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Science Education in the Middle or Junior High School Grades

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The following article has been condensed from a review paper which Mr. Carleton prepared as a basis for a seminar which he was invited to lead at the Third Annual International Curriculum Conference in Oxford, England, in September 1967. Mr. Carleton's editorial in this issue of TST was inspired by the program of the Curriculum Conference.

A phenomenon of the past decade that we need to have in mind for this discussion is the development of science curricula or programs by nationwide or regional groups. These may be funded—that is, supported financially—by government funds, but are not, at least in the United States, either prepared or prescribed by the government. The rationale behind government interest is not only to update science teaching and content, but to encourage innovation and experimentation at all grade levels. When I refer to projects, I am speaking of these activities. All such projects in mathematics and science are listed in the *Report of the International Clearinghouse in Science and Mathematics Curricular Developments.* [7] More than 40 are classified as being for the middle schools.

Why all this ferment, feverish activity, and heavy expenditure of money and effort? I judge the answers to fall into two main categories: either to "catch up" in science education, as in the developing nations, or to "modernize" outdated courses and curricula, as in the U.S.A. and perhaps in the other so-called advanced countries. Philip H. Coombs, director of the International Institute for Educational Planning in Paris, says in the August 19 issue of *Saturday Review:*

> Among the changes sweeping the developing regions of the world, none has been more important than the worldwide revolution in education. . . . the less developed nations are endeavoring to move from an earlier vest-pocket educational system, which served only limited purposes and a lucky minority, to a full-blown educational system designed to serve the whole population and the full gamut of national developmental needs . . . a goal which more advanced countries have been pursuing for a century or more, and have not yet fully achieved. . . . Educational expansion . . . is the product of widespread popular demand. Around the world the impatient masses see education as the upward ladder for their children. [3]

In the U.S.A., science has been in the curriculum of the junior high schools for about half a century. Usually called simply "General Science," the internal content, and perhaps the goals and purposes, of the course are revealed by a sampling of the titles of typical chapters or units contained in the textbooks, as follows:

Science and Our Water Supply
The Air Around Us

Our Insect Friends and Foes
Transportation—Land, Sea, and Air
Foods, Medicines, and Your Health

For at least the last two to three decades, 80 to 90 per cent of all U.S.A. pupils have had at least one year of study of this kind of science during their three years of junior high school. With almost total emphasis on description, utilitarian uses, technology, and memorization, with little or no laboratory work for the pupils, with teachers poorly prepared for this course and high turnover among even these—small wonder that "general science" of this kind, by and large, is considered wholly inadequate for today's educational goals in science. Serious analysts and critics allege that traditional general science has tended to kill off rather than nurture children's interests in things scientific and further study in science, that it has done little or nothing to advance scientific literacy widely among the total population, and that it has failed to present science as one of man's humanistic endeavors and to differentiate between science and technology.

In any event, the science curriculum reform movement has finally enveloped the middle school range in the U.S.A. and a dozen or so major projects are now in progress—to say nothing of numerous local school district efforts and the publication programs of several private, commercial textbook publishing houses. Science curriculum reform in the U.S.A. began, of course, with PSSC physics over a decade ago, gradually moved to biology and chemistry, and finally to physical science and earth science for the junior high school level and to elementary school science (K-6).

I suppose that is the way it had to be and that we should be grateful that the middle school curriculum is at long last receiving substantial attention. The sad fact is, however, that probably 95 per cent or more of all children in grades seven to nine in the U.S.A. right this minute are studying a general science type course, and it will likely be five to ten years before today's innovations will be reaching significant numbers of the pupils—say, as many as 50 per cent. And yet it would seem that *massive, major programs should be mounted for these precious, critical years of the middle or junior high school.* These are the years that provide science teachers with their last chance to have a go at "science for all" (or a major fraction) of the school and future adult population. In the U.S.A., which prides itself on maintaining an enrollment of more than 80 per cent of the age group through grade twelve, *beyond what science they have had in elementary school and junior high school through grade nine,*

—about 10 per cent of the pupils take no more biology,
—60 to 65 per cent study no more chemistry, and
—75 to 80 per cent have no more study in physics.

Curriculum reform, innovative designs, and the investment of money, time, and effort on the part of literally hundreds of teachers, educators, scientists, psychologists, and others—all focused on science education for the 12- to 14- or 15-year-olds—are indeed welcome and tremendously significant contributions to Coombs' so-called "world-wide revolution in education."

