Science Teaching in Elementary and Junior High Schools

A study made by the AAAS, with the aid of a grant from the National Science Foundation, is reviewed by the steering committee.

"It is not at all necessary that the average man should be acquainted with the latest theory of the universe or the newest hormone, but it is very necessary that he should understand as clearly as possible the purpose and methods of science. This is the business of our schools, not simply of the colleges but of all the schools from the kindergarten up."—GEORGE SARTON

There is urgent need for major improvement in the science instruction offered in elementary and junior high schools. In the hope of finding ways to effect this improvement, three conferences of teachers and scientists, all sponsored by the AAAS but conducted independently, recently considered the following aspects of science instruction: present practices and materials; recent efforts to create new courses for senior high schools; and recent experiments in teaching young children.

The conferences reached the following conclusions: instruction in science should be a regular part of the curriculum from kindergarten through grade 9 (and beyond, but the conferences considered only these grades); a major effort to improve science instruction in these grades should be undertaken; and this effort should involve improving both course materials and classroom teaching.

Conference Arrangements

In order to keep conference discussion groups to a manageable size and in order to include representatives of different parts of the country, three regional conferences were held instead of one large national conference. The conferences were held in St. Louis, Missouri, from 8 to 10 January 1961; in Berkeley, California, from 5 to 7 February; and in Washington, D.C., from 12 to 14 March. Each conference was arranged by a local committee, with Dean Thomas Hall of Washington University chairman of the St. Louis committee, Professor Owen Chamberlain of the University of California chairman of the Berkeley committee, and Professor John Toll of the University of Maryland chairman of the Washington committee.

Each conference included about 50 participants, drawn from the ranks of elementary and junior high school teachers, school principals, supervisors of elementary and junior high school science instruction, science educators, scientists from various disciplines, representatives of one or more of the senior high school course-content-improvement programs, and psychologists interested in learning and learning theory.

The local committee for each conference scheduled two or three addresses related to science education but left most of the conference time for discussion in small panels. At the final session of each conference the panel reports were presented and discussed by the entire conference.

Each panel was given a set of questions prepared by the local committee. The questions varied from one conference to another. Each conference worked without knowledge of the recommendations of any previous conference. Participants in all three conferences were furnished background information concerning the current status of science teaching in the elementary and junior high school grades and the texts available for these grades. The background papers (*1*) were "Science for grades seven, eight, and nine," by Abe S. Fischler; "The current status of science education in the elementary schools," by Jacqueline V. Mallinson; "Current activities in elementary and junior high school science," by Dorothy C. Matala; "Elementary school science and mathematics education in Western Europe," by Margaret J. McKibben; and "Review of science textbooks currently used in elementary schools," by Albert Piltz.

The independence of the three conferences and the somewhat different questions that were posed to start the discussion groups to work should be emphasized, for out of this diversity came clear agreement upon a number of statements and recommendations.

Points of Agreemeent

There was very substantial agreement upon all of the following points.

1) *Science should be a basic part of general education for all students at the elementary and junior high school levels.* As a part of general education, science should constitute a regularly scheduled part of the curriculum in all grades. The purpose is to equip all persons for life in a scientific and technological society. If all of the more than 35 million pupils in elementary and junior high schools can be given good experiences in science, all will have a good start toward scientific literacy. Young children are naturally curious about the universe and are continuously exploring their immediate environment. During these early years children form their basic attitudes, patterns of thinking, and modes of behavior. It is therefore during these years that particular attention must be given to establishing the attitudes and modes of inquiry that are associated with the scientific enterprise—its processes and content. Whatever the school does, children are inevitably exposed to "science" and technology through all forms of mass communication, but they can acquire understanding of these powerful forces only

Members of the steering committee for the study are Thomas S. Hall, Washington University, chairman; Paul E. Blackwood, U.S. Office of Education; Margaret W. Efraemson, Rudolph S. Walton Public School, Philadelphia; Philip G. Johnson, Cornell University; John R. Mayor, AAAS; Thornton Page, Wesleyan University; and Dael Wolfle, AAAS.

through an orderly intellectual experience in the study of science. This orderly intellectual experience is the responsibility of the school.

2) *Instruction at the elementary levels should deal in an organized way with science as a whole.* Science instruction should not be limited to one of the separate disciplines, such as biology, chemistry, or physics, but should develop specific awareness of natural phenomena, good habits of observation, understanding of classification, function, quantification, order, and other basic ideas used in science, drawing on all the sciences for examples. Certain areas serve best to illustrate or instruct in certain aspects of scientific reasoning, and the significance of scientific principles can best be made apparent when they are shown to be applicable in several fields. Although flexibility and variety are desirable, it is essential to have a well-defined structure for science courses, so that the load of answering extraneous questions does not become impossible for the elementary teacher, and so that the order and connectivity of science can be properly presented.

