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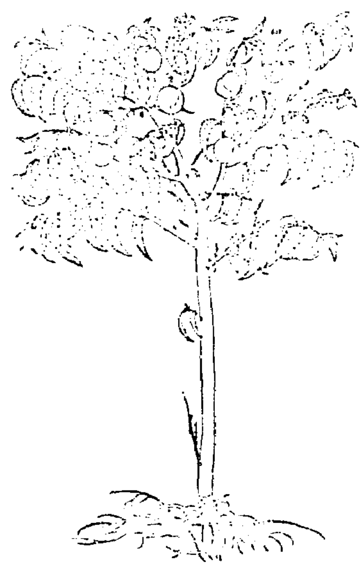
ABSTRACT

Under the auspices of the Massachusetts Advisory Council on Education, the status of science teaching in Massachusetts elementary schools was studied by the project staff of the Office of Tests at Harvard University. The quality and use of the National Science Foundation (NSF)-supported programs were analyzed through a historical discussion of contemporary reform movement in elementary science. Information about use of the Elementary Science Study, Science Curriculum Improvement Study, Science - A Process Approach, and Minnesota Mathematics and Science Teaching curricula was collected from superintendents' responses. Questionnaires, interview results, meetings, and informal conversations were used to determine teachers', principals', and science coordinators' attitudes and experiences. Fifth- and sixth-grade children's interests were surveyed to explore relationships between teachers' characteristics and their impact on children's attitudes. Adoption of the NSF curricula was found to produce lively and interesting instruction in classrooms, and teacher specialization was described as a problem in practical implementation. Included are 13 recommendations and tables of operational differences among NSF and non-NSF systems, perceived strengths and weaknesses of NSF curricula, numbers of the classrooms and buildings involved, and percentages of use by grade. (CC)

ESSENTIALLY ELEMENTARY SCIENCE

A Report on the Status of Elementary Science in Massachusetts Schools



SUBMITTED TO THE MASSACHUSETTS ADVISORY COUNCIL ON EDUCATION BY DEAN K. WHITLA, PROJECT DIRECTOR AND DAN C. PINCK, ASSOCIATE PROJECT DIRECTOR

OFFICE OF INSTRUCTIONAL RESEARCH AND EVALUATION
IN THE
FACULTY OF ARTS AND SCIENCES
AND
THE HARVARD GRADUATE SCHOOL OF EDUCATION
HARVARD UNIVERSITY
CAMBRIDGE, MASSACHUSETTS

MARCH 1973

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Letter of Transmittal

To Dr. Ronald B. Jackson
Acting Director of Research
Massachusetts Advisory Council on Education

Sir:

The Massachusetts Advisory Council on Education commissioned the Office of Tests at Harvard University to conduct a study during the academic year 1971-1972 to determine the extent to which the new elementary science curricula are being used in Massachusetts schools; to make a broad appraisal of the quality of instruction in elementary science; to determine the effects and utilization of the innovative curricular programs -- with particular emphasis on American Association for the Advancement of Science (AAAS); Elementary Science Study (ESS); Science Curriculum Improvement Study (SCIS); and Minnesota Mathematics and Science Teaching Project (Minnemast), each of the four supported by funds from the National Science Foundation; and to make recommendations and suggestions to further the sound use of elementary science in Massachusetts schools.

The conduct of the study necessitated gaining information from elementary schools throughout the Commonwealth. The cooperation and counsel of teachers, superintendents, science coordinators and principals made this study possible and we acknowledge their support and interest. Questionnaires, field visits, interviews and extensive case studies were accepted by them willingly and with candor. We acknowledge also the support of the Advisory committee members to us and the helpfulness of officials in the State Department of Education.

It may be unfashionable now to stress the importance of the curriculum in the school. Yet the time is propitious to conduct a study such as this, because by examining in detail how successful innovations are made, we may be better able to provide a guide to new directions and to discern some of the reasons for encouraging the use of more effective and imaginative teaching materials. In examining the curriculum in elementary science and the environment in which it is used, we have taken a critical look at schooling in general, and the picture is not disheartening. Improved curricula and teaching materials can and do make a difference, and the schools in Massachusetts possess strong resources in their teaching and administrative staffs in effecting educational change.

We have a proliferation of new course materials in many academic subjects, not only in elementary science. What is now needed are new tools to help people in the schools make sound choices in the selection of programs and to develop congenial teaching and administrative strategies after the choices have been made. These kinds of strategies do not result from the customary blueprints that are often found in books on implementation. A linear flow chart on the change process may not be of much help to a teacher or a principal. A prescriptive approach with the usual condiments of "things to do" may not be of much help either. We have prepared in an accompanying document a kind of handbook that may help teachers and principals make sound choices by offering suggestions on deciding how to decide. The handbook may be viewed as a concordance to the self-initiation of elementary science programs based on the attitudes and objectives in each school. It contains case studies and interviews and our personal observations gained from our work in the schools. It is more a planning document for each school and system than it is a grand master plan for all of them. In short, it is a helping tool and not a prescriptive one. The handbook and Essentially Elementary Science complement and supplement each other.

It is our expectation that pertinent information and insights may have resulted from our inquiry, useful to all who share your concern for awakening and developing in children an interest in science.

Dean K. Whitla
Director of the Study

Marvin C. Grossman	Mary Sheffield Rutherford	M. Joseph Bastian
Nancy S. Lindsay	George T. Ladd	Kristi Moore
L. Wallace Clausen	Charles McArthur	Dan C. Pinck

FOREWORD

Two years ago the Advisory Council on Education contracted with Harvard University for a study aimed at increasing the effective installation of soundly-based, innovative elementary science curricula in the elementary classrooms of Massachusetts. During this period, the Harvard Study Team, under the leadership of Dr. Dean K. Whitla, visited and observed in over 50 school systems and involved over 150 persons concerned with elementary science. Questionnaires were sent to all public school superintendents and science coordinators in the state as well as to a wide sampling of teachers, students, and elementary principals.

Only where learning and teaching are taking place will this study and its companion handbook come fully alive. This is the first MACE study to invade directly the realm of the classroom and the student. We expect the invasion to be a welcome one, since no aspect of the elementary school is more vulnerable to criticism and improvement than science programs. The materials presented are practical and usable today and tomorrow in elementary school classrooms and in teacher training and in-service training programs. Myth and speculation are to be replaced by reality and facts.

The major finding that asserts itself throughout is obvious but in constant need of repeating. If teachers are given choices...are allowed to make decisions... are, in short, treated as both professionals and human beings...better teaching and better programs result. According to the study team, when teachers are not "locked" into programs...are not tied into textbook structured courses of study...their classrooms are alive and stimulating.

The Council hopes that readers of this report will give its findings and recommendations serious consideration. In addition, we would be pleased to hear your reactions to and suggestions for the products of this study.

Dr. Allan S. Hartman, Associate Director of MACE, conceived this study and ensured that it would end in a practical report with a unique handbook. He deserves special mention for his many contributions to the study.

On behalf of the Council, let me thank each member of the study's advisory committee for the help provided in both giving advice and suggestions and in cooperating with the study team in many other ways. Your assistance was invaluable.

The challenge of implementation has troubled the Council since its inception. Too often implementation means relying on others, since the Council lacks the powers and resources to mount a wide-scale implementation process. Here, for a change, we have a study which can be put to work in the classroom tomorrow morning. Go to it.

Ronald B. Jackson
Acting Director of Research

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I

THIS RESEARCH AND THE RESEARCHERS

"Human capacity is more varied than educational researchers know," a distinguished literary historian and social critic wrote several years ago, "though their methods ensure that they shall never find this out." This constitutes a fair warning to any one who attempts to examine the educational system or any part of it. In this document we accept our capacity to err but we try to avoid making facile judgments or easy, intellectual factorisations.

The ten members of the study committee have taught science in elementary schools; devised evaluative schemes for new curricula; supervised elementary teachers in science; been responsible for elementary schools using innovative new curricula and varied teaching strategies; taught science to undergraduates; worked with handicapped children in special education programs; worked in school administration; taught in Peace Corps organizations in Asia and United Nations organizations in Africa; worked in testing and measurement and in developmental and clinical psychology; worked in National Science Foundation curriculum projects; and conducted workshops for elementary teachers. The study committee members derived their information from questionnaires, interviews, informal conversations, documents, classroom visits and observations, and group meetings with science coordinators, scientists, administrators, students and teachers, and faculty members at state colleges. Some members of the committee have been part of the curriculum reform movement; others have observed it; still others have been influenced by it.

This book presents the descriptive data we have obtained and our interpretation of it. To ensure the partnership and involvement of others, we have made connections between pertinent data and present certain inferences and assumptions to which the reader may react.

In the companion report, we present case studies of our visits to schools in the state; interviews with key persons in the schools, from teachers to superintendents, and with scientists and state education officials; recommendations for reform; and a discussion of possible sources of funds for elementary science education.

John Steinbeck wrote in the Sea of Cortez, an account of an expedition he made to observe the distribution of invertebrates, to see and to record their kinds and numbers, how they lived together:

> "Such things we had considered in the months of planning our expedition and we were determined not to let a passion for unassailable little truths draw in the horizon and crowd the sky down on us. We knew that what seemed to us true could be only relatively true anyway. There is no other kind of observation....
>
> We suppose this was the mental provisioning of our expedition. We said, Let's go wide open. Let's see what we see, record what we find, and not fool ourselves with conventional scientific strictures. We could not observe a

completely objective Sea of Cortez anyway, for in that lonely and uninhabited Gulf our boat and ourselves would change it the moment we entered. By going there, we would bring a new factor to the Gulf. Let us consider that factor and not be betrayed by the myth of permanent objective reality. If it exists at all, it is only available in pickled tatters or in distorted flashes. Let us go, we said into the Sea of Cortez, realizing that we become forever a part of it; that our rubber boots slogging through a flat of eelgrass, that the rocks we turn over in a tide pool, make us truly and permanently a factor in the ecology of the region. We shall take something away from it, but we shall leave something, too....

We determined to go doubly open so that in the end we could, if we wished, describe the sierra thus: 'D. XVII-15-IX; A. II-15-IX,' but also we could see the fish alive and swimming, feel it plunge against the lines, drag it threshing over the rail, and even finally eat it. And there is no reason why either approach should be inaccurate. Spine-count description need not suffer because another approach is also used. Perhaps out of the two approaches, we thought, there might emerge a picture more complete and even more accurate than either alone could produce. And so we went."

II

AN HISTORICAL NOTE ON THE CONTEMPORARY REFORM MOVEMENT IN ELEMENTARY SCIENCE

Let's begin with a definition of science:

Science is a systematic method of studying the phenomena encountered in nature. The method is best illustrated by the natural sciences, such as physics, chemistry and biology, but the techniques are by no means restricted to these fields. The method consists of systematically observing things under controlled conditions and trying to formulate the rules which describe the observable behavior. It's by no means certain that this works in all fields.

Basically, science hasn't changed much in the past fifty years. Not too many years ago -- at least up until World War II -- science was a preserve for the scientist, and a good bit of science in schools and colleges consisted, as Edward M. Purcell says, "in learning something that was so and it stayed that way." For example, older students learned that light traveled in a straight line, a fundamental, underlying idea. But the behavior of light was considered irrelevant to the education of young children, and, besides, the notion was considered too complicated for most teachers to demonstrate in a classroom. Science, with the exception of nature study and health science, was reserved for high school science classes, and a younger student had to wait until he had reached a certain grade or age before he had the opportunity formally to become acquainted with natural phenomena.

Science can be an immensely rich activity in the elementary classroom. It can serve to energize classroom teaching and create an harmonious ambience of teaching and learning throughout a school building. Science can help to set in motion a process of thinking critically about the world and man, enlarging a young person's ability to perceive possibilities for the improvement and care of the social condition of a society. But can science do this if elementary school students are introduced to it in the manner of the following excerpts from a textbook series?

> "The ancient Greeks knew how to get electricity by rubbing. But they could do nothing useful with it. Then Galvani and Volta showed the world how to get electricity by using chemicals. This was very much better. Batteries made of chemicals are now used in flashlights, in small radios, in automobiles and for ringing bells. But that is not enough in a world where so much work is to be done. We need electricity to light up billions of lamps."

The science that a younger student studied in school usually came from textbooks written by non-scientists. This was also true to a certain extent for many high school courses in chemistry, physics and biology. Although some work in improving high school physics by professional physicists had begun as early as 1951 at the University of Minnesota, it was not until the launching of the Russian Sputnik in 1957 that science became a public concern. If the nation was to remain competitive with the USSR it had to increase its supply of professional scientists.

The revamping of pre-professional science courses was a necessity. High school science was given a thorough examination through the efforts of the National Science Foundation. With the aid of the foundation, national curriculum development efforts produced a number of different programs, giving schools imaginative alternatives to the standard textbook approach. The new science courses reflected the professional scientist's view of science. Naturally, there is a great diversity among scientists; some see nature one way and others see it another. The new science programs reflected this diversity, more so in the elementary school than in the high school.

In most cases -- perhaps in all -- the scientist's desire to improve science instruction was motivated by self-interest: he read the books his own children were reading in elementary and high school science courses and became sufficiently incensed at the misinformation that he was willing to put aside his own research to devote several years of work to the design and preparation of new courses. Some of the national curriculum development groups were large, with as many as several hundred persons, including teachers, principals, psychologists, and physical and biological scientists. Yet it is fair to say that in the main, at least three of the elementary science programs resulted from the vision and determination of an individual with a unique concept of how science should be experienced by younger children.

Robert Karplus, professor of physics at the University of California at Berkeley, directed the Science Curriculum Improvement Study (SCIS); John R. Mayor, professor of mathematics and of education at the University of Maryland, directed the Science -- A Process Approach program of the American Association for the Advancement of Science (AAAS); Paul C. Rosenbloom, professor of mathematics, and James H. Werntz, Jr., professor of science, both at the University of Minnesota, directed the Minnesota Mathematics and Science Teaching Project (Minnemast); the late Francis L. Friedman, professor of physics and director of the Science Teaching Center at the Massachusetts Institute of Technology, organized the Elementary Science Study (ESS) and provided a philosophical framework followed by the five subsequent directors of that project. Each of these programs received support from the National Science Foundation, and together they appear to have succeeded in developing the diverse and varied set of approaches to elementary science that the National Science Foundation intended when it initiated course content improvement programs.

The foundation favored no one program. It wanted to provide more choices for the schools and to allow these materials to become available to the schools through the customary channel of commercial publication. (Only Minnemast has yet to become available through commercial distribution.)

The curriculum developers' purpose was to bring the attitudes of the scientist and the things he works with into the elementary classroom and to offer alternatives to the stringent, dry and often misleading textbook. Science is an activity and an attitude, they felt, that can be understood only by first-hand experimentation and observation.

Since education is an experiment and by its nature an incomplete one, it may be desirable to include varied starting points for the thoughtful educator. If one believes that choices are desirable in elementary education, then a variety of philosophical approaches will be an aid to him now.

What does each of the programs seek to accomplish? What is its underlying philosophy? What view of science is each trying to get across to teachers and students? How does each attempt to respond to the way children think and act?

We can best understand the claims and assumptions made by each of the programs if we allow each one to speak for itself. The following excerpts state the philosophies and goals of the new elementary science curricula and show examples of their teaching materials:

The Science Curriculum Improvement Study (SCIS)

"....is attempting to develop a teaching program of which the objective is the increase of scientific literacy in the school and adult populations. To accomplish this aim, the Study has to formulate a view of the nature and structure of science; it has to devise learning experiences that achieve a secure connection between the pupils; intuitive attitudes and the concepts of the modern scientific point of view; and it has to find out how one can determine what the children have learned....A science program constructed in this way will, it is hoped, have a pattern that is understandable by teachers and will not merely be a prescription to be followed by them.

The general strategy of the Study is to confront the elementary school children with first-hand experience of natural phenomena and with intellectual challenges that will stimulate their further cognitive development.

I should like to stress the fact that I consider the framework to be an essential part of science, a part that can be developed in a properly guided substantive study of natural phenomena. A science curriculum should therefore be judged both on the opportunities it affords pupils for having stimulative experiences and on the conceptual hierarchy that these experiences nourish. The development that takes place in the absence of such instruction is haphazard and leads to many invalid generalizations that are serious obstacles to later learning. The superstitions and fears regarding natural phenomena in primitive societies and even among adults in our own advanced culture illustrate this point.

What I have written must not be interpreted to mean that a pupil can learn only what he himself observes; the world is too complicated to permit that. It does mean, however, that the early years of school should provide a sufficiently diversified program based heavily on concrete experiences. The difficult part, which is often overlooked, is that the concrete experiences must be presented in a context that helps to build a conceptual framework. Then, and only then, will the early learning form a base for the assimilation of experiences that come later, experiences that may involve direct observation or the report of observations made by others. In other words, to be able to use information obtained by others, to benefit from the reading of textbooks and other references, the individual must have a conceptual structure and a means of communication that enable him to interpret the information as though he had obtained it himself. I shall call this functional understanding of science concepts "scientific literacy." It should be the principal objective of the elementary school science program.