Let us turn to some of the specifics

of what is actually happening *now,* in thinking and in action. I have tried to tease out a suitable sampling from a variety of sources, and these gleanings I have assembled under three key questions:

Why Teach (Learn) Science at All?
What Shall We Choose to Teach (Learn)?
How Shall We Teach—and *Evaluate?*

I. The Why of Education in Science

Science education in elementary and junior high schools, if not senior high, in the U.S.A. during the late 1920's, into the mid-1940's, more or less, was heavily influenced by the prevailing general educational philosophy of the times—sometimes stated briefly as "education for more effective personal, civic, and social living" or "life adjustment education." It should not be surprising, then, that general science turned out to be what it was and that we still have chapter or unit titles like those quoted earlier. When we look only to personal, daily experiences and our superficial observations, or to science as revealed in socioeconomic problems and endeavors, or to incidental reports of "science in the news"—then the "general science" picture is what we get: fragmentary, unorganized bits and pieces of information, descriptions, and look-sees at technology and fleeting scenes and events. It's only when we look into *science* itself—both as noun and as verb—that we come face to face with today's notions of why teach science, of what the central, long-range goals, purposes, and objectives are perceived to be. The scientists, having entered into the business of curriculum reform a decade ago, have also made their mark on the *what* and *how* of science education by first challenging us on the *why.*

In the main, today's notion of the central, long-range purpose for science education stresses such goals as these: development of scientific literacy as far as possible in as many people as possible;

development of understanding, insight, and functional control with respect to concepts and conceptual schemes of science and useful in understanding events and phenomena of science encountered in the environment;

development of the skills and processes of science—observation, measurement, recording, classification, hypothesizing, inferring, and so on;

development of understanding of the differences and of the interplay between science and technology and of the social impact of these kinds of enterprise.

Emphasis has shifted from the utilitarian to the intellectual, from the trivial to the more sophisticated. This is generally true of all education in the U.S.A. today, and especially in subjects that previously concentrated on skills or techniques. This "spirit of our time" has caught up with, or been embraced by science curriculum committees, conference groups, private textbook authors, and others all around the world.

Following are a few samples of what the current textbook authors have written in the preface or foreword sections of their books where, presumably, they state a position or philosophical basis to explain and justify the rest of the content:

> The goal of this entire course is to provide a plan by which the student

> may systematically, through simple and meaningful investigation, build a conceptual understanding of the structure of matter and the nature of energy. . . . The consequences of the students' explorations can readily lead to interpretation of concepts that are worthwhile as a general background as well as fundamental to further study of science. [8]
>
> The aim of this book is to help you gain a deeper and fuller understanding of the world about you and how scientists investigate this world. It is not only concerned with some of the main concepts that scientists have developed, but also with the activities scientists engage in. [5]

Following is a statement of the rationale and goals of one of the nationally funded U.S. projects in science for the junior high school years; namely, the Intermediate Science Curriculum Study at Florida State University:

> The fundamental assumpton underlying the ISCS curriculum plan is that science at the junor high school level should serve essentially a general education function . . . the ISCS materials are being written to give the student a sequence of content and experience that will lead him to a valid understanding of the nature of modern science and of the way scientific knowledge is gathered. [6]

II. The What of Science Education

Supposing widespread commitment to the previously stated long-range purposes and goals for science education, and given equally widespread agreement that the core, the skeleton, the framework of the school science program should consist of a relatively few (say, six to ten or so) "big ideas," patterns, themes, or conceptual schemes and processes of science, one might expect to find ready agreement on "what" it is that comprises this core. Alas, such is not the case—not quite. Curriculum workers and science teachers have looked to the scientists and to other leaders saying, "We are convinced; we accept your notions; now *you* tell *us* what it is we should be striving to teach." And answers, not *the answer,* have been forthcoming. There is no final agreement, at this point, as to which are the basic patterns or conceptual schemes most useful in building optimum understandings that can function in interpreting and coping with natural phenomena and science-related events throughout a person's lifetime. However, it is interesting and helpful to note similarities in the suggestions coming from different sources.

