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ABSTRACT

The author describes a comprehensive science program for the elementary school. The program should include six components: (1) The story of the great generalizing constructs of science, such as the atom, the universe, the layers of the earth, and evolution--even though the students do not have the observational evidence to support the constructs; (2) Specific training in the vocabulary of science; (3) Classroom pencil and paper lessons which use learned scientific concepts to bring order to the child's world and which use the experiences of the child outside the classroom to define important scientific concepts; (4) Laboratory experiences which teach scientific concepts which are not part of everyday experience; (5) Laboratory experiences which teach the ways in which information is processed to establish scientific truth; and (6) A library-laboratory which contains a full range of audio-visual and model materials. This library-laboratory is a place which the child explores in a direction of his own choosing with a minimum of adult supervision. (Author)

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A SUGGESTED APPROACH TO THE ELEMENTARY SCHOOL SCIENCE CURRICULUM

Joseph I. Lipson*

Abstract

It is proposed that there is now enough information which has been generated by educational studies and by efforts on innovative elementary school science programs to begin to form comprehensive science programs. One such comprehensive program is offered here. This should include:

1. the story of the great generalizing constructs of science, such as the atom, the universe, the layers of the earth, and evolution--even though the students do not have the observational evidence to support the constructs;

2. specific training in the vocabulary of science so that the seemingly trivial problem of word familiarity and recall does not interfere with more important learning;

3. classroom pencil and paper lessons which use learned scientific concepts to bring order to the child's world and which use the experiences of the child outside the classroom to define important scientific concepts;

4. laboratory experiences which teach scientific concepts which are not part of everyday experience and the absence of which will lead to false expectations and difficulty in later, more formal instruction involving relationships between fundamental, definable concepts;

5. laboratory experiences which teach the ways in which information is processed to establish scientific truth; and

6. a library-laboratory which contains a full range of audio-visual and model materials (with books at the head of the list) and a wide variety of laboratory materials. This library-laboratory must be a place which the child explores in a direction of his own choosing with a minimum of adult supervision.

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Introduction

For several years, scientists have been working on a variety of programs for elementary school science and on programs with implications for elementary school science (Lockard, 1966). It seems that the community of teachers, scholars, administrators and other interested parties (e.g. textbook publishers, parents, legislatures) must now start a discussion which will define some possible comprehensive science curriculum programs which will place severe demands upon the time and material resources of the public schools. In this article I will not argue the importance and implications of a modern science program, although this discussion, too, needs to continue (Russell, 1965, p. 55). Rather, I will assume that my audience is willing to concede the importance of science instruction in the elementary school. The question spoken to will be the various kinds of instruction which should take place in the science program.

A specific list of lessons will not be proposed. The lesson sequences mentioned will be only for the sake of example. The actual lessons, topics, and concepts taught must await the results of the discussion I will look for. However, near the end of the article I will state my prejudices so that you will know where I stand.

Terminal Goals

What are the terminal goals of the elementary school science curriculum?

1) An elementary school science program should prepare the student to engage in more formal science instruction and science-related instruction. At the present time, each level of science education from post-graduate down to the junior high school is wrestling with massive problems whose solution seems to require better preparation of the incoming students. This has reached the point of serious program development for the elementary school (Karplus, 1966).

2) The student should have attained scientific concepts which refine his common sense or intuition so that relationships between concepts can be defined in later instruction. Many students enter college without having

attained the concepts of mass, force, acceleration, velocity, etc. When poorly prepared students memorize F = ma or $F=\frac{qq'}{r^2}$, the relationships defined are symbols with no basis in experience for the abstraction represented by the formulas. Today, our society has the economic strength, and science has the knowledge, to warrant bringing important concepts to the elementary school laboratory. In the world of direct experience, many concepts can be learned which are difficult to form through purely verbal instruction (Novak, 1966).