3) *There must be a clear progression in the study of science from grade to grade.* Science instruction at the elementary and junior high school levels should be planned and coordinated as a ten-year sequence, beginning with kindergarten and continuing through grade 9. (Science should continue to be a part of the curriculum in grade 10 and beyond, but this report covers only the kindergarten-to-grade-9 period.) Haphazard samplings, uncoordinated repetitions, overlap and glaring omissions should yield to systematic developmental instruction in science, based on the best knowledge of science itself, the scientific needs of society, the maturing child, and the learning process. While one purpose of a planned progression is to avoid boring and wasteful repetition of the purely descriptive treatment of such subjects as the solar system, weather, and the classification of leaves, a more important purpose is to introduce as early as possible the methods and systematic characteristics of scientific inquiry.

4) *There should be no single, national curriculum in science.* The conference participants were insistent that no attempt be made to develop a single program for use in all school systems. This judgment was based partly on philosophical objections to central dictation of curricular planning, and partly on recognition that alternative choices of subject matter and order of progression might be equally effective. In different regions of the country different illustrative materials are available. The pace and level of instruction differ from one school to another. So do the details of the curricular organization into which science instruction must be made to fit. Schools will therefore wish to have some choice among well-designed sets of science materials. Moreover, no one knows the best order and selection from among all that might be taught; alternative sets of material should be tried out.

5) *Science teaching should stress the spirit of discovery characteristic of science itself.* Nothing is more contrary to the spirit of science, and nothing more damaging to student and teacher morale, than to present science as a series of factual findings to be memorized. The science curriculum will, of course, teach concepts, theories, principles, and content areas, but the real purposes behind their selection must be kept in mind, and while the student is learning content he should also be learning methods of observation, the importance of checking observations, the role of measurement and the use of instruments to extend man's senses, how to interpret and be critical of data, and that as a quest for new knowledge science is constantly changing. These purposes are not achieved if students simply memorize findings without "discovering" them, or recognizing how they were discovered. Discovery is possible at all levels. The simplest step for the child is to discover phenomena and to observe relationships that are new to him; at a higher level he can learn to discover relationships by experimentation; and at a still higher level he should learn to discover by abstract reasoning.

6) *New instructional materials must be prepared for in-service and pre-service programs for science teachers.* In addition to the instructional materials to be used by the pupils, it will be necessary to prepare a comprehensive set of instructional aids to be used by the teachers and by those who provide instruction for teachers—a clear rationale of the science program, manuals and guides to provide ideas for various types of activities, monographs for basic information and for supplementary study, descriptions of suitable demonstrations and displays, instructions for appropriate experiments, and films and other audio-visual aids. Sample tests and examinations should also be provided as a basis for proper evaluation of student progress, and as guides to the teachers in preparing examinations that will emphasize scientific principles and methodology instead of the memorization of facts.

7) *The preparation of instructional materials will require the combined efforts of scientists, classroom teachers, and specialists in learning and teacher preparation.* A substantial team effort will be required to produce the high-quality materials needed for a major improvement in science teaching. This high quality can best be assured if scientists, classroom teachers, science supervisors, college staff members who offer science courses for teachers, psychologists and experts in child development, and specialists concerned with reading and other instructional aids work closely together in the production and in the revision of materials.

8) *There is great urgency to get started on the preparation of improved instructional materials for science.* Each year of delay means that one additional age group of children will finish school without the advantage of the kind of excellent science instruction that could be provided. We lack sufficient knowledge of child development and of how children learn science to assure production of the best possible teaching materials, but improvement based on the knowledge that is available should be started now, while investigations or research go forward to lay the basis for still better teaching materials in the future.

Discussion of the Curriculum

The present concern regarding science education in the elementary and junior high schools derives from the feeling that future citizens must be generally cognizant of the nature of science and its role in human existence.

This basic point and those stated earlier were expressed by all three conferences. A number of additional recommendations for improving science instruction and a number of specific suggestions were made in the reports of one or more of the discussion panels of the three conferences. The reports of the individual discussion groups have been distributed to the participants and

will be made available to those who may be assigned responsibility for the proposed major effort. A sampling of these recommendations is given in this section.

The conference participants believe that science is an essential part of balanced educational development, and one panel recommended that the basic core of the elementary school curriculum be science and the humanities. Modern technology is an increasing part of common knowledge, but the study of science should not be subservient to the study of technology. More than anything else the purpose of science in general education is to develop a more complete view of life in a scientifically oriented world culture.

