have been in the best interest of good education. The more promising practices make use of television as a tool to extend the visual observation of students. A close-up view of a demonstration of the dissection of a frog or of a dangerous chemical reaction gives every student a "front row seat." Because of the limitations of time, place, and distance, many science activities would have to be "just read about" if it were not for television and video tape. Whether a closed or open circuit television system is used is not important, but if the purpose of the televised program is to *supplant* rather than supplement the teacher or laboratory activity, then there are serious grounds for *not* using television in science teaching. There is also some doubt of the value of the practice of using television for science instruction at the time a program just happens to be "on the air." The science teacher should decide what and when his class should view because only the science teacher knows his particular students and just what their needs are as far as teaching aids are concerned. Television can be a potent and valuable aid to science instruction when used to provide experiences that students could not have in any other way, but again it should not be used as a substitute for the direct experiences needed by science students if they are going to learn the processes of scientific inquiry and develop a conceptual understanding of science.

Programmed instruction by both the programed textbook and by a teaching machine has thus far had only limited use as instructional aid in science. Their use can be justified when some material needs to be memorized or learned in sequence so that the facts can be applied to help understand a more important concept. A chemistry student might benefit by using a programed lesson on the periodic table of the elements. Much of what is used in this table, including the symbols of the elements and their atomic numbers, can be very useful if they are memorized early in the course according to their relative activity and placement on the table. Another example might be the use of programed instruction to learn the organization of biological terms for taxonomy and identification keys.

Mobile science laboratory carts and demonstration tables are being used extensively in elementary and junior high school classrooms in schools where a laboratory room equipped with science apparatus and equipment is not available. Some elementary classrooms are also supplied with science kits in small portable boxes that contain the basic equipment and supplies needed for simple experiments.

Some other aids to improve science instruction are: new types of cut-away models, new projection methods (including polarized light), units or sets of apparatus and supplies for one specific experiment, and books that cover a major science concept to be explored in depth over an extended period.

## IV. Summary: Problems and Issues: Trends and Outlook

How does one differentiate between problems of the future and issues of the present? How can one identify and separate these trends which hold promise from those which do not? Hans Margolius once said, "Only in quiet waters things mirror themselves undistorted. Only in a quiet mind is adequate perception of the world." Certainly those who are deeply and directly involved in the present reforms would have a most difficult task if asked to be impartial in predicting the role to which history will relegate their efforts. Perhaps, as this paper purports to be resource material for others, the best approach is to describe (as impartially as one can) the current situation and leave judgment to those who are somewhat removed from the revolution itself.

It is clear that a revolution is taking place in education in science and mathematics in the United States. There is heartening evidence that this reform is spreading to the humanities and the social sciences. As this revolution is complex and involves all levels and disciplines, as well as all the aspects of the social and educational structure of the Unites States, no categorization of the concommitant problems, trends, and issues can prevent a great deal of overlapping. Categories relating to the public (the average citizen), the materials of science, and the professions (relating to personnel most intimately involved) have been used. In order to maintain some degree of brevity in Section IV, detailed information and data pertaining primarily to trends in the implementation of the reform movement are contained in Appendix "B." Some problems will not be dealt with in any detail as they relate more to the whole of education than to the current reforms. Such broad problems pertain to the school dropout, consolidation of small schools, increased mobility of the population, isolated rural areas that remain little affected by the current revolutions in science and technology, and commercial pressures which might effect the educational enterprise.

### *The Public*

Any problems relating to the average citizen in a democratic society can be attributed in part to the relationships of the people to the educational system inasmuch as the goals of education in general are determined by the needs, hopes, and aspirations of that society. However, certain problems seem to center currently with the public in general and through the public are reflected in the school. It should be the whole of society, through its philosophers, scientists, artists, political scientists, inventors, and other thinkers that ultimately determines the goals and ends of education for its members. Ordinarily, education and educators cannot create these goals; they can only implement them. In these times of rapid change this fact must sometimes be reiterated, for there are those in the United States who sincerely seek improved education for their fellow citizens, but at a more rapid pace than it can be achieved, in spite of the current dynamic reform movement.

Two near-opposites in public reaction constitute one of the most prevasive problems in efforts to improve science education in the United States. While on the one hand, too many people simply do not care whether the school science program is updated, others will vehemently insist that their local school adopt the "modern" curricula, but as soon as one class in their local school is using a "modern" course, react as though a complete revolution has been achieved and be complacent about any continued improvement. Change for the sake of change, with too little regard for proved quality and demonstrated worth, guides too large a portion of those in positions of responsibility at the various levels in the education structure.

The secondary school level was the first to be attacked in the current movement. Probably this was due mostly to the fact that this is the first level at which the disciplines are taught as separate courses. It became immediately evident that, in order to be most effective, such changes should involve all levels. However, such wholesale changes are simply not likely to be accepted by local level teachers, administrators, and citizens. It is one thing to say to local school people that, for example, their high school chemistry needs complete revision, and quite another to say, or even intimate, that their entire 1 through 12 structure, and beyond, might need careful scrutinizing and revision. Even though those intimately involved in the reforms are convinced (by their direct experience) that broad, all-level reform is needed immediately two things preclude such a possibility. First, the personnel for such a job are simply not immediately available, and secondly, almost all schools and districts must, to a certain extent, go through their own stages of trying limited reforms in order to be convinced of the broader needs.