3) The student should be able to describe and give instances of the ways in which scientific knowledge is developed. The minimum result of this goal is to remove the semi-religious mysticism from pronouncements in the name of Science. The processes of science are used to process information and guide activities. These processes can be taught by suitably chosen instances just as any other content area is taught (Gagne, 1966; Heathers, 1961). The fact that elementary school children will have a much less sophisticated idea of scientific inference than a Nobel prize winner is no more reason for concern than the fact that a child's concept of a dog is much more rudimentary than that of a physiologist's. The child has developed a useful concept of a dog when he can correctly classify a dog that he has never seen before. If elementary school students can, for example, suitably classify statements as inferences or observations for a suitable set of instances, they will be on the road to being able to process the many kinds of information with which scientists deal. The ability to analyze information is important if we are to keep statements made in the name of Science from having the aura and mystique of religious dogma.

Elementary school science education should prepare the future scientist, the future member of society who will make decisions in a scientific world, the future technically employed worker, and the future citizen who will find a scientific component in so many political decisions. In the author's judgment, the public school science curriculum should be the same for all children in a school (but not all schools need have the same curriculum) unless the child and his parents can, in conjunction with the schools, have a voice in the selection of another path. The following activities then, should be engaged in by all elementary school students, although not all will go equal distances in the years before the electives of the junior high school begin to sort students into different career patterns.

Proposed Comprehensive Science Activities

It seems that American education often swings between extremes and divides into rival camps because each group in its own place and time sees different things as important. This program is proposed following an attempt on my part to extract the beneficial aspects of the major science programs which have been represented in the educational discussions of the last five years.

1. The story of the great generalizing constructs--the fairy tales of science. A young student cannot see an atom. He does not have the experimental experiences which would force him to accept the construct of the atom as the most plausible and useful explanation of all the facts. Thus any learning about the atom must be of the nature of the student learning to retell or paraphrase a story such as the story of Columbus or the Wizard of Oz. In each case, the student is learning to say certain things as a catechism or as dogma. Certain authors have argued (Swartz, 1964) that it would be better to teach nothing that the student could not observe for himself--that the fallacies and simplifications required in telling the fairy tales of science to young children cause learning difficulties later on. The danger they warn against seems to be that the student, in learning the verbal behavior, will not know how little he knows and will become stereotyped in his thinking and insensitive to the world to be observed around him.

I would argue that the problem, to the extent that it exists, lies in allowing the verbal learning to masquerade for discriminations, concepts, and abstractions formed from laboratory experience. Once warned, we need not allow the story to pass as scientific understanding any more than we allow a memorized story to masquerade as reading. An important step in clarifying relationships and avoiding confusion between the various kinds of responses that students are asked to make, involves the writing of educational objectives in terms of the desired student performance. If one wants the student to write or paraphrase a verbal passage, one writes this into the performance objective. If one wants the student to demonstrate an effect with laboratory equipment, then this is specifically stated in the list of performance objectives which define the curriculum sequence (Walbesser, 1965; Brown, 1967). Properly written performance objectives enable us to be more analytic about elements of the curriculum.

What are the possible benefits of learning to paraphrase certain things such as "All substances are composed of atoms" or "The core of the earth is molten metal"? There are two benefits I look for: (a) The story (a statement unverified by personal observation) provides a context for many disconnected observations. By providing context, the story gives pattern and significance to certain relevant experiences. In a sense, the story is a mnemonic for the student's experience. (b) The second benefit from the fairy tales of science is the inverse of the above. I expect that the story provides a familiar pattern which each relevant experience gives color and texture much as each thread in place brings a tapestry to life. Suddenly, the student will grasp the construct as a necessary abstraction from experience. The two processes complement each other. The story gives context to experience and experience brings Pinochio to life. Thus the story of earth and sky, solar system and star, atom and molecule, seed and fertilization should be told in a manner which is both honest and pleasing. One of my favorite books of the kind I have in mind is "About the Sky," a Little Golden Book by Rose Wyler costing 25 cents (Wyler, 1956). It begins, "No matter how small you are or how tall you are, you can touch the sky. The sky begins at the ground. Above the ground there is air--miles and miles of it." Sophisticated examples are the Mr. Tompkins stories of George Gamow (Gamow, 1944).