Such goals are not to be accomplished by an encyclopedic approach; appreciation of science can be developed only through understanding the qualities of scientific enterprise—the *process* of science. This process is an intellectual pursuit; to the extent that that it deals largely with concept formation and validation, it is a creative activity. Science education at all levels should be based on these major aspects.

The role of speculation, prediction, and test in science implies a quantitative as well as a qualitative approach. Thus, measurement and quantitative reasoning should play a role in the curriculum comparable to the observational and descriptive aspects of science. The participants felt that better coordination between science and mathematics is important, particularly in the junior high school, and that a definite effort should be made to make use of mathematical ideas and methods in science in grades 7, 8, and 9.

Several of the conference groups provided lists of examples of the science content for grades up through the ninth. Among broad concept areas listed in the several conference reports were cosmology, evolution, ecology, structure and function, reproduction and development, structure of matter, energy interrelations, and changes of state of matter. Two of the discussion panels proposed that in the junior high school one year each be devoted to topics from the earth sciences, the biological sciences, and the physical sciences.

In junior high school science the participants believe that it is much more desirable to study a limited number of topics in depth than to provide a sketchy introduction to a great many ideas. One group listed geometrical optics, electricity, mechanics, states of matter, structure of matter, use and control of energy, and environment and human needs (including earth, atmosphere, water resources, and biological resources). Any one of these areas was thought to deserve at least one fourth of the time in one of the junior high school years.

Other suggestions from various groups, on which there was general agreement, and which refer to science programs from kindergarten through junior high school, are as follows.

1) Strong blocks of knowledge should be developed which cut across traditional science disciplines. The sequence in which these units are used should be determined within a three-grade range by cooperative planning of the teachers concerned.

2) The curriculum should be flexible enough to provide satisfaction and enlightenment to all students and to challenge the academically talented.

3) Teachers should employ the experimental approach to science, with emphasis on inductive learning.

4) As he enters grade 10, the student should appreciate such philosophical aspects of science as the distinction between operational definitions and theoretical definitions, the relationship between speculation and observation, and the displacement of one theory by another.

Improvement of Teacher Education

One study panel at each conference was devoted to problems of teacher education. All agreed upon the great need for improvement in the science education of teachers at the elementary and junior high school levels. It is unrealistic to try to provide summer institutes for the nearly one million elementary school teachers who devote some of their time to science teaching. Hence institutes for this level of instruction may well be limited to elementary school personnel who can provide leadership for and assistance to other teachers.

The conferences gave a considerable amount of attention to administrative changes that would enable school systems to take greater advantage of teachers with special interest and training in science. One group recommended the use of specially competent science teachers to serve as consultants to classroom teachers in the elementary schools, in a ratio of one consultant to not more than 50 classroom teachers. This plan would require some 17,000 specialized teachers, employed by single school districts or groups of smaller adjacent districts.

The situation for junior high school teachers is of course very different. The numbers are not so large as to make it impossible to reach individual teachers. Some of the institutes for secondary school teachers are quite appropriate for junior high school teachers, and quite a number of the latter are already attending these institutes. Institute proposals based on new approaches to junior high school science may well be invited and supported.

The recommendations on institutes are intended as means of meeting an immediate need and also as continuing activities to supplement the teacher aids which may be prepared for the new courses. The great value of summer institutes for secondary school teachers, both as a means of strengthening their education in science and as a way of encouraging them to use the new course materials, is recognized in the strong and urgent recommendation that science institute programs for elementary and junior high school teachers be greatly strengthened and increased. The institute program should include the following.

1) Summer institutes and in-service institutes for elementary and junior high school principals, curriculum directors, science supervisors, special science teachers, and other teachers of known leadership qualities. An important criterion for attendance should be the potentiality of the individual as a leader in improving science programs in his own school system.

2) Institutes for junior high school science teachers under the regular secondary school institute program, but with special attention given to the problems of junior high school science.

3) In-service institutes for elementary or junior high school teachers within a school system or at a center serving several schools or school systems. Consulting scientists and consulting specialists in science education should be involved in the planning and teaching of these institute courses.

It is also urgent that college programs for prospective teachers be strengthened. These programs are likely to be modified when the new ma-

terials for elementary and junior high school instruction become available, but in the meantime, and more fundamentally, the following steps are proposed.