....there is extensive direct contact of the children with natural phenomena. As much information as possible is gathered by the children through their own observations. Little is told them by the teacher or by their books. Second, there is a slow accumulation of abstractions in a hierarchy, with broad concepts being introduced early and more sophisticated distinctions being made later. These abstractions (sometimes called conceptual inventions) are introduced by the teacher. In this dual approach, abstract relationships are pointed out by the teacher, but examples that illustrate the relationships are discovered by the pupils themselves.

The course outline of the curriculum is related to the hierarchical level of abstraction in the program. First level abstractions are the conceptions of matter, of living matter (including activity and growth), of conservation of matter (including the systems concept), and of variation in one property among similar objects. Second level abstractions are the conceptions of interaction (including casual relations or associations). Third level abstractions are the conceptions of energy (including energy transfer during interaction), of equilibrium, of steady state, and of behavior, reproduction, and speciation of living matter. The abstractions on the earlier levels have to be grasped before the ones on the later levels become meaningful. Each abstraction can be illustrated on its own level, but it is further enriched by illustrations on the succeeding levels. Thus, for example, understanding of energy transfer both depends on and enlarges the understanding of interaction, the ability to isolate a system and subsystems, and the awareness of material objects.

The details of the classroom procedure are spelled out in teacher's manuals for several units at each of the levels mentioned above....The program reflects as great a breadth of natural phenomena as is consistent with the concepts being developed. The first part of the unit on Material Objects, for example, leads the children to manipulate, describe, compare, and transform samples of metal, wood, plastic, granular materials, liquids, and gases.

It presents a natural history of the objects and their composition rather than of their manufacture, of their use, or of some other aspect. A basis of this unit, of course, is prior awareness by each child that objects in his environment have an existence separate from his own existence. Such an awareness by first graders can be taken for granted.

The pedagogical device for introducing the key concepts in each of the units is similar....There is an instructional period of several class sessions in which the children are engaged in observations on a natural history level of some new or some familiar materials which they can explore quite freely. At this time, they enrich their understanding of previously formed concepts, but they also are faced with some problems which they cannot yet deal adequately. There is then a suggestion of a new way to think about the observations. This conception introduces the conceptual <u>invention</u>. Finally, there is further experimentation and exploration by the children to <u>discover</u> the consequences of using the conceptual invention. Thus, <u>invention</u> is the introduction of an interpretive construct, and <u>discovery</u> is the recognition of the usefulness of the construct. Alternately, this procedure may be called guided discovery, a process of going from observation to interpretation by means of <u>Invention and Discovery</u>."

Robert Karplus
<u>Journal of Research In Science Teaching</u>
Vol. 2, Issue 4, 1964

3 Exploring Pulleys *(Interaction and Systems)*

Children assemble and operate pulley systems. They make a record of the objects in their pulley systems and draw pictures of the systems in operation.

TEACHING MATERIALS

For each child:

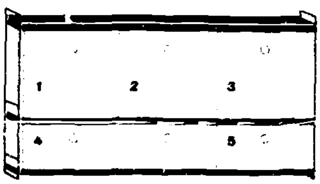
sheet of paper (provided by teacher)
student manual page 12

For each pair of children:

pulley set consisting of:
2 large pulleys
2 medium pulleys
2 small pulleys
rubber band
2 shafts
1 propeller
1 handle
1 wooden base
paper tray

For demonstration purposes:

1 pulley system with opaque cover



ADVANCE PREPARATION

The labeled illustration identifies all objects and parts of objects in a pulley set. To assemble an operable pulley system, place one pulley on each bearing. Slip the shaft of a handle through one pulley and into the bearing so the hexagonal shaft fits the hexagonal hole in the pulley, and in the same way attach a propeller to the other pulley. Stretch a rubber band around the pulleys to link them.

For your demonstration you will need a covered pulley system that conceals the pulleys and rubber band. To assemble a covered system, place the pulleys on the bearings and stretch the rubber band around them before putting the cover over the base. You can slip the handle and propeller shafts into the bearings through the holes in the cover. Scrape the edges of the holes with a sharp knife if the handles rub against the cover. Hold the cover in place with a rubber band. In preparing this system, use pulleys of different sizes and arrange the objects so that the propeller turns faster than the handle.

To speed the distribution of the materials, you might ask two or three children to arrange the individual sets ahead of time in plastic bags or on cardboard trays.

TEACHING SUGGESTIONS

Mystery systems. Let the children sit in a semicircle so that all can see the demonstration. Hold up the covered pulley system, turn the handle, and let them observe the movement of the propeller. Ask the children whether the handle and propeller are interacting and what kind of objects they think might be under the cover. Listen to their ideas, and then tell the children that you will give them some objects with which they can experiment to solve the mystery. You might demonstrate how to assemble an operating pulley system or else let the children find out for themselves. Explain that the wheels with grooves are called *pulleys*, and write this word on the board.

Experimentation. Ask the children to return to their desks, and distribute the materials. Walk around the room and help those children who have difficulty assembling their pulley systems. Children often begin with pulleys of equal size, so you might encourage them to experiment with other combinations of pulleys.

You or the children can make more complicated pulley systems by using two bases and connecting the pulleys on one base with pulleys on the other. You can also slip one shaft through two pulleys. These will then turn together as one unit and may be connected in various ways with other pulleys. Encourage the children to be creative in their experimentation.

Science -- A Process Approach (AAAS)

This elementary program, developed by the American Association for the Advancement of Science, sees as its primary aim "to develop the child's skills in using science process."

Characteristics of the Program

"Science -- A Process Approach shares certain purposes and characteristics with other modern science curricula. Like them, it is designed to present instruction which is intellectually stimulating and scientifically authentic. Like other programs, it is based upon the belief that an understanding of the scientific approach to gaining knowledge of man's world has a fundamental importance as a part of the general education of any child.

The program also has characteristics which make it different from other curricula in elementary science. The noteworthy and distinctive features of Science -- A Process Approach may be summarized as follows:

1. The instructional materials are contained in booklets written for, and used by, the teacher. Accompanying kits of materials are designed for use by teacher and children. Except for certain data sheets in the later grades, there are no printed materials addressed to the pupil. What the teacher does is to organize and set up science problem situations designed for participation by the children.

2. The topics covered in the exercises sample widely from the various fields of science. The exercises are ordered in sequences of instruction to provide a developmental progression of increasing competence in the processes of science.

3. Each exercise is designed to achieve some clearly stated objectives. These are phrased in terms of the kinds of pupil behavior which can be observed as outcomes of learning upon completion of the exercise.

4. The coverage of fields of science is broad. Mathematics topics are included, to be used when needed as preparation for other science activities. Some of the exercises draw from social and behavioral sciences. Most involve principles in physics, biology, and chemistry, with lesser representation of earth sciences and astronomy.

5. What is to be learned by the children is an accumulative and continually increasing degree of understanding of, and capability in, the process of science. Progress begins in the kindergarten with observation and description of object properties and motion, and advances through the sixth grade to the design and conduct of scientific experiments on a variety of topics.

6. Methods for evaluating pupils' achievement and progress are an integral part of the instructional program. The exercises contain tests of pupil achievement reflecting the objectives of assessing outcomes. In addition, separate measures have been developed for use in determining pupil attainments in process skills prior to instruction.

7. A Commentary for Teachers and a Guide for Inservice Instruction include essential general information on the science principles and processes involved in the program, and a set of exercises providing opportunities for teachers to practice relevant instructional techniques.

The Meaning of Process

There are a number of ways of conceiving of "process" as exemplified in Science -- A Process Approach. First, perhaps, it should be mentioned that an emphasis on process implies a corresponding deemphasis on specific science "content." Of course, the content is there - the children examine and make explorations of solid objects, liquids, gases, plants, animals, rocks, and even moon photographs. But, with some few notable exceptions, they are not asked to learn and remember particular facts or principles about these objects and phenomena. Rather, they are expected to learn such things as how to observe solid objects and their motions, how to classify liquids, how to infer internal mechanisms in plants, how to make and verify hypotheses about animal behavior, and how to perform experiments on the actions of gases. For example, in an exercise on the movement of liquids in materials (Part E), the children learn to design and carry out experiments on the relation between kinds of materials and rate of movement of liquids within them, including the control and manipulation of relevant variables; but they are not required to learn particular facts about the rate of liquid movement in blotting paper, fabrics and clay, or other materials employed in the exercise. Such facts may be incidentally learned, and may be useful to the child, but the primary objective is one of learning to carry out the process of controlling variables in an experiment.

A second meaning of process, referred to by Gagné (1966), centers upon the idea that what is taught to children should resemble what scientists do - the "processes" that they carry out in their own scientific activities. Scientists do observe, and classify, and measure, and make hypotheses, and perform experiements. How have they come to be able to do these things? Presumably, they have learned to do them, over a period of many years, by practicing doing them. If scientists have learned to gain information in these ways, surely the elementary forms of what they do can begin to be learned in the early grades. This line of reasoning does not imply the purpose of making everyone a scientist. Instead, it puts forward the idea that understanding science depends upon being able to look upon and deal with the world in the ways that the scientist does.

The third and perhaps most widely important meaning of process introduces the consideration of human intellectual development. From this point of view, processes are in a broad sense "ways of processing information." Such processing grows more complex as the individual develops from early childhood onward. The individual capabilities that are developed may reasonably be called "intellectual skills," a phrase which many would prefer to the term "processes."

When one considers processes as intellectual skills, certain general characteristics become apparent. One of the most important is the degree of generalizability one can expect in human capabilities of this sort. The typical development of intellectual skills, as Piaget's work (cf. Flavell, 1963) amply reminds us, is from the very concrete and specific to the increasingly abstract and general. Highly general intellectual skills are typically formed over a period of years, and are thought to depend upon the accumulated effects of learning a considerable variety of relatively concrete principles. Accordingly, the skills which Science -- a Process Approach is designed to establish, begin in highly specific and concrete forms, and increasing generality of these skills is systematically provided for by a planned progression of exercises. Evidence shows that these skills do generalize to a variety of new situations (Newsletter, 1967, Volume 3, No. 3; An Evaluation Model and Its Application, 2nd Report, 1968). The instructional program of Science -- A Process Approach attempts to deal realistically with the development of intellectual skills, in the sense that the goals to be achieved by any single exercise are modest. In the long-term sense, substantial and general intellectual development is expected to result from the cumulative effects of an orderly progression of learning activities."

Robert M. Gagné
Science--A Process Approach
Commission on Science Education
American Association for the
Advancement of Science, 1970

INSTRUCTIONAL PROCEDURE

Introduction

Show the class a healthy geranium plant and ask, **What are some of the things a plant needs to live and grow?** From their previous experience, the children will probably say that a plant must have air, proper temperature, soil, sunlight, and water. Ask if they have any idea what happens to the water when a plant is watered. **Where does it go? Does all the water stay in the soil, or does it go into the plant? Will a plant live very long without getting more water? How long?**

Activity 1

Set the two pots of growing bean plants on a table in front of the class. Ask, **How could we use these plants to discover whether plants require water?** (Give water to one pot of plants but not to the other.) Tell the children to mark one pot "To be watered" and the other "Not to be watered," to put both plants in a well-lighted place, to schedule the daily watering of one pot, and to keep a simple record for a week or so, as in the following example:

Date	Time	Watered Plants	Unwatered Plants
Monday, 3/4	9:00 AM	Appear healthy	Appear healthy
Tueday, 3/5	9:00 AM	Appear healthy	Appear healthy
Wednesday, 3/6	9:00 AM	Appear healthy	Becoming limp
Thursday, 3/7	9:00 AM	Appear healthy	Droopy leaves; losing color
Friday, 3/8	9:00 AM	Appear healthy	Bent over
Monday, 3/11	9:00 AM	Appear healthy	Leaves are dry

Discuss these observations with the children. **Do your observations give you any information about where the water went?** (No, they indicate only that plants will not live very long without water.)

Activity 2

Remind the children of the potted plants they observed in *Activity 1*. Ask, **Where did the water go that we gave the plants that remained healthy?** (Into the plant, or it evaporated.) **Are these observations or inferences?** (Inferences.) **Can we test these inferences?** Discuss any ideas the children have. Then say you know one way they might like to try.

Put a number of celery stalks with leaves and a large dishpan of water on a table at the front of the room. Tell the children they are going to see what happens when you put a cut celery stalk in colored water and let it stand for a while. Say, **You should observe everything that happens and write your observations down on a piece of paper.**

Divide the class into groups of four children. Then give each group (or each child, if you have enough celery) a plastic cup about half full of water colored with red food coloring. Have each group or child, in turn, bring a cup (or cups) of red-colored water to your supply of celery stalks and water. As the group watches, submerge the lower part of a stalk in the pan of water; then, with a razor blade or a sharp knife, make a slant cut completely through the stalk about 2.5 centimeters from the bottom. Discard the small piece you have cut off. (You must make the cut under water to prevent air from getting into the conducting tubes in the stem. Also, the blade must be sharp enough to make a clean cut and to prevent the tubes from being crushed or pushed together and thereby closed.)

Ask a group representative (or each child) to quickly transfer the cut stalk with the leaves from the pan to his cup of colored water. Tell him to label his cup, put it in a brightly lighted place in the room, and leave it there for several hours.

As soon as they notice a change in the color of the leaves, have the children retrieve their cups. Tell them to remove the stalk from the water and observe the color in the stem and in the leaves. If they hold the leaves up to the light, they will be able to observe the color pattern more closely. Then cut across the stems in several places for the children and ask them to find the tubes in the stem that carry the water to the leaves. Also, tell them to break a piece lengthwise and to try pulling out the dyed strings (conducting tubes).

Ask the children to review their list of observations. **Do your observations support and verify the inference that the water moves into the celery plant?**

The Minnemast Science Program

"has conveniently classified the operations of science into the following: Observation, Measurement, Experimentation, Description, Generalization, and Deduction. While other processes may be equally suitable, these seem useful as a point of departure. The operations listed above are clearly interrelated and interwoven. It then becomes evident that an activity in such a program will involve not one, but several of the operations of science.

The problem of developing for the child the operations of science in appropriate teaching units is by no means a simple one. In fact, the success of the program is dependent upon the manner in which this is done. There is more to the operation of Observation than just training children to be observers. The operation of Description implies more than teaching children to give reports of their observations. The operation of Experimentation is much more than the duplication of some scientific experiment. It is therefore evident that if the operations of science framework are to be developed into a sound science program, a logical, complete, and sequential series of teaching units must be achieved.

A science program which makes use of mathematical skills will add to the child's capacity to gain a quantitative and deeper understanding of his physical and biological environment. In reciprocal fashion, the science program can serve to initiate and develop concepts of mathematics .... If young children are encouraged to examine critically the intimate relationship between science and mathematics, it should be possible to teach these children both mathematics and science in greater depth and understanding.

The emphasis of the Minnemast science program is placed upon the activities of scientists -- what they do; how they think; how problems are approached and solved; and how these activities lead to prediction, new problems, and new experiments. The Minnemast program does not have as one of its objectives the teaching of the "scientific method" in the all too familiar way. Instead, the program is keyed to the operations of science.

The Minnemast sequential teaching units may be best illustrated by tracing the development of the operations of science through several units. A kindergarten unit encourages the child to disregard most of his physical and biological surroundings and to focus his attention upon simple objects one at a time. The children actually collect their own objects while participating in an "object hunt" activity either on the playground or on a walk through the neighborhood. Examination of the collected objects provides an observational technique that permits full use of the child's sensory equipment in a productive way. The child is then asked to sort the objects into groups called sets (mathematics program reinforcement). This forces the child to focus his attention on the properties of objects. He may place the objects into sets according to size, color, function, etc. A description of the object is then made in terms of its properties.

This type of Observation and Description approach is extended much more fully a year later in a first grade unit emphasizing the properties of objects. A later first-grade unit places two or more objects into a system. Again the child is encouraged to ignore the objects outside the system. Here the child is confronted with the problem of the function that each object performs in the system. Experimentation begins when the child changes the initial state of a system in another first-grade unit and observes corresponding changes in its final state. A second-grade unit requires the child to employ data gained from measurement to predict the height of plants at a given future time.

The Minnemast science curriculum is based on a spiral structure. The structure is not based on the familiar repetition of subject-matter topics that one finds in the usual curriculum of this type. The Minnemast spiral is based on the operations of science as mentioned earlier: Observation, Measurement, Experimentation, Description, Generalization, and Deduction. The first "loop" of the spiral would include grades kindergarten through grade two. In this loop, the child will gain some experience in all the listed experiences in the entire structure of scientific activity. As a result, sequential acitivities in the next loop will have more meaning when they can be related to the overall structure .... The Minnemast science program has attempted to incorporate the findings of the Swiss child psychologist, Jean Piaget, into the curriculum.

It is expected that children involved in the program will actually obtain more information in an incidental way than those exposed to an information-oriented curriculum. Children will acquire knowledge only for the purpose of winning new knowledge. Factual information unrelated to the purpose has little value. Children will instead learn fundamental operations common to all science."