2. Specific training in the vocabulary of science. Our ability to code experience, concepts, and ideas in words is the key to the power of

human learning (Sandiford, 1963; Lawson, 1967). It is equally true that academic learning has often developed programs which implied that it did not matter what you knew as long as you said it properly--to paraphrase Shaw. Language can be a shining light or a will-o'-the-wisp. The symbolism of language has led to mathematics and the power of discourse. Yet the rigidity of language forced many physicists to look for an ether and forced Maxwell to interpret his equations in terms of a mechanical model (Dyson, 1964).

I argue that with proper precautions, vocabulary development is one of the most potent weapons in developing competence in science. One precaution is that, as with the stories of science, the vocabulary development must not be mistaken for ability to demonstrate scientific effects in the laboratory world. The other precaution is, of course, that the student must encounter enough instances in which words alone form a trap so that he is careful in the jungle of verbal behavior. The solution to this problem of rote verbalism which is unconnected to the world of sensory experience is to require the student to look at problems in an original way with laboratory experimentation as a verifying operation (Lawson, 1967).

One positive aspect of vocabulary training is that if the vocabulary of a lesson is readily available in the mind of the student, the student can concentrate on the lesson which may in fact be defining the words. Otherwise the simple, but essential, task of sorting through one's memory for some contact with a word can seriously interfere with one's ability to follow an argument. By vocabulary training I mean the ability to use a word in a sentence (which may be only superficially meaningful to him, e.g., "A dog is a carnivorous mammal"), the ability to pronounce the word, the ability to read the word. It would be nice if the student could also match a picture with a word, match a verbal statement with a word, and give synonyms and antonyms where possible. A second benefit of vocabulary training is related to the fact that there is evidence that being able to say and/or read a word, sensitizes a student to its future use (Silberman, 1965). Having discriminated the word in his environment, the student now finds it easier to notice the word in a future context which may be instructive (Glaser, 1967). In general, we find it easier to notice and pay attention to things that we have noticed before (within limits--a truly novel stimulus is more noticeable than a completely familiar one).

Examples of the desired kind of verbal experience are songs, nonsense rhymes, scientific poems and games. Commercially available instances are the LP record, Space Songs, (XTV 60928 produced by The Science Materials Center) and the book A Space Child's Mother Goose by Winsor (Winsor, 1963). The point of citing the above is that vocabulary learning need not be dull. The work can be integrated into the reading program and the children can be challenged to write their own songs and poems. An analogy I use is that the word is like the starting element of a crystal and that verbal and laboratory experiences crystalize around the vocabulary seed. The vocabulary has fulfilled its role when it is a code for many scientific experiences.

3. Classroom pencil and paper lessons which use the child's experiences outside of the classroom. If we can build upon the experiences which students have had, we can make education more efficient. We often assume that a student has learned nothing, had no experiences outside of the classroom. On the contrary, I would argue that the most "culturally deprived" slum child in the United States has had a wealth of experiences which, if determined, provide a useful basis for further science instruction (Gans, 1967). If we build upon the experiences which children have outside of school, we can save time and materials. Pencil and paper exercises, pictures, and textbooks can be adequate representations of the children's world so that the student can make responses drawn from the laboratory of the world outside of formal instruction.

There are two ways that classroom instruction can unite science and the child's world of experience. On one hand, science can bring order to the disorganized observations of the student. For example, the reason that the sky is blue and that the light of the setting sun is red can be simply related to the filtering aspect of the atmosphere (without necessarily getting into the scattering of light from individual atoms). To many people, myself included, the ordering effect of science upon the information thrust upon us by nature makes one more sensitive to form, structure, and change.

The second use of experiences outside of the classroom is to use the child's experiences to define a concept or the magnitude of some event. Thus size can and should be related to cars, people, houses, football field lengths, etc. Time relations can be defined by events such as bouncing a ball, running for a touchdown (or running a 100-yard dash), the time it takes a car to go from 0 to 60 miles per hour, the time per breath, the time per heartbeat, etc.