1) College science courses should be designed to give a fuller and wider spectrum of science. The courses would probably include materials drawn from several science departments and should teach the logical and operational assumptions on which science is built. The courses need not be specially designed for elementary teachers; those most appropriate for liberal arts majors and other nonscientists might be excellent for prospective teachers in the elementary grades. A working conference to clarify patterns may be useful.

2) Professional education experiences for prospective elementary teachers should include opportunity to observe the work of well-qualified teachers who like science and who like children. Prospective teachers should also be provided opportunities to gain experience in formulating questions that are meaningful to children, in developing methods for using quantitative approaches, in using audio-visual and laboratory materials, and in adapting to science instruction materials found in the surroundings of children.

3) All prospective elementary teachers should have an area of concentration. For some, this area should be science. The teachers who had concentrated in science could then become special science teachers or could assist other teachers less well acquainted with science.

Studies of Learning

Conference participants agreed upon the importance of encouraging additional studies of the learning process. The investigations proposed fall into two categories—those concerned with fundamental research in learning and those directly concerned with the selection and organization of content for science courses and with methods of teaching science.

It is not proposed that fundamental research in learning—research which could contribute to the improvement of teaching in all disciplines—become a part of the proposed national course-content-improvement program for elementary and junior high school science. The conferences and the steering committee, however, recognize the need for such research and strongly recommend that it receive more adequate support.

There are, however, problems for investigations that would directly support the development of improved elementary and junior high school science materials. Work on some of these problems should be planned as part of the recommended study. Examples are the kinds of instructional materials that are most effective in learning at different grade levels; the most effective use of textbooks, reading materials, laboratory equipment, films, television, and automated learning devices; development of better means of early identification of scientific and technical talent and appropriate instructional materials for talented pupils; study of readiness for the kinds of intellectual activities that are required in science learning and of the extent to which such readiness is a function of earlier experience; and development of better means for comparing the effectiveness of new teaching materials with that of other, more traditional ones.

Developing Course Materials

The program for the development of science materials for use in the elementary and junior high schools and of all of the supporting materials to be used by the teachers should be under the direction of a national advisory or steering committee. The steering committee should include scientists, science educators, teachers, supervisors, and learning specialists.

The following steps or stages, whether carried out at one or more centers simultaneously or successively, were agreed upon as necessary.

1) Identification of major scientific concepts, principles, and content areas to be covered and preparation of a sequential plan for their development.

2) Collation of present research data related to elementary and junior high school science instruction and definition of problems that need careful study.

3) Preparation of alternative blocks of material (texts, teachers manuals, tests, and so on) for the several grades or content areas.

4) Classroom trial, feedback of criticism and suggestions, and revision of the preliminary materials.

5) Preparation of sets of materials for general school use.

As a plan of action for accomplishing these goals we propose the establishment of several centers for the development of course materials. Each center should have its own working group of scientists, teachers, and other educational leaders and each its own set of cooperating schools trying out the new materials. The number of centers can be better determined after there has been more detailed consideration of all of the problems involved; we tentatively recommend that there be three. This number seems to offer a good compromise between the advantages of wide choice and the requirements of cost and other practical realities. While each center should have considerable autonomy to develop materials it considers best, the activities of all centers would be coordinated by the national steering committee, and all would have access to common supporting services—such as facilities for the development of films or equipment.

Administrative coordination and management of the centers for course and materials development might follow either of two patterns.

One possibility would be for the foundation that provides financial support to contract directly with the universities or other institutions that undertake to develop courses and materials. If this procedure is followed, the funding agency should establish a national steering committee that would work closely with the centers both in initial planning and throughout the developmental program. The steering committee could be established directly within the funding agency or through a separate contract.

The other and perhaps more desirable possibility would be for the supporting foundation to arrange with a single agency or organization to appoint the national steering committee and to establish the course materials development centers, either directly or through subcontracts with universities or other appropriate agencies.

Independent Studies

In recommending a massive and coordinated attack on the problem of improving science education, the study participants explicitly indicated that they do not wish to discourage or in-

terfere with other, independent efforts aimed at the same goal. While such independent studies are unlikely to attain the national attention that would be given to a more massive attack, they may well turn out to be more imaginative and bolder in conception and method of attack. Such independent studies should be encouraged, not discouraged, by the existence of a large and coordinated effort.

An Observation

A most encouraging aspect of the three conferences was the ease and satisfaction with which scientists, representing all of the major scientific disciplines, and educators, representing teacher education, administration, and the classroom, were able to reach agreement about needs for improvement of early science education and ways of bringing about that improvement. It was heartening to both scientists and educators to find such a high degree of agreement upon the importance and the feasibility of the task. The general spirit of the conferences was one of enthusiastic acceptance of joint responsibility and confidence that a large-scale, coordinated, and cooperative attack would produce major improvements in science education at the elementary and junior high school levels.