Robert B. Ahrens
"Minnemast: The Coordinated Science and Mathematics Program"
Science and Children
Vol. 2, No. 5, February 1965

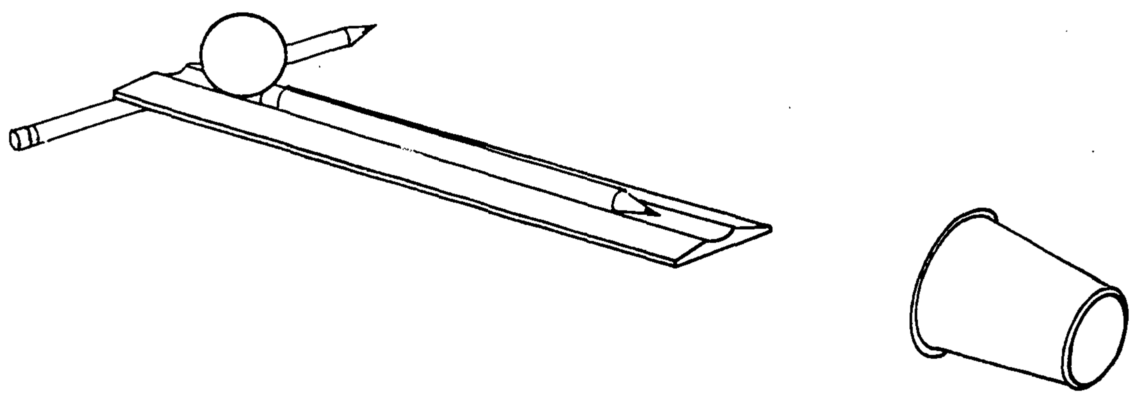
Now look at the pencil on the ruler.

IS THE ERASER ON THE PENCIL NECESSARY TO KEEP THE BALL FROM ROLLING?

HOW CAN WE FIND OUT? (Try using a pencil from which the eraser has been removed.)

3. The children have now observed the relations among the objects in the assemblage, and they have noted the significance of particular properties of the objects. Next they will observe the system in action and consider how to modify the system so that it can serve particular purposes.

Have a paper cup, a marble, and a ping-pong ball ready. Set up the system just as it was at the start of the lesson. Place a paper cup on its side with its opening about 6" away and facing the lower end of the ruler.



Have a child remove the pencil on the ruler so that the ping-pong ball can roll into the cup.

Then ask if the marble would do the same thing. Have a child come up and "work the system" with a marble.

Now place the cup a little to one side so that the rolling ball will miss it. Ask a child to work the system (without moving the ruler) and let the children see that the marble does not roll into the cup.

The Elementary Science Study

"The teachers and scientists who have worked together at ESS have developed units which satisfy two criteria: their scientific content is significant, and the activities, materials, and subject matter make children curious about some part of their world and encourage them to learn more about it.

'Basic threads of scientific investigation' -- inquiry, evidence, observation, measurement, classification, deduction -- are part of the fabric of all ESS units, but they are not the whole cloth. No units aim solely to teach individual skills, nor are any units intended primarily to illustrate particular concepts or processes or the like. Instead, by presenting interesting problems and real materials to explore, the units invite children to extend their knowledge, insight, and enjoyment of some part of the world around them.

It has been our conviction that children's interest in what they are doing is a powerful force in a learning situation. At the same time, all people do not find the same things interesting, nor do they all learn the same way or at the same rate. We have tried to account for such differences among people by offering choices -- many alternative paths to follow within units, and a considerable diversity in style and organization among the many separate units themselves.

In developing ESS units, we have not proceeded primarily from theories about the structure of Science or from a particular conceptual scheme of learning: rather we have relied upon taking what we thought were good scientific activities into classrooms to see how they worked with children. We have tried to find out what, in fact, six-year-olds, and nine- and ten- and thirteen-year-olds find interesting to explore. What kinds of materials and problems are able to inspire children to look at some part of the world with greater attention and care? What sorts of questions, answers, organizational schemes, equipment, and the like turn out to be most effective in a variety of classrooms? ESS units are, in essence, the result of a search for answers to questions such as these.

In each ESS unit, children do their own experiments with materials, equipment, or some part of the natural world. This interaction with "stuff" is of central importance. With bits of the real world before him, a child can observe for himself; he can interact with objects to try to change and to control their behavior; and he can check his own ideas and the assertions of others against what actually happens to the system which concerns him. When he learns with things he handles, all a child's senses become tools to help strengthen the links between his thought, his imagination, and the physical world.

The 56 units (for grades K-9) extend over a wide range of subjects in the natural sciences and mathematics. All of them can be appropriate at more then one grade level. But more important, they offer schools and teachers a resource of considerable diversity in teaching and learning style and in the manner in which material is organized and topics are introduced.

The time span and suggested working schedule of activities also varies from unit to unit: some units can occupy a class period every day for several weeks; others are intended for concentrated use over short periods of time or for weekly classes over a longer period. Some work nicely with units of study or can be left in the classroom for the children to come to again and again in their free time.

The whole enterprise is best seen as a series of classroom resources: equipment, printed materials, and films which can help teachers and children carry out activities centered on interaction with the physical world.

The variety among units and the abundant opportunities for independent excursions within each unit provide room for the development of each individual. To realize the full benefit of these materials, teachers need to give children time enough to investigate new materials in their own way to pursue their own questions as they work.

ESS units will be most effective in classrooms where inquiry is encouraged: where teachers are able and willing to listen more than to talk, to observe more than to show, and to help their students to progress in their work without engineering its precise direction. Students will need their teachers to help observe carefully, ask questions, design experiments, and assess the results of their work. To do those things without telling or directing too much requires a restraint that is born of self-confidence, as well as confidence in, and respect for, children. We have seen our materials reinforce these qualities in teachers. We have also learned that in the long run these qualities are more important to the teaching of ESS units than a substantive knowledge of science.

A single specified sequence of activities is not imposed on the teachers within a given unit. We feel strongly that good curriculum includes options. Teachers need to be able to modify units to suit the requirements of any class; they need room for their ideas and those of their students; and we suggest a variety of approaches and leave the choice of sequence to the teacher. ESS units are self-contained; they can be used independently of one another or grouped together, not in just one but in many ways. There are enough ESS units (56 in all) so that teachers at any grade level will have a variety from which to choose.

In the same spirit, ESS units do not come as pre-arranged curriculum. No group -- ESS or any other -- can design a single curriculum which will be suitable for the enormous variety of schools and school systems in this country and elsewhere. Planning a curriculum involves decisions which should be made only with knowledge about particular adults and children: their educational goals, their financial resources, and the circumstances in which they live and work. Those people whom the curriculum affects should be responsible for its shape and substance."

<u>Introduction</u>:
A Working Guide to the
Elementary Science Study
Elementary Science Study
Newton, Massachusetts

Some Early Investigations

In this section, we discuss a number of phenomena and problems which are likely to come up early in the investigations, or which are sometimes fruitful to introduce if they do not come up, or which a particular child will want to come back to if he has got an early start on some more complex problem.

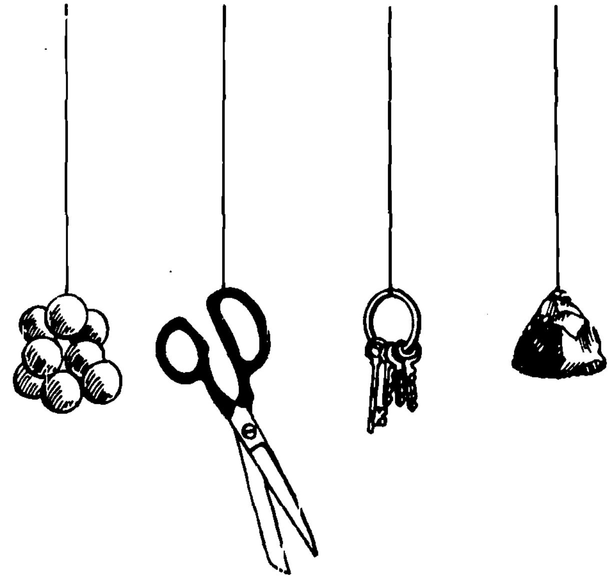
1. Swinging together

"Can you make two pendulums stay together when they swing?" Some children will do it in a few minutes; others will take longer.

Sometimes two pendulums will be so nearly the same length that they appear to swing together for ten swings or twenty, but the discrepancy gradually becomes visible. How long does a child watch before he decides they do stay together, or don't? Does he count the swings? There are differences in children's early style of attack, some impulsive or casual, some careful or fussy. We are not recommending an emphasis on precision here — it is often more fruitful to be approximate. We are only calling attention to the differences. As a child proceeds, changes in style in either direction sometimes reveal changes in involvement and understanding.

In the process of adjusting two pendulums to stay together, the effect of varying the length becomes familiar. Most children will soon show by their actions, and be able to tell you, that the shorter one "swings faster," "getting ahead" of the longer one. But there are other variables that children often will be thinking of too, such as the width of swing and the weight of the bob. These are often very surprising in the effects they do *not* have as well as those they do have. In addition, children's attention is often drawn to changes in the direction of the swing, so that two balls are no longer considered to be swinging together if one of them starts "going crooked."

These variables will not all be sorted out at once, and we don't expect them to be. When a variety of bobs is available or when several bobs are hung on one string (if you have them around, it will happen), we have the effects of weight and shape (and length too, sometimes) together — but the sorting may come much later.



Can you ever make these swing together?

During the past few years several reports have been prepared that deal with the new elementary science curricula. The following excerpts from some of these reports bring us up to date:

> "The national reform movement to improve the teaching of science in American schools began a little over a decade ago. The origin of this movement was in a period of crisis, and the need for reform was regarded as a national emergency. In the years following the crisis, the scientific community took on the major responsibility for building new courses in science from kindergarten through high school. The original intent was to update the subject matter of the curriculum to bring it in line with contemporary thinking on science, particularly with reference to modern theories, laws, and systems of ideas. But some scientists and educators saw the need to redirect the goals for teaching science as well as to reorganize the courses. They would have science taught for the contribution it makes to intellectual development. To accomplish this purpose, the development of inquiry processes was identified as a major purpose of science instruction. The scientists and educators also recognized the overload of factual information in science courses, and they selected the content for the new courses in terms of a limited number of fundamental concepts and basic theories. These decisions made new demands on how science was to be learned by young people and on the ways of teaching science.
>
> These developments were not intended to be radical, but for many reasons they did come as a curriculum 'shock.' The subject matter of courses was different from the past. 'What it means to learn science' had a new interpretation."

California State Advisory
Committee on Science Education
Science Framework for California
Public Schools, 1970

Another report began:

> "New and spirited attention has been given to the improvement of the teaching of science in elementary schools beginning about 1962. This important work is continuing, and thousands of school systems throughout the country are adopting new science programs or are in the process of revising their present elementary school science curriculums .... The new programs teach children the nature and spirit of modern science as they work with their hands and heads in small groups or as individuals in conducting investigations to find answers to scientific questions. The methods and spirit of these new elementary school science programs are already influencing the revision of elementary school science text series and the production of new ones.

Developments in Elementary School
Science: A Report of Seven
Regional Conferences for School
Administrators, 1970

Another survey of elementary science began:

> "In recent years science education has become an established part of the elementary school curriculum. It is no longer necessary to convince educators and the public in general that those who live in a scientific world should know more about it. Rather, the current concern is the improvement of science education for children, a concern which has as its focus identification of defensible objectives, reconstruction of the curriculum, utilization of pupil interests, studies of concept learning and development, encouragement of inquiry and discovery, evaluation of achievement, development of effective teaching resources, and more adequate preservice and in-service education."

Maxine Dunfee,
Elementary School Science: A Guide to Current Research,
1967

A survey of each of the new science curricula for the elementary grades noted:

> "Most broadly stated then ESS' goal is to bring participation in real science to the average school child, who will grow up to become the ordinary citizen. He should experience science not from the television screen, the textbook, the teacher or the expert 'demonstrating nicely', but in his own work -- Morrison's words, 'with his own hands, with his own microscope and his own belabored arithmetic .... We are not disturbed by slowness for what goes slow can run deep. And school hours are not all of life. To stroll into reality, the detail of it and the context, to unravel and to uncover it, is a better thing than to sprint past, reading the billboards of science."

Phillip Morrison,
quoted in Elementary Science Information Unit
Far West Laboratory for Educational Research and Development,1970

Another way of assessing the NSF-supported programs is to consider their effect on the environment or atmosphere in the school community. The availability of, and easy access to, materials that can engage each child in experimenting means that a rich learning environment can be created. The classroom using new curricula can be more responsive to individual tastes and interests than what we think of as the traditional classroom, which may still be characterized in the words of Charles Dickens:

> "'Now,what I want is Facts. Teach these boys and girls nothing but Facts. Facts alone are wanted in life. Plant nothing else, and root out everything else. You can only form the minds of reasoning animals upon Facts: nothing else will ever be of any service to them. This is the principle on which I bring up these children. Stick to facts, sir!'

The scene was a plain, bare, monotonous vault of a school room .... "

Charles Dickens
Hard Times, 1854

That elementary science education can be vital is not a novel idea of this decade. Fifteen years after Charles Dickens attacked apparently sterile educational environments, T.H. Huxley, clearing away some of the musty underbush of primary education, wrote:

"If the great benefits of scientific training are sought, it is essential that such training be real: that is to say, that the mind of the scholar should be brought into direct relation with fact, that he should not merely be told a thing, but made to see ... that the thing is so and not otherwise. The great pecularity of scientific training, that in virtue of which it cannot be replaced by any other discipline whatsoever, is this bringing of the mind directly into contact with fact, and practicing the intellect in the completest form of induction; that is to say, in explaining to a child the general phenomena of Nature, you must, as far as possible, give reality to your teaching by object-lessons; in teaching him botany, he must handle the plants and dissect the flowers for himself; in teaching him physics .... Don't be satisfied with telling him that a magnet attracts iron. Let him see that it does; let him feel the pull of the one upon the other for himself. And, especially, tell him that it is his duty to doubt until he is compelled, by the absolute authority of Nature, to believe that which is written in books.

Pursue this discipline carefully and conscientiously, and you make sure that, however scanty may be the measure of information which you have poured into the boy's mind, you have created an intellectual habit of priceless value in practical life?"

T. H. Huxley,
Scientific Education: Notes of an After-Dinner Speech, 1869

If one simple distinction is to be made between a traditional science curriculum and the new curricula it is that the new programs permit students and teachers to gain first-hand knowledge through individual experimentation rather than by reading about an experiment. The textbook is transformed from a heavy compendium of all knowledge into a series of pamphlets and exercises that accompany the varied course materials, and each child can do his own experiments with them. A host of learning aids -- from filmstrips and film loops to inexpensive but accurate balances and microscopes -- are integral parts of new science programs.

Consider the kind of science experience that a young student might have in this Massachusetts system:

"At present our science program might possibly challenge a moron. It is so traditional and dated that it is a burden for me to even visit the classes. The level of real student inquiry is abysmal. Of the current staff, one is an enthusiastic novice lacking any real exposure to any innovative science programs and the other has the graceful sensitivity of a wanton rhino and totally alienating most of the science students. The secondary supervisor considers the elementary program with disdain and to my knowledge has never observed an elementary science lesson .... Our science equipment is minimal. In addition, most of it is never used. The students view fifteen to twenty-five demonstrations a year. In short, if national scientific awareness were dependent upon a norm equal to ours, we would have a national disaster."

And compare the above description (by a Massachusetts science coordinator) with the following one by an elementary school principal:

"In the primary building in our open classrooms it's pretty obvious that science has a fairly large role in the child's play. If you walk into a room you will see a minimum of ten to fifteen animals -- mice, gerbils, rabbits, turtles, guinea pigs, and many different plants. In our general program we are trying to teach the children how to observe. The whole process of observing skills starts in the first grade and gets going in the second grade. All the animals provide the children with information to put in their journals. This observational work is considered language arts; somebody else might consider it science. That's fine with me. The better teachers have taken all labels off the curriculum, and others are getting to that point. In job sheets there still might be the words <u>science</u>, <u>math</u>, <u>English</u>, <u>art</u> and <u>social studies</u>. Most of our rooms have water tables and sand tables and a great deal of work is being done with water play. This work could be classified as science. Sink and float. Oceanography. Pond water. Surface tension. The children do such things as graphing and again that could be math or science. Simple bar graphs are being made by seven-year-olds."

How do children feel about having the new science programs and about learning in a nontraditional environment? A Massachusetts coordinator asked some children:

"We organized opposing conditions in the classrooms, some with a lot of stuff or materials, some with a quantity insufficient to allow each student to do his own experimenting during the entire class period, and some classrooms with a minimum of materials. We asked each kid which lesson he liked best and tallied and analyzed their answers. The classes studied the same topics, used the same units, but some had loads of stuff to work with and some had not enough to go around and some had next to nothing. Invariably when kids had a choice, it was for the science lesson with lots of materials. Let's say eighty percent of the students preferred the classes that had the most stuff. That was the information I needed. Materials make a large part of the difference."

A Chinese scholar at the Yenching Institute at Harvard University was asked to confirm the veracity of a Chinese proverb that has gained much currency in elementary education -- in science especially -- in the United States and England. He looked at the proverb and said, 'Ting te wang laio, Kan tao chi te. Tso kuo tung te.' There is no such proverb in China but it is a good thought: in Chinese it would say, if indeed it existed, 'If you perform the work, you'll understand it.'"