In bringing abstracted representations (pictures, drawings, and words) of outside experience into the classroom, one must be especially careful to measure the entering experience pool of the student so that we do not assume that our children have all had certain experiences. When a student shows that certain experiences are not part of his repertoire and available for use in instruction, then the program must either develop the relevant experiences through a program of home observation and experiment, or the school must develop an adequate set of laboratory experiences to compensate. Diagnostic evaluation of the student's abilities is judged to be critical for successful instruction.

4. Laboratory Experiences to Define Scientific Concepts. In a sense almost all of us are culturally deprived. Surrounded by a fantastic technological civilization, we grow up without the experiences which will give us correct expectations about bodies moving in a curved path, about the motion of the electrons which generate our television picture, about the effects of moving air which cause our airplanes to fly. If we then go on to the properties of order-disorder (entropy), relativity, and quantum mechanics, the deprivation comes close to starvation. Yet, through our technology and through the laws of nature that are far better understood today than at any time in the past, we can bring to our children the experiences which would make the laws, relationships, and concepts of science a reasonable abstraction and restructuring of experience.

Since this point has been argued rather extensively (Whitehead, 1929; Swartz, 1964) and since there seems to be general agreement on the need for laboratory work for young children in the science community, I would like to emphasize another point. These lessons should be carefully chosen to be the best that the adult world can agree upon. Once chosen, the objectives of the lessons should be stated in such a way that each child can operationally show, in the laboratory setting, that he has achieved the objective of the lesson. With very few exceptions, all children should be expected to master the objectives of the laboratory program in sequence, from simple to complex, from those requiring less abstraction to those requiring greater abstraction, from those involving one step and simple discriminations to those involving multiple steps and experimental problems. These lessons should represent the best sequence that we can provide to introduce the student to the verifiable, public world of science. It is important that these experiences not be punishing to the students. If the work is well taught but punishing we might arrive at the situation in reading; ninety-five per cent of the American public can read, but seventy-five per cent of the adult American public choose not to read a book a year. Further, if motivation is to be maintained, these required lessons must acquire relevance to the interests of the children. This point will be returned to in the discussion of the library-laboratory.

5. Laboratory experiences which teach the ways in which information is processed to establish scientific truth. Quite often we see statements to the effect that since the facts are changing and since we live in a vast sea of facts which is too great to know in detail, we must teach not facts but the ways in which facts are arrived at, verified, and the limits of the facts established. We must teach the processes by which nature is interrogated and the information obtained is processed. These processes are the basis of the AAAS lessons entitled, Science - A Process Approach (Commission on Science Education, 1966).

I would contend that we do not need to kill the edifice of content in order to establish a course of teaching the operations of scientific investigation (Hayweiser, 1966). A course in the experimental method can be justified on its own merits, and a good case can be made that the two courses are in fact supportive and complementary. Just as a child learns the concept of dog and red from a rich number of instances associated with the code word, children can learn to abstract the meaning of observation and inference from an adequate set of instances in which the words must be used discriminatively.

It seems to me that the means of establishing truth should not belong exclusively to the science curriculum. The entire school system and whole of society should be concerned with the means by which we process information and the ways in which we ask for evidence. The differences between science and other areas of activity lies in the extent to which we can control variables and the extent to which results can be generalized, but the differences tend to be that of degree. Sensitivity to the extent to which an historic, legal, political conclusion or truth meets the criteria of dependability and reproducibility might help to make many of our social conversations more productive. Recently, a game has been developed called Propaganda (Allen and Green, 1967), which attempts to build sensitivity to fallacy in argument. I was immediately taken by the rather obvious relationship between the operations of this game and the operations of the AAAS process lessons. In making decisions based upon limited and uncertain knowledge, I would hope that all people would use the processes of observation, inference, experimentation, measurement, communication, classification, ordering, etc.

To summarize, the recommendation with regard to the process skills is that they be made the basis of instruction as another area of content which is interwoven with the content of science. The process objectives will develop another set of abilities which the student can use in later learning and as an educated citizen.

6. The Library-Laboratory. We have evidence that we learn most effectively what we use in directions of our own choosing and that we are motivated to do things which allow us the control of our surroundings.