Textbook author Gerald S. Craig has suggested the following ideas as useful guidelines to teaching and learning:

(1) The Universe Is Very Large—Space
(2) Earth Is Very Old—Time
(3) Energy Is Involved in All Motion and Change—Energy. Everything in the Universe Is in Motion—Motion. The Universe Is Constantly Changing—Change
(4) Life Is Adapted to the Environment—Adaptation
(5) There Are Great Variations in the Universe—Variety
(6) The Interdependence of Living Things—Interrelationships
(7) The Interaction of Forces—Equilibrium and Balance [4]

Six basic ideas of conceptual schemes suggested by Paul F. Brandwein are as follows:

(1) Under ordinary conditions, matter can be changed but not annihilated or created.

(2) Under ordinary conditions, energy can be changed or exchanged but not annihilated or created.

(3) There is an interchange of materials and energy between living things and their environment.

(4) The organism is a product of its heredity and environment.

(5) The universe and its component bodies are constantly changing.

(6) Living things have changed over the years. [2]

A conference of scientists convened by NSTA also prepared a set of major conceptual schemes and process items in science, which were then published in *Theory Into Action in Science Curriculum Development.* [9] As our committee pointed out, there is not yet any either final or firm agreement on selection or statement of major schemes. However, as the few quotations and my inquiries revealed, a very great many curriculum workers and textbook authors are using this kind of framework. It helps them to eliminate the unnecessary or trivial and to devise experiences that will help the student grasp the big ideas and perceive their interrelatedness. How precisely is this being attempted in practice? Let us see whether we can detect a pattern in the school offerings.

The new middle school science courses now being developed in the U.S.A. appear to be of three principal kinds which might be characterized as:

I. Discipline-centered

II. Concept-centered and interdisciplinary

III. Process-centered (with a tendency toward discipline orientation but no major effort to "survey" an entire field)

These categories, of course, do not represent watertight compartments; practically everyone claims to be concerned both with the process and with the product of scientific endeavor. In those courses which claim to give primary attention to process, with knowledge content drawn in as needed, the elements of inquiry or specific process skills that are sought are likely to be quite similar to those listed as objectives of the Florida State University ISCS [6], as follows:

a. *Recognition of significant problems in science*

b. *Delimiting and defining of broad problems in science* to levels which allow attack by empirical means (particular attention will be given to such tools as operational definition and the systems concept and their relevance to this process)

c. *The ability to state testable hypotheses* upon which critical experiments may be designed

d. *The design and conduct of experiments* which yield data appropriate to the testing of hypotheses

e. *Interpretation of data* obtained from experiments and other measurements of nature to the level of simple statistical techniques

f. *Drawing conclusions* from a relevant set of data and the ordering of such conclusions into generalizations

g. *Testing the general applicability of conclusions* drawn from limited data

h. *The building of scientific 'models'* (with particular emphasis upon the advantages which such models provide in scientific investigation and their tentative nature)

III. The How of Teaching and Evaluation

It is in regard to actual instruction and the learning activities engaged in by pupils that the new courses lay greatest claim to innovations. "Inquiry," "investigation," and "the pursuit" or "the search" are key words to the new spirit of the new courses. Teaching and learning are supposed to emphasize science as a verb, and to stress the *doing* of science by individual pupils. The laboratory is expected to play a new, vital role in the learning of science. Obviously, this function calls for new types of laboratory activities of the kinds that engage pupils in "seek-and-ye-shall-find" adventures rather than require them merely to follow directions, fill in blanks and tables with trivial words or measurements, and, at best, confirm or verify the already known. However, David P. Ausubel (an educational psychologist), feels that the role of the laboratory in the total process of learning science as part of general education is rather sharply limited and that some individuals and projects, in their zeal for "learning by doing," have claimed or sought the impossible. He says:

> The principal function of the laboratory is not to transmit subject-matter content or to demonstrate principles of science on an audiovisual basis, but to teach scientific method. Curriculums in science must also be concerned with transmitting organized bodies of knowledge rather than with the mere development of inquiry skills in which subject-matter content is only of incidental concern in the development of such skills. [1]

It is also worth noting that the new purposes and the new concepts of laboratory learning have produced demands for new designs in apparatus and equipment, to say nothing of new concepts in space layouts and major facilities for science rooms, laboratories, and adjunct centers. Many individuals and the various curriculum projects themselves, of course, have responded with innovations and creative ideas. The commercial scientific apparatus makers and supply houses have converted these ideas and models into marketable realities, and in the U.S.A., at least, it appears that "business is booming" in this field throughout the range of both the elementary and the secondary schools.