THE CURRENT PERSPECTIVE: SIGNIFICANT QUESTIONS IN SEARCH OF ANSWERS

In examining the four NSF curricula in elementary school science, it is easy to distinguish the different thrusts among them. One NSF program emphasizes the concepts and conceptual schemes; another stresses the processes of science; another aims to develop a scientifically literate person; and the last desires most to take advantage of a child's natural curiosity, to grow along with their curiosity and does not emphasize concepts or doctrinaire processes. Yet, in recognizing these differences and perhaps conflicting philosophies and approaches -- we might ask: is it not the intent of each program to produce the foundation of scientific literacy and to encourage the student to become familiar with the conceptual schemes, processes and investigatory functions of science?

What is a scientifically literate person? Can he even be defined?

A statement on school science education for the seventies, prepared by the National Science Teachers Association, reads as follows:

"The scientifically literate person

* uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment;
* understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories;
* distinguishes between scientific evidence and personal opinion;
* identifies the relationship between fact and theory;
* recognizes the limitations as well as the usefulness of science and technology in advancing human welfare;
* understands the interrelationships between science, technology, and other facets of society, including social and economic development;
* recognizes the human origin of science and understands that scientific knowledge is tentative, subject to change as evidence accumulates;
* has sufficient knowledge and experience so that he can appreciate the scientific work being carried out by others;
* has a richer and more exciting view of the world as a result of his science education;

* has adopted values similar to those that underlie science so that he can use and enjoy science for its intellectual stimulation, its elegance of explanation, and its excitement of inquiry;

* continues to inquire and increase his scientific knowledge throughout his life.

Which of the new elementary science programs contributes most to the development of a scientifically literate adult? In the pragmatic world of the elementary school, we look for curricula that reach as many children as possible without limiting the ablest children and without losing the less able. We ask:

* Will students and teachers be equally interested in the physical, biological and earth science, and does this program serve those interests?

* How much will it cost to implement the new curricula? How much will it cost to sustain a program yearly?

* How necessary is it to provide inservice and workshop training for teachers of the new curricula?

* Will the new curricula help children increase their mastery in basic competency skills in reading and arithmetic?

* What are the experiences of others using the new curricula?

* How do teachers who have used the new programs view them? Do they feel that they are significantly different from the traditional science textbook?

* Do the new curricula require additional teaching time in the classroom and in preparation time for the teacher?

* Are special facilities and physical settings required for the new curricula?

* How are the new curricula used in an informal classroom and in an integrated day approach?

* Should a new curricula be introduced as a trial or pilot program? How should it be monitored?

* How have others evaluated the new curricula? Are there gains in learning?

* Will the new curricula become outdated rapidly?

* What are some of the differences among the new curricula?

* Do the new curricula make extra demands on principals? What have been some of their experiences with the new program?

* Is it essential to have a K-6 science coordinator to operate the new programs successfully?

* How important is it to involve teachers in the curriculum activity?

* How do children like the new curricula? Do they really have an opportunity to do more science than in a traditional course?

* How do teachers feel about the structure of the new programs?

* Is it essential for teachers of the new curricula to have strong science backgrounds?

Other important questions that might be asked are:

* What are the characteristics of the most innovative systems?

* How adequate are the teachers' guides of the new curricula?

* If a school is not in a position to adopt new curricula, should it supplement present materials in use? If supplementary materials are adopted, is it necessary to train the teachers?

* Will teacher training continue without NSF support?

* How great is the danger of a school adopting materials that are unsuited for it, and how can this error be avoided?

* Who must approve an adoption of a new curriculum by the schools before it can be introduced? What is the best method for gaining approval?

* Do the activity-centered new curricula create undue noise and discipline problems?

* Is there any carryover from an activity-centered science classroom into other classrooms?

Any one of the new elementary science programs can be viewed from a distinctive background and attitude toward the education of young children. Structure, process, conceptual thinking, freedom, discovery -- each word may strike strong responses. In the complex and buffeted social setting of public education, it is important to try to remove some of the emotional overtones from our judgments. This report attempts to answer some of the significant questions about their quality and their use.

IV

ELEMENTARY SCIENCE IN MASSACHUSETTS

HOW WIDELY ARE THE NSF ELEMENTARY SCIENCE CURRICULA BEING USED IN OUR SCHOOLS?

Our first objective was to discover how widely the National Science Foundation-supported programs were being used in Massachusetts schools during the academic year 1971-1972.

A questionnaire was sent to the 244 school superintendents in December, 1971. Responses were received from 214 systems (88 percent) that represent 90 percent of the elementary schools in the state, 92 percent of the teacher population and 96 percent of the student population. The superintendent usually delegated the task of answering our questionnaire to the person in his system who was primarily responsible for elementary science. This happened in 166 systems; the superintendent answered himself in the remaining systems.

Q. 1. <u>To what extent are NSF curricula being used in Massachusetts systems?</u>

A. 1. The new curricula are being used in 116 systems, 48 percent of all systems with elementary schools. The extent of use varies from several classrooms or several schools in a system to total adoption in all elementary grades. We estimate that nearly 20 percent of the classrooms are using the new curricula and that roughly 78,000 children are studying NSF science programs. This means that about 13 percent (or slightly higher) of the children in Massachusetts public elementary schools are learning about science from the new programs.

Q. 2. <u>How many systems are committed to the new curricula as the major elementary science activity?</u>

A. 2. Forty-five (18 percent) of the 116 NSF systems are committed to the new curricula as a major district program. Among these systems, there was strong evidence of commitment in thirty-three systems (13 percent) and an ambivalent attitude toward them in twelve systems (5 percent).

Seventy-one systems (29 percent) use the new curricula but are not committed to them as the major program in the system. Twenty-seven of these systems (11 percent) apparently have chosen NSF curricula either for some grades only or as supplementary materials to other science programs. The remaining systems are using the new programs to a limited extent and give no indication of a strong commitment to them.

Q. 3. To what extent is each of the four major curricula being used by Massachusetts school systems?

A. 3. SCIS

Forty-five systems report they are using SCIS in one or more of their schools. This represents 40 percent of all systems reporting use of an NSF program and 20 percent of all systems responding to the survey. Following is the breakdown by grade levels of the use of SCIS:

Grade	Number of Systems Reporting Use at This Grade Level	Percent of Total SCIS Systems Reporting Use at This Grade Level
K	12	27
1	35	80
2	35	80
3	28	64
4	18	41
5	15	34
6	2	5

ESS

Seventy-three systems report they are using ESS in one or more of their schools. This represents 64 percent of all systems reporting use of an NSF program and 33 percent of all systems responding. Following is the breakdown of the use of ESS by grade level:

Grade	Number of Systems Reporting Use at This Grade Level	Percent of Total SCIS Systems Reporting Use at This Grade Level
K	25	34
1	39	53
2	42	58
3	46	63
4	59	81
5	59	81
6	62	85

AAAS

Thirty-nine systems report they are using AAAS in one or more of their schools. This represents 34 percent of all systems reporting use of an NSF program and 18 percent of all systems responding to the survey. Following is the breakdown by grade level of the use of AAAS:

Grade	Number of Systems Reporting Use at This Grade Level	Percent of Total AAAS Systems Reporting Use at This Grade Level
K	20	51
1	37	95
2	35	90
3	29	74
4	17	44
5	11	28
6	3	8

Minnemast

Nine systems report they are using Minnemast in one or more of their schools. This represents 5 percent of all systems reporting use of an NSF program and 3 percent of all systems responding to this survey. Following is the breakdown by grade level of the use of Minnemast:

Grade	Number of Systems Reporting Use at This Grade Level	Percent of Total Minnemast System Reporting Use at This Grade Level
K	6	67
1	6	67
2	6	67
3	4	44
4	0	0
5	0	0
6	0	0

From this information we learn that ESS is the most widely used NSF program, followed, in order, by SCIS, AAAS, and Minnemast. (Minnemast, a K-3 program, is not available through commercial publication as are the other three.) SCIS and AAAS are more popular in the early grades, while ESS is used primarily in grades four to six.

About fifty school systems are using more than one of the NSF programs.

Q. 4. What is the relation between the use of NSF programs and the size and per pupil expenditure of the school systems?

A. 4. The highest proportion of NSF use (100 percent) is found among systems in the very large (over 10,000 elementary pupils) and middle (2,000 to 5,000 pupils) (67 percent) sized categories. Half of the responding school systems in the under 1,000 pupil category reported using NSF programs. Of the school systems spending over $900 per elementary pupil, 90 percent report using

NSF programs. Only about 30 percent of those spending less than $600 per pupil were among the users.

Q. 5. <u>How many dollars per pupil are spent on elementary science?</u>

A. 5. In the small number of questionnaires that contained a specific answer to this question, the modal amount for materials was under $1.00 per year (or about one trip to a McDonald's hamburger stand) and only three systems reported spending more than $4.00 per year per pupil.

Q. 6. <u>To what extent do systems plan to expand the use of the new programs?</u>

A. 6. Of the systems reporting, 54 percent indicated they planned to expand the use of the new programs. Systems using SCIS and ESS were in the majority in expansion plans.

Q. 7. <u>How many systems have a method of evaluating elementary science curricula?</u>

A. 7. Only 79 systems (37 percent of all those responding) indicated that they had a method for evaluating elementary science programs. Although each of the NSF elementary science programs includes an evaluative scheme, our respondents tell us that they either are uncomfortable with the suggested evaluation schemes, do not follow them closely, or disregard them completely.

Data in later sections of this report show that the main standards teachers use in judging or evaluating their work in science are the interest and enjoyment of their students in the subject.

Q. 8. <u>How many systems currently are reviewing their science programs?</u>

A. 8. A total of 163 systems replied to our question on the review status of curricula decisions. Forty-two systems (26 percent) said they had a review presently underway. Eighty-six systems (71 percent) told us that they had completed a major review during the previous five years. We note that 16 (just under half of the 35 systems that reported neither a present nor a past review) are using NSF programs. Also, we learned that 24 of the 32 systems that are now reviewing their status in elementary science are using the new curricula.

Q. 9. <u>Are NSF programs more likely to be used in richer school systems?</u>

Q. 9. Unfortunately, yes. In systems that spend less than $700 per pupil the chances are that NSF curricula will not be found, while above $800 the new curricula are nearly certain to appear.

Q. 10. Do the systems make use of Federal Title funds?

A. 10. Of the systems reporting, 76 percent indicated that they had used Federal Title funds in their elementary science program at least once. Just which Titles have been used is discussed in Question 84.

Q. 11. To what extent have Massachusetts systems that once used the new programs discontinued them?

A. 11. At least six systems have used one or more NSF programs in the past and currently are using none. An additional six systems that seriously considered NSF programs eventually adopted a non-NSF program.

Thirty-two school systems or 20 percent of all of our respondents (one-third of all of those systems that have ever used an NSF program) have discontinued the use of at least one of the NSF programs but are still using one or more NSF programs.

Q. 12. How many systems give no evidence of being exposed to the new curricula?

A. 12. There are 128 systems (52 percent) among those reporting that are not using NSF programs. Forty-two of them (13 percent) have had some exposure to the new curricula; they have either discontinued or rejected an NSF program (5 percent) or they are considering the new programs. Forty-five systems (18 percent) apparently have never been exposed to the new programs or have not considered using them. Of this number, thirty-two are using a textbook program (13 percent) or Concepts in Science, a textbook series with science kits (5 percent).

Q. 13. Who hold administrative responsibility for elementary science?

A. 13. The principal or assistant superintendent are most commonly responsible for the elementary science programs. Of the 193 systems responding to this question, one-quarter reported the principal responsible and almost 40 percent reported the assistant superintendent responsible. Only 23 percent of the systems have a designated science coordinator.

Person Responsible for Elementary Science	Number of Systems	Percent of Total
Principal	48	25
Assistant Superintendent	43	22
Assistant Superintendent (Elementary)	33	17
K-12 Science Coordinator	27	14
K-6 Science Coordinator	18	9
Specialist	8	4
Science Committee	5	3
Science Department Head	2	1
Others	9	5

Q. 14. To what extent do Massachusetts systems have new programs on trial?

A. 14. It is difficult to determine what constitutes a trial. A trial may be viewed as a means of assessing the appropriateness of a curriculum in a system, a way to learn about the new programs by limited use or as a way to avoid making a total commitment to the new programs. Twenty systems (9 percent) reported using new curricula on a trial basis, and nine of them indicated little use over a long period of time.

Less than 5 percent of the systems using NSF programs introduced a new program simultaneously in all grade levels of its elementary schools. Commonly, a first step in introducing the new curricula is to try it out first on a limited basis.

Q. 15. How do the respondents rate the quality of science teaching?

A. 15. Our respondents told us that about 33 percent of the teachers "do an excellent job" and 57 percent "do an adequate job, but do relatively better with math and reading." (The remaining number "do no science teaching.") Apparently, from an administrator's point of view, more than half the teachers do just an adequate job in science.

Q. 16. What kinds of provisions for science teaching are commonly available?

A. 16. In 85 percent of the school systems the classroom was the only place that science was taught. The other school systems had a science center to which the children could sometimes repair during their science period. Only two school systems did all of their science teaching in the science center. In 15 school systems the central facility -- it may be the science room -- is open only to teachers.

Q. 17. What is the approximate time spent in teaching elementary science by grade level?

A. 17. The average times spent on elementary science per week are recorded below:

Grade	Average Minutes of Science per Week
K	61
1	76
2	85
3	96
4	121
5	151
6	157

More time, on average, is spent on elementary science at each succeeding grade level.

Time is no indicator of the quality of instruction, but it does show that science is given an increasing importance as the child progresses through the elementary school.

Q. 18. <u>How many children are not studying science at all?</u>

A. 18. We assume from our data that all children have the opportunity to study science in the elementary grades. Roughly 78,000 out of approximately 600,000 children are using the new curricula; the rest are studying science from commercially purchased textbooks, local curriculum guides or locally developed science programs.

BRIEF SUMMARY

Data in this section show that the new programs are not being used widely in Massachusetts schools yet there is sufficient evidence to indicate a fairly strong interest in them.

Thirteen percent of our elementary students are being taught the new curricula. This figure is not high, but it is higher than the national average of 4.6 percent.

The new curricula are used in 116 systems or 48 percent of the systems with elementary schools.

SCIS is used in forty-four systems; AAAS in thirty-nine systems; Minnemast in nine systems; and ESS in seventy-three systems.

About fifty school systems are using more than one of the new curricula. Relatively few -- only six systems -- have discontinued the use of any of the new curricula and not continued to try out another one.

Fifty-four percent of the systems plan to expand their use of the new curricula.

Only seventy-nine systems (37 percent) have a method of evaluating the elementary science activity.

One out of every four systems in Massachusetts has never used any of the federal title funds to support elementary science activities, and more new curricula are likely to be found in the systems that have a per-pupil expenditure of over $800 per year than in systems spending less. Less than one-third of systems that spend less than $600 per pupil are using NSF programs.

Only forty-five systems have designated science coordinators, and of them twenty-seven systems have K-12 coordinators, and only eighteen have K-6 coordinators. The remaining systems give the responsibility to principals, assistant superintendents or other ranks.

About one-third of our teachers are doing an excellent job in teaching science, according to the respondents of this section's questionnaire, and more than half of the teachers do only an adequate job. More time is spent on science as a child moves from grade to grade, with the least amount of time in kindergarten (an average of 61 minutes weekly) and the most (157 minutes) in the sixth grade.

V

SCIENCE IN THE CLASSROOM

TEACHERS' ATTITUDES AND EXPERIENCES

In our survey of science teaching in Massachusetts elementary schools we are especially concerned with the experiences of teachers who use any one or any combination of the NSF programs. We are also concerned with the use of traditional science programs that include uni-text or multi-text approaches as well as locally developed curricula.

To differentiate between using a new elementary science curriculum and teachers using a "traditional" or textbook approach, we call teachers in the latter category "non-NSF teachers" and the teachers in the former category "NSF teachers." When the teaching includes a combination of NSF materials and traditional materials we simple describe the interweaving of the two. The NSF curricula will be noted by their initials in the following pages.

The field research of this study, done during the academic year 1971-72, would have been premature to undertake earlier because many school systems were making tentative explorations in the use of the new curricula and their experiences were limited or inconclusive. As Miriam L. Goldberg noted in her article "Evaluations of Innovations" in Strategies for Planned Curricular Innovation (Teachers College Press, 1970), "Thus, decisions about the merits of a new program can hardly be valid if they are made on the basis of a first trial, or before there is evidence that the people who are carrying out the new program have had a chance to become acclimated to it." The academic year we have chosen seems to be an appropriate one, allowing us to take advantage of much experimentation as well as of sustained experiences in implementing new science curricula during the previous few years.

Teachers in all of the elementary grades, representing eighty-three systems, large and small, in cities, suburbs and rural communities throughout Massachusetts, have aided us in this study. They have completed lengthy questionnaires, allowed us to participate in some of their classroom activities and willingly cooperated in extensive interviews.