The hi-fi addict learns highly sophisticated techniques and acquires knowledge which one would despair of teaching to laymen in a course. Football players who had to be carried along in school by a benevolent establishment learn hundreds of plays with multiple contingencies and keep a notebook which would do justice to any research laboratory. In these activities and others, such as learning to speak, the student tolerates an amazing amount of error as he interacts with his environment. Morrison has commented upon this observation (Morrison, 1964) in relation to the problem of curriculum building. I would change the focus somewhat and suggest that formal, sequenced, required instruction is useful, but that we must provide a place within the school where the student can explore in a direction of his own choosing. This place should generate the self-chosen, self-directed activity which stimulates the intense attention and throwing off of error which is seen in so many out-of-school activities.

The name, library-laboratory, is chosen to suggest the way in which the place is to be used and the range of materials which would be housed there. That is, a library suggests that the individual takes and reads books of his own choosing. Thus the library-laboratory should include a full range of materials from books, through a rich set of audio-visual materials, to workir model kits and laboratory supplies and equipment (Keppel, 1966, p. 132). These materials should be available to be taken home just as library books are taken home. The problem of handling the equipment is not a real problem according to the information which I have.

The importance of the library-laboratory to a complete education program rests upon three aspects of self-chosen exploration or activity. (a) The library-laboratory supplies a continuous pay-off for learning the things required by the adult world. This can be a significant reinforcement for classroom activity. Here the environment is arranged to make it likely that by using the abilities he has been taught, the student will be able to do things that he finds pleasing to himself. (b) There is no learner as intense as the hobbyist. The student is likely to become extremely active in learning all about his chosen interest. Many of my physicist friends tell me that they got started by becoming ham radio operators. The experiences they had and the relationships they learned were rich instances for much of their later learning in physics. The hobby becomes the life work. The enhanced motivation which results from moving toward one's own goal is an important argument for the library-laboratory. (c) The student, in attempting to accomplish some private task, may be challenged to learn something through formal instruction--the utility of which had not been obvious before. For example, a student who could not appreciate the usefulness of exponential notation might return to the classroom with renewed attention if he decided to build a transistor radio in the library-laboratory and found that he was surrounded by exponential notations for frequency, resistance, capacitance, etc. (Keeping the activities self-chosen is critical. As soon as the student begins to get the idea that he can accumulate points toward a higher grade or teacher approval, most of the utility and power of the library-laboratory would be gone.)

The time for the library-laboratory should be allocated during the school day so that the library is not competing with baseball and television, but the activities permitted in this environment must be as unrestricted as saftey and sanity will permit. The teacher who supervises this library-laboratory, then, must be a very wise adult. He must be someone to talk to about the things that interest the student. While opinions and temperament are certainly as proper to a teacher as to anyone else, the librarian must be careful that the adult opinion does not suppress and intimidate the student who is trying to develop his own image of himself as an explorer and investigator. In the social transactions between the student and the teacher, we must not load the rules of the game so that the teacher always wins, or that the only way that the student can win is through retreat into alienation and apathy.

Time for the Program

A prime question seems to be, "Science education has a hard enough time finding a place in the elementary school curriculum; how are you going to convince the decision-making elements to give you enough time for all the things you propose?" The answer lies partly in distributing some of the activities over other school subjects. For example, the stories of science and vocabulary could be a part of the reading, literature, language arts program; much of the relation between the child's outside school experiences and science could be brought out in the social studies, geography, art, and music programs. The formal laboratory experiences constitute the irreducible core of science instruction which must find time in the schedule. A reasonable time allotment would seem to be two 40-minute laboratory periods a week. In our experience, this is sufficient time for getting materials, performing at least one lesson and cleaning up after the lesson.

Time for the library-laboratory is another matter. Properly conducted and organized, the students can get along with a larger pupil-teacher ratio in the library-laboratory than in the classroom. Conceivably, this period could release teacher time for planning sessions which should become a regular part of the school day. If time cannot be generated in the school day, then the problem becomes much tougher. Options such as working before and after school and during lunch hour might be tried. Another partial solution lies in having the children take motion pictures, tapes, books, and kits of materials to their homes to work on their chosen interests.