Reference

1. The background papers appear as articles by the authors in *School Science and Mathematics* (Apr., May, and June 1961).

Forthcoming Events

July

16–21. International Conf. on Medical Electronics, 4th, with Electrical Techniques in Medicine and Biology, 14th annual conf., New York, N.Y. (L. E. Flory, RCA Laboratories, Princeton, N.J.)

16–22. International Soc. for Clinical and Experimental Hypnosis, Rio de Janeiro, Brazil. (ISCEH, 33 E. 65 St., New York 21)

17–22. Soil Mechanics and Foundation Engineering, 5th intern. conf., Paris, France. (E. Caminade, Secretaire General, 23 rue de Cronstadt, Paris 15)

18–20. Pulmonary Structure and Function, Ciba Foundation Symp. (by invitation only), London, England. (Ciba Foundation, 41 Portland Pl., London, W.1)

18–21. Inorganic Polymers, intern. symp., Nottingham, England. (General Secretary, Chemical Soc., Burlington House, London, W.1, England)

21–22. World Power Conf. (members only), Moscow, U.S.S.R. (Central Office, 201-2 Grand Buildings, Trafalgar Sq., London, W.C.2, England)

23–28. Otolaryngology, 7th intern. congr., Paris, France. (H. Guillon, Secretary General, 6 Avenue Mac-Mahon, Paris 17)

24–28. Nematology Symp., 6th intern., Ghent, Belgium. (J. van den Brande, Soc. of European Nematologists, Rijkslandboushogeschool, Coupure links 235, Ghent)

24–29. Medical Electro-Radiological Societies, Latin Federation of, 5th congr., Paris, France. (C. Proux, Secretary, 9 rue Daru, Paris 8)

24–30. Urology, 12th intern. congr., Rio de Janeiro, Brazil. (J. Silva de Assis, Secretary, P.O. Box 1275, Belo-Horizonte, Brazil)

26. International Commission for the Prevention of Alcoholism, 7th annual meeting, Washington, D.C. (International Headquarters, 6840 Eastern Ave., NW, Washington 12)

26–28. Detection and Assay of Hormones by Immuno-Clinical Means, Ciba Foundation Colloquium (by invitation only), London, England. (Ciba Foundation, 41 Portland Pl., London, W.1)

27–1. Macromolecular Chemistry, intern. symp., Montreal, Canada. (Organizing Committee, P.O. Box 816, Sarnia, Ontario, Canada)

28–29. Linguistic Soc. of America, Austin, Tex. (A. A. Hill, Box 7790, University Station, Austin 12)

30–2. Soil Conservation Soc. of America, Lafayette, Ind. (H. W. Pritchard, 838 Fifth Ave., Des Moines 14, Iowa)

30–3. International Psycholanalytical Congr., 22nd, Edinburgh, Scotland. (Miss C. de Monehaux, 53 York Terrace, Regents Park, London, N.W.1, England)

31–4. Biophysics, 1st intern. congr., Stockholm, Sweden. (B. Lindström, Dept. of Medical Physics, Karolinska Institutet, Stockholm 60)

31–4. Differential Equations in Non-Linear Mechanics, Air Force Acad., Colorado Springs, Colo. (J. P. Lasalle, 7212 Bellona Ave., Baltimore 12, Md.)

31–11. Physics of the Solar System and Re-entry Dynamics, conf., Blacksburg, Va. (Bureau of Public Relations, Virginia Polytechnic Inst., Blacksburg)

31–12. Electric Power and Problems of Nuclear Power, seminar, U.N. Economic Commission for Latin America, Mexico, D.F. (A. Dorfman, Chief, Energy and Water Resource Program, Avenue Providencia 871, Santiago, Chile)

August

1–26. Functional Analysis, 8th American Mathematical Soc. summer institute, Stanford, Calif. (P. D. Lax, AMS, 190 Hope St., Providence 6, R.I.)

2–5. International Conf. of Pure and Applied Chemistry, 21st, Montreal, Canada. (R. Morf, Hoffmann-LaRoche, S.A., Grenzachterstrasse 124, Basel, Switzerland)

3–5. Canadian Chemical Conf. and Exhibition, 44th, Montreal. (Chemical Inst. of Canada, 48 Rideau St., Ottawa 2, Ont.)

5–9. International Rorschach Soc., 5th congr., Fribourg-en-Brisgau, Germany. (A. Friedemann, Chemin des Pêcheurs 6, Bienne, Switzerland)