There are approximately 26,000 elementary teachers in Massachusetts. A total of 814 elementary teachers are included in our sample -- representing slighly over 1,000 classrooms (some of the specialist science teachers teach more than one class) and with responsibility for roughly 25,000 students. From the teachers who have worked with us, we have been able to draw a fairly comprehensive picture of science instruction and to make inferences about the science teacher.

The teacher in our sample has spent an average of seven years teaching in the same system and has spent an average total of nine years in teaching. Ninety-sever percent of them have had at least one undergraduate science course, 12 percent have had at least six undergraduate science courses, and 73 percent have had science methods courses (only one out of every four teachers thought that the science methods courses were helpful). Eighty percent of the teachers considered their student teaching experiences helpful.

Ninety-four percent of the teachers in the sample are classroom teachers with general teaching responsibilities, and 6 percent are special science teachers. Eighty-six percent of the teachers are women. The average number of children taught in the science class is 26, and the deviation ranges from 21 to 31 children in the class.

Seventy-six percent of the teachers felt the need for a new science program (whether NSF or text) before they began using their current programs, but only 12 percent of the teachers helped select the new program in their system and only 20 percent in their schools. Forty-one percent were among the first teachers in the system to use the new program and 39 percent volunteered to use the new program.

Sixty percent of the teachers reported that they adapted and modified science units considerable and 37 percent said they taught the units as they were presented in the teachers' guide and workshops. (Three percent reported doing both.) Among the teachers who adapted units considerably, 55 percent did it to meet the abilities and needs of the students; 34 percent to make it fit with the facilities available; 30 percent to make it fit into the time available for science; and 29 percent to make it more compatible with their personal style.

Fifty-five percent of the teachers teach science as a separate subject. Twenty-two percent correlate science with other subjects. Five percent teach science incidentally as the need and interest arise, and only one percent teach science as an occasional enrichment for children who are interested in it. (18 percent had "other" ways of accommodating science in their teaching.)

Forty-one percent of the teachers reported that they stored materials in the classroom where children can easily get them. Twenty-three percent said they kept materials in a storage area until they were needed for a specific lesson, and 8 percent stored materials in the classroom but "safely out of reach." (Various other accommodations were made by 28 percent of the teachers.)

By presenting some of our information in the following sections as replies to questions, we have had the obligation to sift through some of the complexities and to try to avoid some of the irrelevancies.

QUESTIONS AND ANSWERS

The First Broad Issue

Q. 19. Do the NSF elementary science programs improve the quality of science in the classroom?

A. 19. Yes. Quality is improved. The following data support the use of these programs.

Q. 20. Do elementary school students like the new NSF elementary science curricula?

A. 20. Students using the NSF curricula like science more than students using the textbook approach. (Some of the children's wisdom is quoted in a later section.)

A larger proportion of NSF teachers (61 percent) than non-NSF teachers (55 percent) felt that their students liked science more than other subjects.

Q. 21. How do NSF teachers and non-NSF teachers compare in the perceptions of the progress of students in elementary science in relation to their progress in other subjects?

A. 21. A greater number of NSF teachers reported favorably on their students' progress in science. We learned that 62 percent of the non-NSF teachers felt that their students made less progress in science compared to their progress in other subjects; 38 percent of the NSF teachers felt the same way about the progress of their students in science.

Q. 22. Do elementary teachers like teaching science?

A. 22. We found that there is neither an overwhelming liking for science teaching nor an overwhelming dislike in the elementary grades.

One-fourth of the teachers in our entire sample said that they liked teaching science more than other subjects; another quarter said that they liked science teaching less. One-half the teachers in our sample reported that they liked teaching science the same as teaching other subjects.

Q. 23. Do NSF teachers like teaching science more than non-NSF teachers?

A. 23. Once a teacher begins using an NSF program the odds favor the new curricula. A higher percentage of NSF teachers (79 percent) liked teaching science more or the same as teaching other subjects than non-NSF teachers (65 percent).

Q. 24. Is there a relationship between how well teachers like teaching elementary science and their undergraduate preparation in science?

A. 24. Teachers with strong science backgrounds are more satisfied with teaching science than those with weaker backgrounds. Twelve percent of the teachers in the sample had taken more than six undergraduate science courses. Only 3 percent of the teachers have not had at least one science course as an undergraduate.

Q. 25. Have NSF teachers had a stronger science background than non-NSF teachers?

A. 25. There is no evidence that NSF teachers have had more undergraduate science courses than the non-NSF teachers. Therefore, we can assume that at least part of the NSF teachers' liking for science teaching can be attributed to the curriculum itself and to the classroom activities engendered by the use of the NSF programs.

Q. 26. <u>Which group (NSF or non-NSF teachers) feels its programs are more adaptable to different teaching styles, or more flexible? Which feels strongest about the program being suitable for a range of pupil differences?</u>

A. 26. NSF programs appear to be significantly different in the way teachers perceive the "suitability" of the new science curricula. NSF programs are more flexible than the non-NSF programs; they can be adapted more readily than non-NSF programs to meet student needs. Forty-two percent of the NSF teachers reported that their programs were "very suitable" for use by all pupils, while only 23 percent of the non-NSF teachers felt this to be the case.

NSF teachers more often reported that the NSF curricula were more flexible than did non-NSF teachers.

Q. 27. <u>Do the NSF curricula provide more opportunities for students to engage in science activities than the non-NSF programs?</u>

A. 27. NSF classrooms more frequently offer opportunities to "do" science and not just "read" about it than non-NSF classrooms, according to the teachers. This is hardly unexpected considering the supply of materials that come with NSF programs. Although there are no significant differences between the two in the writing of reports and making collections, displays, and models, other science activities reveal a difference. NSF classrooms do more experiments and record data from them than do non-NSF classrooms. Apparently one effect of being more active is to encourage independent learning: we found that activities such as taking home science materials and supplementary readings, and the like, occurred 25 percent more frequently in NSF classrooms than in non-NSF classrooms.

Q. 28. <u>How do science teachers feel about the adequacy of their teaching guides?</u>

A. 28. A higher percentage of the NSF teachers (80 percent) felt that their guides were adequate than did the non-NSF teachers (65 percent).

Q. 29. <u>Do the NSF teachers spend more time in class preparation than the non-NSF teachers?</u>

A. 29. Yes. A higher percentage of the NSF teachers feel that their programs require "much more" preparation. On a one to four scale, 38 percent of the NSF teachers, compared to 22 percent of the non-NSF group, felt that their programs require a great deal of preparation. In view of the evidence that a high proportion of NSF teachers like teaching science "the same or more" than teaching other subjects, we may assume that the NSF programs have succeeded in enlisting teacher support, even though more time and effort is required.

Q. 30. <u>How do NSF and non-NSF teachers feel about the science programs' suitability in meeting the needs of boys and girls?</u>

A. 30. On the average, NSF teachers feel more strongly than non-NSF teachers that the new curricula are better suited for meeting the interests of both boys and girls.

Q. 31. <u>Do NSF teachers get together to discuss science more often than the non-NSF teachers?</u>

A. 31. They do. The data reveal that 37 percent of the NSF teachers often discuss problems and share ideas, compared to only 18 percent of the non-NSF teachers. This is a very significant result because a successful science program is predicated on the sharing of ideas among teachers and their willingness to talk about mutual problems. With NSF programs newer teachers presumably would more readily seek and receive advice from the more experienced teachers -- an excellent form of "in-service" training.

We found no evidence to show that NSF teachers had more free time during the day than non-NSF teachers, or that their schools were administered in a different fashion, to encourage informal discussions.

Q. 32. <u>In rating their own performance as elementary science teachers, how does the NSF group compare with the non-NSF group?</u>

A. 32. Twenty percent of NSF teachers rated their own classroom performance in science teaching excellent. Only 10 percent of non-NSF teachers rated their performance in science teaching excellent. (Previously we noted that administrators considered that 33 percent of the teachers do an excellent job of teaching science. It may be comforting to some to know that teachers are more servere than administrators in rating their own performance in the classroom.)

Q. 33. <u>Do the NSF curricula require more teaching time in the classroom than the non-NSF curricula?</u>

A. 33. Apparently not.

It might be possible to conclude that the NSF programs do not require more time than the non-NSF programs, since our data show that NSF teachers spend less time on the average teaching science -- measured on the standard minutes-per-week measurement -- than the non-NSF teachers. This answer is not conclusive, however, because the major portion of NSF curricula is presently being taught at the primary grades, K-3, rather than the upper elementary grades, 4-6, and less time is spent on elementary science in the lower grades.

BRIEF SUMMARY

The NSF curricula allow teachers to be responsive to a wider range of pupil differences than non-NSF courses. The slow learner can be reached more readily while the ablest child simulataneously is being challenged.

NSF teachers like science teaching more than teachers using textbooks.

Students make better progress in science -- compared to their progress in other subjects -- in NSF programs than they do in non-NSF courses. And students in NSF classrooms more frequently engage in scientific experimentation than students in non-NSF classrooms.

The greater the concentration in science as an undergraduate the greater the likelihood of a teacher's liking science. However, since we have no data to reveal that NSF teachers have a stronger science background than non-NSF teachers, the liking for science teaching among NSF teachers can be attributed to a certain extent to the NSF curricula themselves.

NSF teachers spend more time in class preparation than non-NSF teachers, and the NSF teachers feel more strongly than the other group that their teachers' guides are adequate.

NSF teachers do not adapt their material more, for whatever reason, than do non-NSF teachers, but they do get together more often to discuss science with other teachers.

NSF teachers feel that their students make better progress in science than do non-NSF teachers feel about their students' progress.

NSF teachers rate their own performance in science teaching better than do non-NSF teachers.

NSF teachers feel that their curricula are better suited for meeting the interests of both boys and girls than do non-NSF teachers.

QUESTIONS AND ANSWERS

The Second Broad Issue

Q. 34. <u>Which program should we use in our schools?</u>

A. 34. We believe it is premature to answer this question. No one program seems to be best: each program, or combination of programs, appears to evolve into unique adaptations according to the dynamics of a school system. The following questions and answers are part of our process of arriving at a delineation of what factors appear to make a difference.

Q. 35. <u>How do the teachers of the four NSF programs -- ESS, SCIS, Minnemast and AAAS -- compare in their perceptions of the suitability of the curricula to meet the needs of all pupils?</u>

A. 35. SCIS teachers rank this program highest in being suitable in serving a range of pupil differences. ESS teachers agree moderately that their program is suitable for all students. Minnemast teachers feel slightly less often than not that their program has suitability for a range of pupils. AAAS teachers feel strongly that this program is more limited in meeting a range of pupil needs.

Q. 36. <u>Which programs require the most classroom preparation by the teacher?</u>

A. 36. AAAS and SCIS teachers felt that their programs required significantly more preparation than did the teachers of ESS and Minnemast.

Q. 37. <u>Do teachers of NSF programs believe that the teachers' guides for some programs are more helpful than for others?</u>

A. 37. No difference. The teachers of all four NSF programs felt that the guides were adequate.

Q. 38. <u>How do teachers compare the flexibility and "structuredness" of the four programs?</u>

A. 38. We asked the teachers using the different curricula to reply to the following question about the program they were using: "Characterize it on a scale of one to four, from <u>very structured</u> to <u>very flexible</u>."

Teachers' opinions about structure and flexibility differ significantly depending on which program is being used. Classes using ESS alone or a combination of NSF programs were considered by the teachers to be "very flexible." Minnemast teachers rated this curriculum slightly less flexible. SCIS teachers feel that program is in the middle ground -- neither "very structured" nor "very flexible." AAAS teachers feel more strongly than any other group that their curriculum is "very structured."

Q. 39. <u>Do the new curricula create an undue amount of noise in the classroom? Are there classroom management and discipline problems uniquely associated with science classrooms that encourage student activity?</u>

A. 39. Some observers believe that interactive classroom environments -- especially those that may be encouraged by the availability of materials that allow each child to engage in his own experimentation and to discuss his work with his peers -- create classroom management and discipline problems. Yet from our data we infer that the NSF curricula do not create undue problems. A larger percentage of NSF teachers (60 percent) than non-NSF teachers (46 percent) felt that the "noise" and activity in their classrooms were in no way disruptive of teaching and learning. Teachers prefer, apparently, to see students involved and working with one another in busy, active classrooms. (At the extreme, only 4 percent of the NSF teachers and 3 percent of the non-NSF teachers felt uncomfortable.)

Q. 40. Do the activities in the NSF program appear equally well to boys and girls?

A. 40. The teachers of all of the NSF programs felt that the programs appealed equally to boys and girls.

Q. 41. What do the teachers say about some of the obstacles or impediments that keep them from teaching science the way they would like to? Does any one group of NSF teachers feel that there are fewer hindrances than the others?

A. 41. Some programs require more storage space, more facilities, more administrative support, more time. Whether the lack of any of these actually constitutes an impediment is difficult to assess, yet teachers of the four programs differ significantly in their perceptions of some of the obstacles. Teachers who are using a combination of new curricula feel that there are fewer obstacles, followed by ESS, Minnemast, SCIS and AAAS teachers.

Q. 42. Which of the NSF programs offer children the most opportunities to engage in scientific investigation and exploration? Are there any differences among the programs in the amount of scientific activities offered in the classroom?

A. 42. There is no important difference among the programs in "core activities," by which we mean the opportunity to do experiments, watch demonstrations and record observations. However, there are differences in "complementary" and "traditional" activities, by which we mean such activities as taking home materials, using supplementary readings and using science texts to buttress the experimentation in the classroom. ESS ranks highest here and is followed, in order, by Minnemast, combinations of NSF curricula, AAAS and SCIS.

It appears, then, that in the view of the teachers of the different programs, children using combinations of new curricula, ESS and Minnemast, have the most opportunities to "do" science.

Q. 43. What percentage of teachers have had in-service training in elementary science?

A. 43. Forty-seven percent of the teachers have had in-service experiences.

Q. 44. How vital a part of the curriculum experience has the in-service training program been? Have most NSF teachers attended in-service programs or workshops?

A. 44. Further educational opportunity for teachers was a vital component of curriculum reform in the sciences in the high school. Until the past year, almost any interested high school science teacher could attend an NSF summer institute in his particular subject or program. Similar opportunities for elementary teachers -- there are more than one million in the United States -- have been very limited.

Much of the training of teachers occurs within the system, especially at the elementary level. The NSF elementary teachers, we learned, have not been offered many in-service opportunities within the system; about 40 percent of them have been able to participate in training programs within their school systems in Massachusetts; 60 percent have not. ESS teachers appear to have had less in-service work than the other NSF teachers. (It is important to remember that teachers of ESS alone and teachers of NSF combinations were more satisfied with their science teaching than the teachers of other NSF curricula.)

A slightly larger proportion of SCIS teachers (59 percent) choose to attend in-service programs when they are offered by their school systems than do the teachers of the other NSF programs (45 percent).

Q. 45. How many teachers have attended institutes or training programs held outside of their school system?

A. 45. Twenty-nine percent of the teachers (both in NSF and non-NSF) in our sample reported that they attended one or more training programs held outside their system. These were held during the summer.

In addition, nearly one-half of the teachers in our sample (both NSF and non-NSF groups) said that they attended in-service sessions held by other school systems. Slightly more than one-half of the teachers (again, both NSF and non-NSF) have attended one or more in-service training programs of one sort or another.

Q. 46. What relationships exist between a teacher's liking for science and attendance at a summer workshop or institute?

A. 46. Teachers who have attended summer workshops like science more. Whether the summer experience increases teachers' liking for science or not is hard to say; they may well have liked science before they volunteered for a summer program. In any case, teachers who like science seem to attend more summer science programs than those who do not. The summer programs do not appear to decrease a teacher's liking for science.

Q. 47. Do teachers who have attended in-service programs feels that their students make better progress in science than the teachers who have not attended in-service programs?

A. 47. They do. Teachers who have not been to workshops or attended in-service sessions feel that their students make less progress in science than they do in other subjects.

Q. 48. Do teachers who have participated in in-service programs feel that their students like science better than the students of teachers who have had no in-service experience?

A. 48. No. It may be because as we have already seen, most children do like science.

Q. 49. Does participation at summer workshops increase the capability of teachers? How do those teachers feel about their own skill in teaching science?

A. 49. Two-thirds of the teachers who attended workshops in the summer rated their teaching skill in science as either better or the same as their skill in teaching other subjects. Slightly more than half the teachers who have not attended workshops felt this way. This might indicate that summer workshops simply increase a teacher's confidence generally; but perhaps it also helps to have some special help in planning the next year's lessons.

Q. 50. Do the NSF teachers who have had in-service training adapt materials more often than the NSF teachers who have had no such training?

A. 50. No.

Q. 51. Do school systems make use of a teacher's experiences at workshops by involving them in the selection of a new NSF elementary science program?

A. 51. It seems that more systems than not value the judgment of the teacher who has attended an in-service program and teachers with in-service experiences have had a hand in selecting the program. However, it is impossible to determine from our data whether school systems valued their teachers' opinions and thus sent them to teacher training programs or whether their opinions were valued simply because they had attended training programs.

BRIEF SUMMARY

To teach science well requires persistent, hard work, and some curricula make more demands upon the teacher than others. There must be a willingness and interest on the part of the teacher to expand herself if she is going to learn how to become a better teacher. The NSF curricula represent a severe departure for many teachers in the elementary grades, moving from a "production" approach encouraged by the use of textbooks to an activity-based, open-ended laboratory investigation of science. The question could be: which of the NSF programs .low the easiest transition by the teacher from the text to activity programs?