Coupled with the new developments in laboratory teaching is the almost explosive emergence of the new "educational technology." Science educators, along with their colleagues in other aspects of the total school curriculum, are now being challenged by the premise, the problems, the possibilities, and the limitations of film loops and single-topic films, programed instruction, computer-assisted instruction, closed-circuit television, and taped lessons and sound-slides or filmstrips.

The hardware is here, with us, now. The great need is for software and teacher understanding that will assure maximum educational value from the use of the hardware. Many questions need to be answered, and most of the answers will have to be sought through rigorous designs for experimentation along with demanding criteria for educational effectiveness. Science educators, scientists, classroom teachers, specialists in curriculum and in learning, and perhaps still others, must team up with the designers and producers of the hardware in exploring the new avenues to learning.

In projects for elementary schools and in some—not all—of the middle school projects, departure from the standard textbook is almost radical. For example, the projects are melding developments of skills with conceptual schemes in the elements comprising the program. Some are producing "packages" of several kinds of learning materials. However, at the upper school level, widespread departure from textbooks is probably at least a decade away. At this writing, for the great majority of pupils in the middle schools, the textbook is really the course of study, and the pattern of content and organization of the textbooks is pretty well standardized. It consists of chapters or other subdivisions with a sequence of brief introduction, lengthy "presentation" sections, and questions together, usually, with suggested "other activities" of various kinds. It is in these questions and activities, more than in any other part of the book, I believe, that we can find out how "true to the faith" the authors have been—how well, how completely they have carried through with their stated philosophy, goals, and learning values. On this basis, some of the current crop of U.S.A. textbooks rate pretty low, in my opinion; although they make glowing claims to "the new," what the books really give the pupils *to do* is no better than the much-maligned general science of 30 years ago, or else it is so artificial and contrived as to be impractical or barren "busy work."

An innovation or new approach is not necessarily all that it is claimed to be simply because the authors, the innovators, the curriculum project directors, the funding agency, or public relations or advertising personnel say so. The burden of assessing the efficacy of instructional (learning) programs and materials must rest primarily with the classroom teachers, the supervisors and inspectors, and other responsible school authorities. They, on the firing line, in the crucible of the classroom, must develop judgments as to whether innovations (or the "old" ways and materials, for that matter) truly serve to advance *their* educational goals with *their* pupils in *their* particular setting or situation. And that statement, I claim, is loaded with meanings and implications.

Perhaps we have now come to what might be called "the $64 question"—namely, *how can we evaluate?* At present, it is becoming increasingly evident and accepted that evaluation is not to be regarded as a thing apart, as something to be relegated to an end-of-a-unit activity or process. Rather, evaluation is seen as an integral part of instruction and of the curriculum itself. Regrettably, however, this aspect of curriculum development tends to receive but scant attention. It is safe to say, I think, that in the U.S.A. only negligible advances have been made over the work and writings of Tyler, Hawkes, Lindquist, Mann, Zechiel, and others who 30 years ago were active in the Progressive Education movement and in the Eight-Year Study organized by the Commission on the Relation of School and College of The Progressive Education Association. [11]

There are, however, some signs of growing attention to the problems and the role of evaluation. Various approaches are being tried, among them observation of behavior based upon an observation schedule, tests using Suchman's "Predict-Control-Explain" [10] tests as a model, an individual pupil interviews. The new educational technology is adding force to the focus on defining behavioral objectives, both as goals for instruction with the new hardware and as items to be tested for in evaluation. But we still have far to go. "Behavior" involves pupils' actions both in and out of school (and who can follow a child 24 hours a day?). "Conceptualization" involves analysis of the thinking of an individual (and who can get inside another person's head?). We can list some very desirable attributes of the citizen literate in science, but can the goals of attitudes and appreciations be expressed in behavioral terms?

What I seem to have said here—in this candid picture of the situation in the United States—is that some extremely interesting and to some extent profitable ideas have been set forth and are being put into action, but they have come largely from the higher echelons of the educational and scientific hierarchy. We do not yet have a strong and unified groundswell coming from the teachers themselves.

It would seem evident to all of us, I should think, that while some important developments of potentially great significance for science in the middle schools are underway, there is still much to be done. There are many issues, problems, and suggested approaches to be debated or put to the test of classroom usefulness and effectiveness.

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