Specific Lesson Objectives

I believe strongly in the hierarchical structure of science with the line of succession leading from physics to chemistry to biology to biophysics and biochemistry with earth science as an integrated complex area. Someday, I feel sure that the progression will continue to psychology and sociology with economics as a category within these social sciences. Nevertheless, the fact that mathematics is the language of science has not lead me to ask for mathematics as a pre-requisite to studying physics and physical science concepts in the elementary school. The fact that a child does not have physics and chemistry (or even biology) does not prevent him from classifying dogs he has never seen, as dogs. The young student can make a fairly accurate sorting into living or non-living categories. Thus, it is clear that young students can learn biological concepts without courses in physics and chemistry.

The problem is to present a series of experiences, to have the child attain a set of concepts which will be most useful to later learning, later intelligent activity--either in or out of school (Karplus, 1966). Thus, while I would insist upon the primacy of experiences related to concepts in physics, such as mass, length, time, position, velocity, acceleration, force, weight, temperature, heat, energy, light, sound, static electricity, electric current, magnetic force, etc., the student who was brought up on such a diet might encounter such subjects as chemistry, biology, and earth science as too strange and unfamiliar for effective instruction to take place. Too great an emphasis upon the more complex sciences in the hierarchy, though, can lead to two difficulties: (a) a deficiency in the physics, chemistry, etc. which can render a complex problem (e.g. in biology) soluble; and (b) a resistance to learning the simpler but more rigorous concepts and techniques of the more fundamental disciplines. This latter difficulty is a case of the old dog - new tricks problem. Someone who has acquired a rich store of knowledge at great effort is often unwilling to expose himself to the essential pain of learning a new set of abilities starting as a rank beginner. Actually it has often been observed that under certain conditions the old dogs (e.g. veterans after the Second World War) can put their greater experience to good use in learning a new field rapidly.

Taking biology as an example, there are several ways in which the subject can be introduced into the elementary school program in a useful way. Some concepts will be taught as important. Thus, such concepts as the cell, growth, seed germination, roots, leaves, stem, flower, seed, plant, animal, reproduction, adaptation, biological competition, and (possibly) evolution would be taught through laboratory experiences. Other biological experiences can be introduced in relation to a more fundamental physical concept such as gravity. A lesson on gravity might well use the tendency of plants to orient themselves with relation to the direction of gravity. When water, light, temperature, and gases are being studied, biological systems can give richness and intuitive breadth to the concepts involved.

Other lessons can simply use biological instances because the biological instance is as good or better than an artificial instance, while the use of the biological system familiarizes the student to the dimensions of the biological world. Thus, statistical experiences in the process stream of lessons can utilize the numerical properties of seed pods (Variation SCIS unit); symmetry lessons can use instances from nature; classification lessons can be built upon the problem of classifying biological organisms. In short, we need not expect that elementary school science will become the exclusive property of one discipline. I am more concerned with the tendency to give each subject an equal share of time. School curriculum then becomes a political rather than an educational problem. We want good adult biologists, and the way to get them may be to emphasize fundamental concepts of physics and chemistry in the elementary school (Ontario Curriculum Institute, 1963, p. 34).

How will lesson decisions be made? Let us assume that we will get between 500 and 1000 science laboratory experiences into the K - 6 years. If we translate the lessons of reputable curriculum groups into expected student performance, then it is not too difficult to choose the 500 to 1000 that one likes best. It will be anticipated that there will be many bases for decision and that there will be diversity of choice and execution. Until systematic, reproducible evaluation catches up with our ability to make intuitive judgments based upon private and group experience, I can offer no clear path to glory in the selection of lesson topics. In fact, I would argue that society seems to benefit more from intelligent, flexible diversity than from centralized, rigid decision-making (Gans, 1967). The problem is to open up our information and communication system and hope that in the years to come that education will be more susceptible to predictive analysis and less a matter of culture, tradition, and fallible human wisdom. The latter decision-making structures are showing signs of strain in a rapidly changing world.