But the more appropriate question is: which program appears to have the most characteristics that satisfy the largest number of teachers?

In the main, elementary teachers like the new NSF programs although these programs require more hard work than the non-NSF programs. The difficulty for the teacher can be mitigated by the teacher's desire to find more rewarding science experiences for the student.

How do the NSF programs appear to have the potential of reaching large numbers of students, and which of them appear to have created a more favorable climate than others? SCIS and Minnemast appear to be better suited to reach a wider range of pupil differences; but teachers using a combination of NSF programs followed by ESS teachers, feel that these programs are the most flexible. However, the danger in forcing a conclusion regarding the most favored program or programs is made greater by the recognition that the teachers of NSF combinations feel that their students have less opportunity to "do" science than the teachers of ESS or Minnemast.

While NSF teachers of each curriculum feel that the teaching guides are equally helpful, we learn that AAAS and SCIS teachers feel that more time is required in preparing for classes than teachers using the other programs. We know also that the data indicate a greater satisfaction with science teaching among all of the NSF group than the non-NSF group.

Hybrids, we learn from biology, are often stronger than the pure strain, and the evidence we have indicates that teachers using a combination of NSF curricula come out with many points in favor of using several of the new programs.

The majority of NSF teachers have not had in-service work in science, and ESS teachers have had less in-service work than the other NSF teachers. SCIS teachers have had the most. Most of the in-service programs occur during the school year, although the teachers favor a concentrated effort during the summer. Not many teachers appear to have participated in NSF workshops or institutes, but teachers who have had summer workshops like teaching science more than other teachers. In-service work, in general, apparently increases the confidence of teachers in their science classes, and teachers without any in-service experience feel that their children make less progress in science than do the teachers who have had in-service training.

There is some indication that school systems value their trained elementary science teachers, since these teachers are often involved in selecting the science programs.

Two myths are dispelled: the NSF teachers are not bothered by "noisy" classrooms that the activity-centered NSF curricula tend to induce; each of the programs creates a not unacceptable level of noise. Teachers would rather see their children keenly interested in what they are doing even though they are not quietly sitting at their desks. We learn, too, that the NSF elementary science programs appeal equally well to boys and to girls.

QUESTIONS AND ANSWERS

The Third Broad Issue

Q. 52. How do teachers compare the new programs with traditional or non-NSF programs?

A. 52. The answers run strongly in favor of NSF-supported curricula. Each response is from a teacher using an NSF program or a combination of NSF programs -- with only several exceptions. The ratio of favorable comments to adverse ones was about 60:1. These selections sound one-sided but they represent the points of view of teachers and these comments indicate that the statistics understate the positive aspects of the NSF curricula.

"In using the (non-NSF) text, I found the material slightly outdated for the children. Often it was difficult to organize the needed materials for related experiments. With the use of (NSF programs), the children and I have a quantity of equipment at our finger tips. In addition, there is not text (that is, reading) involved so there is a total participation from the slowest to the brightest of children. Also, the children are now more concerned with ways to find conclusions rather than exact fact."

"(Non-NSF) text -- structured, also teacher-centered rather than student-centered."

"I will never voluntarily use a science text again as a basis of a science program. We're not using a single program now but parts and pieces of several (NSF curricula)."

"Current system (NSF) is best yet."

"All have been good, it's the teacher's interpretation and presentation that counts."

"I have used very teacher-centered, demonstration-type programs -- with text and without. They are very unsatisfying to both teacher and children. I much prefer child-centered science study (NSF) -- where kids mess with stuff and talk and write and read about their interests."

"They (non-NSF) are less exciting."

"(Combination of NSF curricula) -- The children had individual kits and materials to work with. They had an opportunity to discover and experiment themselves and to record their findings."

"(NSF). Gives good concepts and ideas."

"I feel that our (NSF) program is the best one I have come in contact with in my school system. (NSF) was better than our text book series."

"We use the best of all the current programs (combination of NSF curricula), rewriting them to fit our particular needs. If we can't find something we like, we write our own programs."

"(NSF) -- the materials are packaged for easy use."

"Textbooks: horrible."

"I do feel that NSF is much more adaptable to a normal classroom environment, taking into account individual differences and intelligence levels. I also feel that many of the (NSF) teacher guide booklets and units are adaptable without the tremendous expense that is incurred in other programs."

"(Non-NSF) text more reading than doing. Teacher should teach/guide leading children to discovery."

"Didn't use any specific program (non-NSF) -- more mishaps."

"(Non-NSF) text too simplified."

"(NSF combination of curricula) are much more flexible and take into consideration individual differences than a specific grade text book."

"I previously have used only the (non-NSF) curriculum. (NSF) is much better."

"Taught from textbook before. Difference -- all children seem to take part well with the present program (NSF). Everyone seems to gain something."

"Feel that children gained more knowledge with the (non-NSF) system."

"Changed over from a textbook concept to an (NSF) concept. Much more successful."

"Curriculum guide (non-NSF) -- not any definite program. Units made out from different textbooks. Since the new NSF program has been in use only two months it is too early to evaluate and compare."

"(1) Less noise (standard textbook approach); (2) very expensive (New inquiry type programs -- NSF curricula combination)."

"I like a program (NSF) that can be individualized or used with small groups. I like a whole class project at times that everyone can succeed at. I want every child to feel success."

"(Non-NSF) not as well put together or as legitimately scientific."

"The science program I used was just texts. The teacher had to 'come up with' the materials. The (NSF) program that I am using now supplies the materials. It is 99 percent better."

"I found that children are the most interested in science experiments that they see or use daily. An incidental approach on the primary level is far superior to a very structured approach. They often at this age figure out different experiments and demonstrations themselves."

"I find our present program (NSF) excellent, easy to teach, good teaching guide, high pupil interest."

"This (NSF) program allows the children to discover things for themselves. They learn a litte about the scientific method -- observing, testing, recording, drawing conclusions -- which certainly is helpful in developing independent thinking habits."

BRIEF SUMMARY

Several teachers offered criticisms of changing over from a textbook approach to an NSF elementary science curricula; one teacher felt the children gained more knowledge in a text approach. Another teacher said that all of the programs have been good but that it was the teacher's interpretation and presentation that counted. The criticisms of these few teachers -- and none of us would dispute the teacher who pointed our that the teacher's interpretation is crucial to the success of any program -- appear, however, as minor cavils in comparison to the responses of the teachers who greatly prefer the NSF programs.

No overriding reason for teachers' preference for the NSF curricula is apparent (this we might view as the strength of the NSF programs; they evoke varying responses in the classrooms). Several teachers mentioned the interest-creating potentialities in the NSF curricula, the child-centeredness of the individual investigations and reporting, the flexibility of these programs, the inherent possibility in them of reaching students of different interests and abilities and allowing them to feel success, the high pupil interest, the need to no longer scrounge up materials, and the good teaching guides. One teacher said that the NSF programs were more scientifically legitimate.

Some mentioned the advantages of an incidental, discovery-oriented approach that encouraged an exciting reciprocity between thinking and doing, leading the child and the teacher into a more creative and satisfying partnership.

The textbook experiences were stultifying to most of the teachers.

OTHER ISSUES

Q. 53. <u>What do teachers say about their science classes?</u>

A. 53. We asked teachers open-ended questions to gain their personal impressions. The questions and their answers are in this section.

Here are some replies from teachers using NSF programs in the classrooms to the question, "What comments can you make about how science is going in your classroom."

"Science is thoroughly enjoyed by my pupils and we usually have several projects going -- mine plus their individual interests. Lack of preparation time is a problem as well as large class size."

"It's an on-going thing. All kinds of animals; gerbils, rabbits, chameleons, fresh and salt water aquariums. Also do many experiments. I tend more toward biological sciences."

"Very popular; high involvement in general. No discipline problems."

"Specific activities set up for children to work with independently or in small groups. Class discussions held to share findings."

"The time element seems to be the most difficult problem. Since I enjoy unstructured science classes with great pupil experimentation, I must 'fight' the clock."

"Remains a special time -- almost has the aspect of entertainment gee-whiz act."

"Continuous enthusiasm for it on part of children. Not enough time to try everything the programs have to offer."

"Very well -- with noise and organization and 'Hey, look at this' bounding off the walls."

"On the whole, I think it is successful although some children still don't participate actively in discussions. All children are usually very excited and involved during experiments."

"When I do have science I feel the children enjoy it and learn from the experiments and discussions. I give reading and math most of my attention because I feel they are most important. Science will often suffer due to lack of classroom time."

"At times very interesting, good responses -- good thinking. Other times it's a drag."

"I have found the discovery method of teaching science successful. The children seem to enjoy these lessons."

"Class enjoys science -- A few have specific interests."

"Science is a major portion of the 'obvious' curriculum. I use the interest in science to teach reading, writing, and language skills as well as math. We have many animals in our room and we do lots of work with machines, electricity, water and its properties, planting, etc."

"Science is becoming a core subject and with individualized projects children are excited. Find difficulty organizing time and materials."

"In previous years -- poor science courses from untrained 'science teachers' or little science has caused present 1971-1972 class to be badly oriented with a very poor science attitude, disliking subject itself. I have gradually developed in most students a far happier, enjoyable and science-oriented attitude at this time. Some just don't like science but are working harder and seem to begin to enjoy it more now."

"I teach four sections of science and one section of social studies, so science had better be going well or I would be in trouble. Actually the adaptability of our program has been of great value. We have been able to present a concept through the lecture, discussion, demonstration method and then use a related (NSF)-type unit to cement the students' understanding of it."

"Whether I use a text or (NSF program) as a separate unit my personal philosophy and methods will not differ to any extent. The interest of the children is there because of interest in the subject matter and in the activities involved in the study."

"Mine is an informal classroom. Science is something the children choose to do on their own as well as a 'subject.'"

"Interest is high at beginning of unit. Dwindles after approximately two or three weeks. Difficult to determine how much children actually learn. Notebooks are kept -- often untidy; language often not very scientific. Children do not seem to know what they are supposed to see if left to discovery method only. Need to be prepared as to what to look for."

"I need a sink!"

"Science has to be done in a classroom which is not suited for many science projects. Also most of the equipment must be supplied by the students. Because of these two drawbacks many excellent science projects have to be abandoned."

"Science has been treated as a separate study with a certain time set aside for it. With little ones, science doesn't come in neat packages -- a youngster finds a caterpillar, wasp and brings them into class -- and that's when I feel science should take place."

To answer this question fully, it is necessary to present a selection of comments from teachers using textbook, or non-NSF, approaches. We will not present as many responses from the non-NSF teachers because the pattern is largely represented by the following selections:

"I wish it were going better but I don't like teaching from text or cut-and-dried systems and I find it difficult to always be racing around trying to gather materials to cover my class and see that each child or even teams of children have things to work with."

"There really isn't enough time to get into a unit thoroughly. Science is allotted two 40-minute periods a week. We are supposed to devote half of our school year to a unit on drugs. There isn't any equipment available for experiments nor is there enough time."

"Motivation is difficult due to lack of working materials."

"Need more lab kits -- 'active science' rather than 'textbook science.'"

"It is going fairly well, under the circumstances, I feel. I don't think elementary students need an hour of science every day and I find I just don't have enough materials to have an interesting class if it meets five hours a week."

"Most kids are bored with it. I try to make it interesting but I can't become enthusiastic over something when I have to do the entire unit alone, with no textual assistance. I'm sure the kids get the negative vibes."

"The children love it, but I lack materials and time."

"Pupils enjoy what we have had."

"It goes quite well and the thing that pleases me the most is that the children have strong follow through and with more materials I could interest children in more areas."

"Since many times textbooks are old editions the teachers need to develop projects and research which will involve students and update the information."

Here are some replies from teachers using NSF programs in their classrooms to the question, "What are the important factors you look for in assessing how your children are doing in science?"

"Are the kids involved and excited about what they are doing?"

"How they apply information we have discovered, researched or learned in everyday activities and related subjects."

"Methods of inquiry and observation. Curiosity. Projects. Feedback of outside information."

"Attitude and development of thinking processes; how to find answers and evaluate progress in a given area."

"Interest, ability to observe, classify and generalize."

"Motivation, understanding of concepts, completeness of record book."

"Can they seek orderly explanations of the objects and events explored? Can they test their explanations through a variety of activities?"

"Their understanding of, and ability to, apply scientific concepts that have been studied and investigated."

"The interest shown by students during discussion, part of this reflecting their preparedness, their wanting to volunteer in doing investigations and experiments and special reports. Their ability to develop basic concepts further, and finally quizzes, and unit test results."

"I look for abilities to use acquired information to generalize for new situations."

"Inquisitive nature. Seek solution to problems. Willingness to test hypotheses."

"Do they understand what they are doing? Are they able to make accurate observations?"

"How well they follow directions on an experiment. How careful they are in running experiments. How well they keep written records. How well they report their results orally. How well they draw conclusions from their results. Can they devise experiments to test theories they have?"

"Initiative and responsibility in designing and following through projects; observation and note-taking completeness; being able to share and work with others as well as to work alone. Development of skills necessary for simple classification, oral presentation or written expression."

"Showing of further interest, bringing in things from home -- or things found on trips -- questions come up long after unit is over."

"Independent reading on subject to further ideas."

"If they question me, they question each other, and then answer me, I feel that the answer they give is most often correct. Science is a questioning subject, the more questions that are asked, the more information each student will have to work with. When they put this information together, and form an answer, that is science. This is what I try to do with my classes -- teach them to organize and interpret data and form their own conclusions."

"The more attention they give to me -- shows more interest -- leads to more independent work. Interest and discovery."

"1. How abundantly they can generate hypotheses.
2. How well they can try out hypotheses.
3. How objectively they can judge their trials.
4. How often they compare notes for verification.
5. How often they 'do' science in their spare time.
6. How frequently they initiate discussions, experiments, etc."

"Interest. Curiosity. Cooperation. Willingness to bring in materials."

"Carrying over what they've learned. Enthusiasm."

"Learning by doing.
Learning by group work.
Learning by application.
Learning by association.
Observing where they were when unit began and what growth they've made during it."

"Do they investigate new ideas? Can they draw conclusions from the experimentation and data? Does their curiosity lead them to other areas?"

"Most evaluation is done subjectively based on behavioral objectives. It is possible to determine an improvement in ability or observe or record by teacher's judgment."

"Interest, participation. Finding a problem, experimenting, solving it -- sometimes in more than one way. Healthy discussion. High pupil participation."

"Their ideas and related questions. The ways they work with each other in science and correlated subjects."

"At a second grade level my biggest concern is that they enjoy science and are anxious to do the experiments."

"If the children are eager to test their ideas and reach conclusions on their own, I think the program is successful."

"As it all related the individual to his own world and his environment: opinions and attitudes changed for better appreciation of science; misconceptions cleared up and understood better; facts related to science as a means to better understand concepts; concepts understood according to individual's ability to discover and explore for himself -- guided by teacher as needed."

Here is a selection of comments to this question from teachers who are using non-NSF programs. (Relatively few teachers who are using non-NSF programs answered the question, "What are the important factors you look for in assessing how your children are doing in science?)

"The questions and inquisitiveness of the students. The amount of volunteering for projects."

"Thinking and taking in information and observation and drawing conclusions."

"Curiosity. Powers of observation. Ability to draw conclusions."

"Their abilities to think, reason, question, use resources, work together and do independent projects (assigned on their own)."

"Greater understanding, predictability and curiosity in the student relative to questions or things connected with science."

"Knowledge of general concepts. Enthusiasm. Willingness to try experiments."

"If they have enjoyed what they are doing and want to go on and do more."

"Independent reasoning and thinking -- the children in our school are very weak in this respect."

"Interest. Cooperation. Questions asked."

"Student interest and willingness of the student to further research the topics without teacher suggestion."

Here are some replies from teachers using NSF programs in their classrooms to the question, "Some people find that teaching science has influenced certain ideas and methods of teaching in general. What has been your experience?"

"Explaining ideas or thoughts in science has helped make me aware of the possibility of exploring and bringing out thinking processes in other subjects. Coming to conclusions because of what we know or have found out."

"More open to several different answers. Questions in all areas are more open-ended -- require more evaluative thinking and less stress on facts."

"The teacher becomes more used to expecting the children to look for and find their own solutions to their questions. Also in science, while the class does experiments, there is the chance to observe and help individuals."

"Teaching is an art that could very well be founded on this short question. Obviously in a science class the concept of this quote can be more closely followed than in any other. However, in teaching science, I have found myself trying, unsuccessfully at times, to use this as a basis for teaching in other subject areas. I feel that this idiom is true to the nth degree and it is what I'm shooting for during my teaching career."

"I have found that the children give many ideas to each other while working on experiments. They frequently come up with tests I might not even consider. They expand the curriculum to their needs. This can apply to other subject areas."

"Science is the easiest area to give the children a chance to discover something by themselves and to talk with their friends about their discovery. I have tried to use this approach in other areas, particularly math."

"Less concerned with noise and movement in the room, allowing more individual choice of activity. More activities around the room."