Until recently, in the minds of many parents the mental image of a scientist was that of a stooped, wild-eyed man with unkept hair, peering into a microscope or tending a bubbling cauldron, an image in many instances transferred to children. Often capable students failed to pursue a career in science solely because their peers would consider them odd. This problem is rapidly becoming a minor one as the public image of scientists is rapidly coming into line with reality.

Of every ten youngsters now in grade schools in the United States, three will not finish high school and only four will continue their education past the twelfth grade. In twenty years, the six who have a high school education or less will outnumber at the polls the other four, even if all four have several college degrees. Scientific literacy among the adult population is highly praised but poorly defined. What constitutes the best science education for the majority who will not go on to college? Although the literature abounds with documentation of educational strife on this point, no clear answer is now evident. Meanwhile, twenty-six million young people will terminate their education in the coming decade. How to educate them, to the best of the nation's ability, to live in the unknown world of 1985, is today one of the most urgent problems facing the nation's professional educators, scientists as well as educator.

### *Materials*

The need for greater numbers of capable scientists to become involved in the creation of new materials for science education of both school and college level is acute, but lethargy and lack of dedication to such "school work" still cause many scientists to remain aloof in their research citadels. A number of new courses and curricula designed to take advantage of the new preparation afforded school students are being developed and tested at various colleges and universities, and many of these and others to follow will be made available to other institutions. The scientific communities are all concerning themselves more and more with mechanisms, such as special written materials equipment and aids to instruction by which a college faculty can keep abreast of modern developments in their fields.

There can be no doubt that financial investment in scientific progress affects a nation's future. As a sound business principle, most people will accept the fact that investment for the future is necessary. With investment in scientific progress, essential terminology used by scientists is so often not understood by many citizens that they simply do not realize what is being discussed. Thus, communication of already accepted principles to the lay citizen becomes a problem. There is reason to believe that both increased sophistication on the part of the citizen and care on the part of the scientist are alleviating this problem.

*The Professions*

Much has been written and spoken about the dichotomy of scientists (and other subject matter specialists) and educators (professional pedagogists) which developed during the past four decades. The improvements made thus far have come from joint endeavors by scientists and educators with the result that this dichotomy is fast being relegated to history.

One serious problem is that many teachers in the schools have responded to pressures to improve the quality of their teaching by greatly increasing the quantity of homework which they assign their students. In some schools this burden of additional "busy work" homework has grown to crushing proportions and seems to be defeating efforts to improve the basic quality of science teaching. Hopefully, this problem is limited to a few schools as no ready answer is now apparent to this problem.

The most important aspect of the revolution is probably not the new courses themselves—they will be superseded before long—but the new attitude of the scientific and teaching communities toward science education. Courses in science are now regarded as proper subjects for research and development by both of these communities, and many capable people, including some of the nation's best minds, are willing to devote time to carrying on such investigations. As students come better prepared from the elementary schools, new opportunities and obligations will be created for the high schools and similarly, for the colleges.

There is an immediate need for basic redirection by many of those who have been concerned with research in science education. So long as such research is directed primarily into various descriptions of the status quo or otherwise inwardly directed (for example, studies of existing texts and tests to determine comparability) there can be little basis for future planning. A cursory look at recent publications in this field would uncover dozens of suggestions for improved research, but few scientifically conducted studies which provide answers to them. A very brief sampling of such needs (suggestions) are listed below:

1. Public policy. What level of scientific literacy is essential for intelligent, responsible citizenship in the modern, technological society that is the United States today? How can one teach, measure, and evaluate such scientific literacy?
2. Curriculum. Should science be integrated into a core curriculum or should it be taught in separate courses at different levels? What is the optimum time quota to be allotted to science at each level, elementary, intermediate, secondary?
3. Learning. What is creativity? How can it be accurately identified or engendered in students? How does the teacher best give the nonscience student a proper appreciation of pure science and the research scientist?
4. Methods. How can teaching aids, such as television, radio, films, film strips, slides, teaching machines, newspapers and periodicals, be used most effectively to achieve the objectives of science teaching at each level and for pupils of varying abilities?

The National Association for Research in Science Teaching has published a list of dozens of unresolved issues in certain fields relating to science education; scientists and scholars involved in the present reform movements could identify dozens more. A few investigators are beginning to undertake the task of attacking these unresolved problems and issues. Indications are that such scholarly research will tend to become the rule rather than the exception in coming decades.

### *The Future*

It has been previously mentioned that it is rather difficult to be clinically honest in appraising a revolution when one is living within that revolution. The direction in which lies the ultimate solution or situation of science education in the United States, or the distance in time to that solution, might best be drawn by a disinterested observer. There is no question that there are ample indications that increasing numbers of both scientists and citizens are becoming concerned, and that rates of innovation and activity indicate massive interest in improvement. Scientists and teachers are dedicated to improvement, and enough citizens are interested in their success to insure increasingly better education in the sciences for both the scientist and citizen. Other countries facing similar problems will find program structures useful in improving the quality of science and mathematics education in their schools. Certainly the United States has profited in the current reform movement through cooperative efforts ranging from translations of materials of other nations to participation and cooperation in the Organization for Economic Cooperation and Development (OECD), the United Nations Educational, Social and Cultural Organization (UNESCO), and the International Scientific Unions. Cooperation between science education leaders in all countries will be instrumental in assuring dynamic change and mutual benefit to all school systems.

## References

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