Summary

A proposal has been made for certain activities in the elementary school science which focuses upon the relation between verbal learning and

laboratory experience, between experiences in school and experiences from outside formal instruction, between self-chosen activity and activity required by the adult world. The activities of learning the stories of science, the vocabulary of science, the application of science to bring order to the outside world and the use of experiences in the outside world to define scientific concepts, and the acquisition of important scientific concepts through formal laboratory experience, constitute the formal school program. In addition, it is argued that there must be a library-laboratory in which the student can explore a wide variety of materials in a direction strictly of his own choosing.

References

Allen, Robert and Green, Lorne. The propaganda game, WFF'N PROOF. New Haven: Authors, 1967.

Bassey, Michael. School science for tomorrow's citizens. New York: Macmillan, 1963. Chapter 9.

Brown, Lee. The knowledge industry reports. A Report to the National Science Teachers Association National Meeting. Detroit, 1967.

Commission on Science Education. Science: A process approach. Washington: American Association for the Advancement of Science, 1966.

Dyson, Freeman J. Mathematics in the physical sciences. Scientific American, 1964, 211, 128-146.

Gagné, Robert M. Elementary science: A new scheme of instruction. Science, 1966, 151, 49-53.

Gans, Herbert J. The mass media as an educational institution. The Urban Review, 1967, 2, 5-10.

Gamow, George. Mr. Tompkins explores the atom. New York: MacMillan, 1944.

Gamow, George. Mr. Tompkins in wonderland. New York: MacMillan, 1944.

Glaser, Robert. Concept learning and concept teaching. In Gagne, Robert (Ed.) Research approaches to school-subject learning. Itasca, Illinois: F. E. Peacock, 1968. (in press)

Hayweiser, Lois. A criticism of the AAAS "Science: A Process Approach." Internal Report of the Learning Research and Development Center, University of Pittsburgh, 1966.

Heathers, Glen. A process-centered elementary science sequence. Science Education, 1961, 45, 201-206.

Karplus, Robert. Science. In Guggenheim, Fred, and Guggenheim, Corinne (Eds.) New frontiers in education. New York: Grune & Stratton, 1966. Pp. 114-135.

Keppel, Francis. The necessary revolution in american education. New York: Harper & Row, 1966.

Lawson, Chester A. Brain mechanisms and human learning. Boston: Houghton Mifflin, 1967.

Lockard, J. David. Fourth report of the information clearinghouse on new science and mathematics curriculum. AAAS & Science Teaching Center, University of Maryland, College Park, Maryland, 1966.

Morrison, Philip. The curricular triangle and its style. Quarterly Report, Educational Services Incorporated, 1964.

Novak, Joseph D. The role of concepts in science teaching. In Klausmeier, Herbert, and Harris, Chester (Eds.) Analyses of concept learning. New York: Academic Press, 1966. Pp. 239-254.

Ontario Curriculum Institute. Science: An interim report of the science committee. December, 1963.

Russell, James E. Change and challenge in american education. Boston: Houghton Mifflin, 1965.

Sandiford, Peter. Reciprocal improvement in learning. Transfer of learning. New Jersey: Van Nostrand, 1963.

Science Curriculum Improvement Study. Variation & Measurement. University of California, Berkeley, 1966.

Silberman, Harry F. Reading and related verbal learning. In Glaser, Robert (Ed.) Teaching machines and programed learning II: Data and directions. Washington, D.C.: National Education Association, 1965. Pp. 508-545.

Swartz, Clifford. Elementary school science by a quantitative approach. Journal of Research in Science Teaching, 1964, 2, 349-355.

Walbesser, Henry H. Behavioral objectives: Their implication for curriculum development and assessment. A paper presented at the Annual Meeting of the American Educational Research Association, 1965.

Whitehead, Alfred North. The aims of education. New York: Macmillan, 1929.

Winsor, Frederick. Space child's mother goose. New York: Simon & Schuster, 1963.

Wyler, Rose. About the sky. New York: Simon & Schuster, 1956.