"I have found that a good science program requires skills of creativity -- critical thinking -- listening -- all essential and basic to the act of learning anything. In short, emphasis on 'learning how to learn.' It reinforces the teaching and learnings taking place in the child's total experience."

"It has made me more flexible in other areas. I am willing to let the children do more on their own."

"I am trying to become more open. I want children to have concrete experiences. I was always more open in my science classes even when I was a more 'structured' teacher."

"Teaching science has definitely influenced my teaching in other areas. During student teaching I found the class bored by my first few lessons and then worked on this weakness. It made me realize how important attitude can be in learning. I was able to gauge the children's attitude from my science experiences and it made me realize during other lessons just when something wasn't working and therefore lead the lesson in a more exciting fashion."

"It has lead me to use of inquiry, open-ended method of teaching in other subject areas with children making 'educated guesses' and then trying to gather data to support or demolish their hypotheses."

"It has convinced me that children are best motivated when they are involved in activities of interest to them, and that experiences arranged to expose them to concepts is superior to reading it in a book or hearing it from the teacher."

"I find that free thinking in science is fine but is not entirely applicable to other subjects. I base this judgment on the obvious tangeability of the science materials."

"I also found the science program we are using (an NSF combination) determines the way I teach science but not necessarily the other disciplines."

The few responses from our non-NSF teachers to this question follow:

"Because of the lack of materials and space, I feel the science curriculum has very little influence in teaching methods. In my particular case, my situation of being in a double-sized room which is over-crowded we can do little except read and discuss for short periods of time."

A teacher with a text series and lab kits wrote:
"Teaching science and seeing the interest pupils have when working by themselves has led me to using this method more and more in other courses. Also, I am finding that one subject is not isolated, and that information devloped in reading or social studies can be tied into science concepts, and also the other way around -- correlation makes a self-contained classroom an exciting adventure -- a piecing together of a puzzle."

Here are some replies from teachers using NSF programs to the question, "What aspects of college training and student teaching were -- or might have been -- helpful to you?

"Being able to make more materials that could be used when teaching."

"1. Demonstrations similar to classroom situations."
2. Manipulation of equipment; i.e., approach it as if a student and experience open-ended experimentation."

"Working with pupils, grades 1-12. This gave me an overall view from the teacher's point of view of the life of the pupil through his school years, an indication of his problems."

"I student-taught for eight weeks. I think more time would have been helpful. It would have been helpful if the methods courses really taught me something useful."

"My science methods course in college was totally void."

"Student teaching for two eight-week periods in two different systems I got an idea of the kind of diversity that is possible in the science program. I also student-taught at two grade levels and perceived the continuity of subject matter that seemed to be evident."

"My experience for three years on the playground helped me in teaching incidental science -- those science experiences that occur naturally: comparing and evaluating similarities, differences, etc."

"Better and basic methods of presenting motivational methods for science."

"Science workshops -- chance to work with, and see, available teaching materials might have been helpful."

"More video-taping of mini-lessons."

"More information on how children learn science."

"Seeing the many available science programs. All I saw were texts."

"Perhaps some training with an elementary science teacher rather than a classroom teacher with as limited knowledge as the person she is trying to train."

"Actually the only practical experience is to spend as much time as possible in the teaching-learning experience."

"I feel my college preparation in the science area was not due to high quality science methods courses -- although they were somewhat helpful; but rather to my own science background throughout Lexington high school and as a biology major my first year in college. I'm just generally interested in science myself."

"It would have been helpful to have observed some elementary science classes extensively."

"Better preparation for dealing in an inner-city type of situation. More emphasis on individualizing instruction."

"Most of the information I retained about science came from my high school science courses and individual study of science. My one college course (general biology) has had little impact on my science teaching."

"Less theory and more opportunity to work with children. Of all of my education courses, student teaching was the most beneficial. A vast liberal arts program and many opportunities for exposure to children would be ideal."

"It would have been most helpful if the materials I used in student teaching related more closely to those I need and utilize now."

"Sharing ideas with other experienced teachers."

BRIEF SUMMARY

There is abundant and conclusive evidence to show that the interest of children is of paramount importance to the NSF teachers in assessing how their classes are doing in science. How this interest is nurtured by the NSF program and how the children's enjoyment of science is heightened by using these materials is amply demonstrated by the teacher's observations. In addition, the NSF teachers can point to increased skills all around in their students that carry over to other subjects.

Not the least important is the teachers' perceptions of how their use of NSF programs has affected their own teaching styles, both in science and in other subjects, allowing them to become more responsive to varying needs of children. We also find, however, that for the most part colleges are not providing elementary teachers with the skills and insights that would make them more effective in the classroom. Only 5 percent of the teachers felt that their undergraduate preparation was entirely adequate. Teachers learn how to teach science by teaching and by getting help from other teachers. (Thirty-four percent wanted "more opportunities to work with children learning science.") It is probably well to keep in mind that teachers reported that two out of three systems do not hold regular in-service science workshops and that only about half the number of teachers attend the workshops when they are offered.

Compared to NSF teachers, the non-NSF teachers are a rather dissatisfied lot. Their programs tend to be rigid, narrow and unimaginative, and materials are at a premium; students have little opportunity for first-hand investigation and a hollow sameness in style and attitude does not allow the teachers to be as responsive to the varying needs and interests of their students. Non-NSF teachers also cite the children's interest in and enjoyment of science as the paramount factors in assessing how their science classes are going and how they would like them to go. But the non-NSF programs lack the diversity necessary to encourage children to be as responsive to science as they might be.

How the school system supports the teacher and how the principal, science coordinator and administrative functioning of the system relate to the elementary science teacher are important to the success of a particular program with a particular teacher, perhaps as important as the selection of the curriculum itself. What kinds of administrative practice and styles of leadership of management tend to encourage or inhibit successful science experiences? How are the program selections made? What kind of review and implementation process is undertaken? What is the nature of curriculum trials? What kind of support does a science coordinator provide the classroom teacher? What relationship exists between per pupil expenditures and the kind of science program or activity offered? How does the rhythm of the school building affect the elementary science teacher? In short, how does the system -- and those in responsible positions outside the classroom -- support the classroom teacher? These questions will be considered in succeeding sections of this report.

VI

SCIENCE IN THE BUILDING

PRINCIPALS' ATTITUDES AND EXPERIENCES

In this section we investigate the role of the principal in guiding elementary science programs in his building. About half of the 208 responses from principals came from schools using the NSF programs in one or more classrooms and about a half came from non-NSF schools. Our principals may not represent all elementary schools and their principals because we oversampled in schools using NSF programs.

Fifty-eight percent of the schools in our sample are K-6 or 1-6 schools, 24 percent of the schools have only primary grades and 10 percent have only upper elementary grades. Six percent (eight schools) were K-8 or 6-8, and one was a special education school.

Q. 54. What are some of the characteristics of the principals whose opinions we sought?

A. 54. We received responses from 208 principals representing sixty school systems in Massachusetts. Each was responsible for some seventeen classrooms on average and together they were in charge of some 66,000 pupils.

As a group they were not particularly mobile, the typical principal having held his present job for the past eight years and having been in the same school system for the past sixteen years. Sixty percent of them attended college in Massachusetts. Since only 7 percent have been principals in another state and only 16 percent of them have taught in another state, it is obvious that a vast majority have achieved their success locally.

Q. 55. What is their background in the teaching of elementary science?

A. 55. Only one out of seven of the principals had ever taught science full time and less than 10 percent had attended an NSF institute. Nevertheless, half of the principals had at some time found themselves working on science curriculum development and one-third of them had made presentations to school committees or PTAs about elementary science.

Perhaps this experience of having to deal with problems without appropriate experience was one reason why four out of five principals expressed a desire to attend future science workshops in the company of other principals. They were eager to have teachers participate with them in workshops so long as the other principals were also there.

Q. 56. What are their educational philosophies?

A. 56. Three-quarters of the principals favored team teaching, behavioral objectives and the teaching of the fundamentals. A large majority were against or in doubt about "the traditional classroom". A slight majority favored such techniques as the open classroom and process education. It is our impression that they were open to trying any of a variety of devices that would improve the operation of the classroom. Whether this openness to new techniques and strategies represented a fundamental revolution in their educational objectives seemed less clear.

There were three issues -- content education, ability grouping, and departmentalization -- on which opinion seemed completely uncrystallized.

A traditional note was struck when 99 percent of the principals ranked reading first in priority in the elementary subjects and 86 percent placed mathematics second. Social studies and science were third with little difference between them. Significantly, these rankings were the same for principals who did and did not sponsor NSF programs in their schools. The percentages appear to describe a pervasive atmosphere in which curriculum change must take place.

Q. 57. <u>What are their attitudes towards change in science education?</u>

A. 57. These administrators were not complacent about any of the curricula in their schools. Only for the reading programs were a majority satisfied with, or at least neutral about, the quality of the work.

Decreasing satisfaction was registered with mathematics, science and social studies. Three out of four principals said that they would probably change or supplement their present science and social studies curriculum materials if money were available.

Principals with NSF programs in their schools are more satisfied with the science activity (50 percent) than are principals with non-NSF programs (30 percent).

Thirty percent of them are satisfied with their social studies programs; 44 percent with mathematics and 56 percent with reading.

Efforts by principals to bring about constructive change have been scattered. The experiments they have introduced, in order of frequency, have included science programs, language arts programs, team teaching, open classrooms, new social studies programs, ability grouping, nongrading, learning laboratories, after-school courses, new mathematics programs, and schools without walls. No one of these changes had been tried by more than a third of the principals. Very few schools appear to have tried to change both the curriculum and the school environment, although we may wonder if structural and content changes must not necessarily go together.

Q. 58. <u>Who has stimulated change in the science curriculum?</u>

A. 58. Our interpretation of the answers to this question must be conditioned by the knowledge that principals themselves account for one-quarter of the "science coordinators" and that another 40 percent of the "science coordinators" are actually central administrators.

The science coordinator has been the person who played the major role in stimulating interest and attention in four out of five schools. Eighty percent of the principals viewed the K-6 science coordinator as playing a major role. The principals feel that they themselves made a major contribution in only two out of five instances, though they claim to have played some role in 98 percent of the cases. Similarly, they report that classroom teachers played a major role two out of five times and some role nearly always. The central administrators were seen as major influences less than one-third of the time and 20 percent of the time were seen as having played no role at all. Strikingly, parents were reported not to have been at all involved in two out of three schools. Parents seem to have played a major part in only five school systems.

In no case is the principal's perception of who plays important roles in changes affected by whether he is working in an NSF or a non-NSF school.

Q. 59. <u>What is the principal's role in fostering science education?</u>

A. 59. Our principals see themselves spending more time on half a dozen aspects of the problem, but a lot of time on none of them. Nearly a third of the principals said that they spent a lot of time encouraging teachers to innovate, but their efforts to maintain the flow of science materials, to help individual science teachers, to evaluate science teaching, to select programs and materials or to work with children or classes were all scattered. Only in regard to actual teaching did they say they did little or nothing. In all of these activities we found no differences between NSF and non-NSF principals. This could suggest, among other things, that NSF programs demand no more of the principal's time and energy than do non-NSF science programs.

The science budget is, of course, part of the concern of most of these administrators. Only 10 percent of them said they did not submit a budget request for science.

Among those who requested funds for science, only 4 percent said that it was rejected. Most of our respondents were evenly divided between those whose budgets were generally approved with some cuts and those whose budgets were generally approved in full. This is an encouraging picture made more encouraging by the fact that 33 percent intend to send in a larger science budget next year, while only 11 percent will ask for less. Again, there is no difference between NSF and non-NSF principals in their ability to obtain replacements of consumable materials.

Q. 60. <u>How adequate are the provisions for science materials in their schools?</u>

A. 60. Lukewarm responses were given most of the time to this question. Only one principal in five said that his science materials were very adequate, but only one in fifty found his supplies totally inadequate. Three-quarters of the principals were able to obtain replacements of supplies as needed. A majority did not have any petty cash or discretionary funds to use for science, and those who did usually had less than $50 to spend during the school year.

Q. 61. What are the hindrances to progress in science education?

A. 61. A majority of principals felt a need for more storage space for the science program. The next most felt need was for a special science room. Presumably that would help the storage problem as well as facilitating student participation in science classes.

One-third of the schools lacked such practical features as sinks and electrical outlets. Presumably if the teaching of science in the elementary schools continues to spread, school architects will one day begin to build in these features, because school systems will request them to do so. The special science room may be the best short-term answer.

Once we broaden the discussion beyond the question of facilities, we find very little agreement about what stands in the way of good science teaching. The nearest thing to a concensus is the feeling that other subjects have a higher priority, but even that obstacle appeared to be of great importance to less than a third of the principals.

The next most important hindrance seemed to be inadequate inservice training. About one principal in four felt the lack of consulting or specialized help.

It is noteworthy that teachers were occasionally seen as an impediment: many teachers agreed with the principals about reading, writing and arithmetic having higher priorities; some principals saw teachers as being afraid of science subject matter. It is striking, however, that a larger number of principals saw this attitude as being no problem at all, nor did the principals often feel their efforts hindered by teachers who were reluctant to try new methods. Few principals saw any aspect of the science curriculum itself as a great hindrance to its use. A few thought the materials too expensive. A few complained of inadequate means for evaluating the results, and one out of ten was concerned about lack of articulation from grade to grade. All other problems were seen as of no great importance.

Q. 62. What are the aids to progress?

A. 62. The principals agree that teacher enthusiasm and skill are most important. Almost none of the principals believe that they as principals can sell a program as a result of their personal interest in it.

Two out of every three principals (both NSF and non-NSF) are content with the quality of science teaching in their schools, yet only 16 percent of them reported that they spent a lot of time talking about science with teachers. They appear to be saying that the most important way an administrator can help is to get out of an enthusiastic teacher's way.

Q. 63. What effect does the science curriculum have on the child's learning?

A. 63. The great effects of these programs were reported to be that the children showed curiosity, asked questions, enjoyed science, and participated actively in the experiments. There was also some carry-over from science to other classes.

The NSF curricula were more effective in bringing about these changes than other curricula. The ratios of NSF programs getting these results to non-NSF programs varied from 2:1 up to 5:1.

Q. 64. Into what atmosphere are changes being thrust?

A. 64. As a simple index of traditionalism we asked the principals whether grades were given in elementary science in their schools. We learned that grades are given in 73 percent of the principals' schools. We went on to ask if the principals believed that this was as it should be, and 59 percent of them felt that grades should not be given in elementary science.

The same uncrystallized state of opinion showed up when we asked if they favored a "traditional" classroom or content education. Some new methods and strategies were given almost unanimous lip service: team teaching, the open classroom and process education. Unanimity also occurred in their support of "teaching fundamentals." In short, they appear to want both worlds -- and perhaps they felt the two worlds could be compatible. This is consistent with earlier responses in which principals made it clear that they were more than willing to try something new and that they were not complacent about present methods. Although we were being told that sometimes conservatism was a problem, we were more often shown a picture of the difficulties of introducing new methods into an existing system.

Q. 65. Do NSF and non-NSF programs each have their own merits?

A. 65. There are important differences among the reasons for liking or disliking each kind of program. The NSF programs were seen as good because the children liked them, they helped the child to succeed, they integrated subjects, they provided process education, they engendered more student inquiry, they were student-centered and they provided active learning. At the same time, the reasons for disliking the non-NSF programs were that they are too structured and that the teachers' guides are poor. Obviously, structure may be regarded as an asset or a liability in a program according to the principal's educational philosophy.

Three out of every four principals who cited "child-active" as a merit of any science program were NSF principals. Only one out of every four who cited this was a non-NSF principal.

The reasons for disliking NSF programs were that they are expensive and that the time available for teaching them is inadequate.

Q. 66. What are principals' perceptions about the different programs?

A. 66. In general, the NSF programs are more unlike non-NSF programs than unlike each other.

Only a few schools in our survey were using Minnemast, but the program was unanimously approved because children seemed to like it. We are not sure that this finding is based on enough cases or whether there has been a Hawthorne effect because Minnemast has come into the schools through summer NSF institute programs held outside the system.

EES is more often seen as having merit because it is so open-ended and SCIS because of pupil involvement. AAAS was occasionally seen as being too structured. None of the programs provided good evaluation of the student's learning.

Q. 67. Is there dissatisfaction among the principals with the science curriculum?

A. 67. Whatever dissatisfaction exists is not marked. More principals were dissatisfied with the social studies curriculum than with science programs, and almost as many principals were dissatisfied with the mathematics curriculum as they were with science. Only the reading curriculum satisfied a majority of principals -- and that was a bare majority. As we noted earlier, 50 percent are satisfied with their NSF programs. Thirty percent are satisfied with their non-NSF programs.

Q. 68. If the principals had the money, which curricula would they like to change and what innovations in teaching strategy do they feel are worthwhile?

A. 68. They would like to change or supplement all of the curricula. Three out of four principals would like to change or supplement their science programs.

Concerning teaching strategies, there seems to be a lot of ferment. There is as much interest in the language arts as there is in science. Principals would like to provide more teacher training. Very few have introduced the integrated day in their schools, yet 59 percent approve of it. Seventy-four percent approve of team teaching; and 55 percent approve of the open classroom and 76 percent approve of behavioral objectives. Only 28 percent approve of the traditional classroom, and 39 percent approve of ability grouping. Principals seem to want an open classroom that teaches the fundamentals. Obviously, they are ripe for a change, but the answers are not in the curriculum alone.

BRIEF SUMMARY

One of the few differences between principals with NSF programs and those with other programs -- and the difference is important -- is that 50 percent of the NSF principals are satisfied with their science programs and only 30 percent of the non-NSF principals are satisfied with their science programs. Three out of four principals in our sample would either change or supplement the science program if they had the money.

Only 18 percent of them have been responsible for program selection, but 35 percent have implemented new programs in their schools. They do not appear to be particularly involved in the science activity that goes in their buildings. They are much more concerned with mathematics and reading, even though some of our principals are also the person most responsible for science in their school system. Although they do not discourage experimentation, they do little to encourage teachers to be innovative and less to support them if their teachers take a novel departure. The science activity in schools runs pretty much by itself.

Only a few principals attend science workshops or run them. However, many principals would like to take part in science workshops, as long as other principals and teachers from their own schools attended the workshops with them.

An underlying feeling among many principals is that children like science, and they feel that the activity engendered by NSF programs is one of the great merits of these curricula.

Our research suggests that having an NSF program does not put additional burdens on the principal.

The principals tend to be parochial, with long years in their systems and with limited experience in science teaching. As a group, they have not got around much.

They feel that the enthusiasm of the teacher is the most important element in the success of a science program, but they do little to nurture it.

Another view of the principals is gained by reading their comments about the different NSF programs. Those favoring these programs offer cogent reasons in their support, similar to those offered by the teachers: the NSF programs create high pupil interest and give children the opportunity to learn by their inolvement in open-ended,laboratory-based experimentation.

PRINCIPALS' COMMENTS

Q. 69. <u>What are the strengths of the various science programs? What are the weaknesses of the programs? What steps, if any, need to be taken to improve the programs?</u>

A. 69. The principals' answers to these broad questions are grouped according to the program used. We will let the principals speak for themselves.

Here is a representative sampling of responses by principals whose schools are using SCIS.

<u>What are the strengths of the SCIS program as you see them?</u>

"Laboratory centered approach. Combines content, process and attitude. Processes of investigation, observation, measurement, interpretation, prediction."

"Continuity. Interest. Current and meaningful."

"Hands-on experiences. Introduces teachers to new concepts in handling children and providing for individual differences. Shows teachers different ways that kids learn."

"Opportunity for children to explore science materials, to observe, discuss, question, draw conclusions as they develop for themselves science concepts and scientific literacy."

"Discovery and developmental concept. High pupil interest. Use of varied materials. Coordination of program through primary grades."

"A child learns through discovery. He develops the ability to think for himself and to really <u>see</u> things around him. His scope is not limited to one assigned objective."

"The strength as we see it is student participation."

"Pupil activity. Every child gets a chance to handle experiments. Pupil investigations. Working in teams stimulates discussion."

"We like the cognitive Piaget approach. We like the discovery approach. It's an active, doing type of program, well-suited to the learning style of young, curious children."

"Stress physiology and life science. Fine progression from level to level. Pupils' enthusiasm and conceptual understandings indicate program is geared within the average pupil learning ranges at each level. Durability and flexibility of materials. Availability of materials. Teacher can coordinate lessons and great pupil involvement."

"Total involvement by students."

"Teachers and pupils are enthusiastic about the program, it gives the children a chance to really participate in many activities. It helps the child with a reading problem to learn and enjoy science without depending on the textbook."

<u>What are the weaknesses of the SCIS program as you see them?</u>

"Needs much teacher in-service training."

"Difficult to individualize."

"Weakness in area of teacher unreadiness -- many cannot accept a different concept of subject matter, pupil evaluation, and lesson presentation, even after a rather good training program."

"Cost -- we have budget problems."

"Extensive time for maintenance of reusable materials."

"It requires a very good teacher with foresight and understanding. (This is probably a strength because all teachers should have these attributes!) Unfortunately, not all teachers can handle an informal program."

"There is a need for a teachers' handbook containing ideas and teaching methods for the extra activities that are suggested. Older teachers are reluctant to go along with the program."

"More optional activities that students could pursue in greater depth certain concepts they are learning about with little teacher direction."

"Minor, but mechanics of distributing materials."

What steps (if any) will you take to improve the SCIS program?

"Wish to God I knew! The problem is teachers' preconceived notions, reluctance to change -- more an emotional block than an intellectual one -- sensitivity training?"

"Increased teacher in-s rvice training in science. Formation of teams for science instruction. More critical purchasing of replacement materials."

"Workshops should help to develop an understanding of the aims of such a program and to aid in carrying out procedures."

"A thorough course in science concepts and methods would bolster teacher confidence in handling the science teaching. More materials. Easier way of acquiring them. Pupil worksheets (mimeographed) to help children acquire a stronger understanding of the concepts taught."

"We are going to supplement it with ESS."

"We have periodic workshops where we meet and discuss difficulties, ways to overcome them, and to make any changes necessary. Any program is in a constant state of evaluation and adjustment today, isn't it?"

Here is a representative sampling of responses by principles whose schools are using AAAS:

What are the strengths of the AAAS program as you see them?

"The ability of the children to discover and work on their discoveries."

"Development of concepts. Materials for the children to manipulate."

"Process approach -- better objectives -- prepared materials."

"Structured."

"Class-centered rather than teacher-oriented. Skill diagnosis is constant. Evaluation in terms of observable behavioral objectives. Success of program is not dependent solely on teachers' scientific background."

"Inquiry approach."

"Behavioral objectives -- process approach -- integrated skills and process skills -- active participation -- sequential in character -- appraisal and competency measures. Many materials to work with -- excitement regarding learning on the part of the pupils -- pupils learn to make judgments of world about them -- pupils learn to be more independent and mature."

What are the weaknesses of the AAAS program as you see them?

"Lack of adequate training for teachers. Would like to see the program on a much more individualized basis."

"Massive in-service training needed to give teachers enough confidence to get involved and committed to the process approach."

"Cost factor. Weak in most areas of current interest. Need for in-service training."

"Calls for too much knowledge on part of teacher. Calls for too much time in preparation."

"Need kits and materials for all teachers. Should not share kits. It is expensive. Need ongoing in-service to keep new teachers to the system in touch."

"Initial cost -- however, I feel it has been worthwhile."

"Needs less structure."

"More natural science needed. Can be supplemented by teacher. Needs extensive in-service for new teachers."

<u>What steps (if any) will you take to improve the AAAS program?</u>

"Conduct a workshop with a company representative."

"Have decided to run my own workshop for the teachers. We now have a science coordinator in the system and I am presently conferring with him."

"To use teachers already trained to give in-service training to the remaining teachers in the school."

"We have a full time science teacher. It is planned that she will supplement by bringing in some ESS materials. Additional media and A/V material will allow for a more complete program."

"We will make more use of supplementary materials and our own neighborhood, including a pond and the bay."

"Science coordination has been procured for the next school year. (Half-time basis)"

"Periodic evaluation of program. Supplement it with additional materials."

"Participated in school system-wide elementary curriculum evaluation -- teachers and principals. Cooperation with coordinator to update program. Enrich the program by including other areas; i.e., nature, space, etc. Although this is a sequential program, it should not be self-limiting."

Here is a representative sampling of responses by principals whose schools are using ESS:

<u>What are the strengths of the ESS program as you see them?</u>

"High student involvement. Leads to diversity of activity. Individuals in a meaningful way."

"Open ended activity and child oriented. Encourages sharing and interaction. Encourages teacher learning."

"Open ended, opportunity for individualization, variety of manipulation in materials."

"Wide variety of units available in all areas of science; adaptability to varying age levels, abilities, and interests."

"Concrete material used -- high pupil interest -- pupil-centered."

"Provides for flexibility -- provides activity on lab-centered instruction while also providing research techniques on research skills from text.

"Student-oriented with each child equipped to participate. A 'hands-on' approach to science. Flexible enough to adapt to now."

<u>What are the weaknesses of the ESS program as you see them?</u>

"More materials are needed to follow up on the leads."

"Some units too structured."

"Costly because of necessity of replacing consumable materials."

"Nondirective and elementary teachers are afraid of it because they do not have training in science."

"Preparation and inventorying -- extremely time-consuming."

"Demands different skills from the teacher. Most elementary teachers have a weak science background and/or lack high interest. Hard to keep track of all materials used."

"A valid form of evaluating the children."

"Some of the kits are too elementary for sixth grade classes."

<u>What steps (if any) will you take to improve the ESS program?</u>

"I would look toward movement away from prepared materials, as teachers get more experience."

"Try to get some more money and yet operate with sense of reasonableness and fiscal responsibility."

"Some teachers are going to workshops. I have asked that funds be made available to have ESS workshops on a system-wide basis."

"Workshops. Consultants to help prepare. Aide to inventory."

"Master sheets should be available for each child -- to check unit and time of study; possible limitation of units to certain levels."

"We need some way to check our inventory and a more efficient method for maintaining it."

"We are trying a checklist-type of evaluation that lends itself more to this type of program."

Here is a representative sampling of responses by principals whose schools are using Minnemast:

What are the strengths of the Minnemast programs as you see them?

"Real strength is involvement of people, commitment of teacher to the program. Because of this, it is having real effect on the children. Something they -- the teacher -- wanted to do, and that is why it's working. They felt at ease in the summer workshop. They were teaching Minnemast, not just observing it."

"The inexpensive materials, a lot you can make yourself which means nonreliance on a heavy budget. The program is strong in the use of activities consistent with the stages of child development á la Piaget. The focus is on learning. Activities spotlight the child, not the teacher. Another strength is interdisciplinary aspect: you overflow into language arts and so forth. Program is in tune with their daily living styles. Another strength: the enthusiasm it generates in teachers and children which has tremendous carryover to the total school situation."

What are the weaknesses of the Minnemast program as you see them?

"In our instance, we have such a definite math program in our system that the applied math of Minnemast may not be brought into the total program. It's too early to say, but I think it could happen this way."

"Program is heavier in science than in math; the limitation of K-3 grades only."

What steps (if any) will you take to improve the Minnemast program?

"If I could let my teachers not slavishly follow our already adopted math program, but use the math side of Minnemast, I would like to see us pilot the math side of Minnemast as well as the science side."

"Two things: build more math into the program and extend it through grade six."

Here is a representative sampling of responses by principals whose schools are using NSF programs in combination:

What are the strengths of the combination program as you see them?

"Activities program with reference skills."

"Teacher enthusiasm. In-service training for teachers -- provided by college instructors.

What are the weaknesses of the combination program as you see them?

"Physical facilities and materials, teacher planning time."

"Goals in science not fully developed at this time. We are working on this aspect of the program."

What steps (if any) will you take to improve this combination program?

"Many of our teachers will continue to take part in NSF institutes which will be held in our school this summer for the second year."

Non-NSF Programs

Here is a representative sampling of responses by principals whose schools are using non-NSF programs:

What are the strengths of the non-NSF program as you see them?

"Serves as a guide for teachers to follow and to supplement in the classroom."

"Gives students a general background before they specialize in life sciences, grade 7 and earth sciences, grade 8."

"All children are exposed to a continuous program."

"Materials readily available. Easy for nonscience oriented teacher."

"Helped us to get into more 'process science'."

"Process-oriented. Well coordinated."

"The unit individually allows freedom to teach anything at any time. Less costly than local text with same material."

"It encourages the discovery processes in science. There is a continuity and sequence from Book I to V. The accompanying lab stocks experimental material."

"Concepts and objectives well outlined. Well spiraled program."

"Uses the experimental approach and gets the youngsters involved. Encourages the teachers to restrict the use of the 'read and discuss' approach."

What are the weaknesses of the non-NSF program as you see them?

"Not up-to-date factually."

"Poorly organized."

"Until this year - no direction - lack of teacher materials and follow through on citywide curriculum. Too 'book' oriented."

"Needs workshops to be properly implemented."

"Textbook. No manipulatives."

"Not complete enough. Materials do not 'last' for money expended. Not individualized enough."

"Materials as supplied are not of the highest quality."

"Sometimes materials for experiment and discovery are used up and not replaced."

"Not enough kits ordered to correlate effectively."

"Lack of materials -- planned experiments."

What steps (if any) will you take to improve the non-NSF program?

"Use supplemental materials to implement the text and its approach to the science program."

"Set up a lab schedule for experiments."

"Broaden through local curriculum development."

"Workshops for teachers."

"Improvement of facilities and use of aids to assist teachers with the program."

Self-Developed Program

Here is a representative sampling of responses by principals whose schools are using a self-developed program:

What are the strengths of the self-developed program as you see them?

"Two teachers are assigned to the same program -- they act as resource persons as well as teaching assignments in grades 1 through 4. I believe that the children of the lower grades are most exuberant about the program. Another strong feature of our program is that the program was set as 'model' for other areas of curriculum. In the 1st and 2nd grades, our male teacher ahs been able to create a great deal of enthusiasm among the children so they are becoming more conscious of science."

"Process approach. Children learn to question, hypothesize, record data, draw conclusions."

"Opportunities for experimentation. Opportunities for firsthand experience. Opportunities for use of science. Opportunities for using materials."

"Freedom for teacher resourcefulness and flexibility."

What are the weaknesses of the self-developed program as you see them?

"We need more space to store and organize materials so they will be more readily accessible for teachers and students."

"Need a coordinator."

"Adapting materials for relevance of the science program."

What steps (if any) will you take to improve the self-developed program?

"More in-service programs are needed to assist teachers. The fear that many teachers have that they are 'not qualified' to answer all questions is unfounded. I believe that science is an important subject concerning life around us and we all have something to contribute. It appears that the major problem to overcome is the 'value' of science teaching that should really be focused in courses, in-service and other seminar type programs. The interest a teacher develops definitely influences the children's desire to learn science."

"Continual rethinking of use of existing space. Continued communication of the need for space."

"Push for summer workshops in science."

"Assistance from head of science department is in the works toward coordinating and procuring relevant science aids and instruction."

VII

SCIENCE IN THE SYSTEM

SCIENCE COORDINATORS' ATTITUDES AND EXPERIENCES

In our questionnaire each superintendent was asked to name "the person most responsible for science" in his system. Although only about one out of every three systems responding had a person titled science coordinator, we have considered in our report the person most responsible for science in each system as a "science coordinator". The "science coordinator" may have been a central administrator, an elementary principal or a science specialist teacher, but he was designated by the superintendent as having the primary responsibility for science.

The varied titles of the respondents indicated that there is no one pattern of responsibility for science. As we noted earlier, in the 23 percent of systems that have a designated science coordinator, 9 percent have a K-6 coordinator and 14 percent have a K-12 coordinator. In 39 percent of the systems this responsibility is in the hands of a central administrator. Another 25 percent of the systems give this responsibility to an elementary principal. The remaining 13 percent of the systems give responsibility for science programs to science specialist teachers, chairmen of science curriculum committees, secondary science department heads or others.

In our questionnaire to the science coordinators we sought to discover some of the dynamics of the system in respect to elementary science activities; to learn about the attitudes and experiences of the science coordinators as implementors of programs; and to delineate some of the reasons why science was a growing, successful activity in some communities and not in others.

Q. 70. <u>What are the characteristics of a science coordinator in Massachusetts schools?</u>

A. 70. Almost three-quarters have been in their present systems more than five years and the majority (over 60 percent) have been in their systems over ten years. However, only 40 percent have been in their present position longer than five years; and only 12 percent have been in their position more than ten years. This indicates both some lack of mobility and the relative newness of the position.

Five years ago, when curriculum reform in elementary science was well underway, 60 percent of the present science coordinators did not hold this position. Ever more pertinent, of the present number of coordinators, 35 percent of them have never been an elementary classroom teacher and 75 percent of them have never been science teachers. However, 95 percent of the coordinators have had some science training; 35 percent were science majors in college.

Q. 71. Do systems tend to be centralized or decentralized in regard to elementary science?

A. 71. In buying materials, there is about a fifty-fifty split, but in distribution of materials over 60 percent are not centralized. Only 36 percent felt that consulting and advising to individual teachers was done on a centralized basis, and yet planning and conducting inservice training was seen as centralized by 65 percent of the respondents.

Evaluation and development of programs and the preparing of budgets was considered by most of the coordinators to be centralized.

It appears that, as the coordinators view the system, there is no clear-cut definition of authority or responsibility, but rather a mix in most areas of elementary science coordination. From the coordinators' points of view, an individual school system cannot be categorized as either centralized or decentralized.

Q. 72. How does a science coordinator spend his time?

A. 72. Coordinators spend on the average only about 20 percent of their time in the coordination of science activities. They exercise most of their responsibilities in evaluating and development activities and in advising and consulting with teachers individually. Planning and conducting inservice training and preparing budgets take about equal amounts of coordinator time and follow behind the first two responsibilities. Over a half of the coordinators felt little or no pressure to be responsible for the buying of materials. In fact, the role of the coordinator seems to be very poorly defined in most school systems. Most coordinators indicated that they were uncertain of both their role and their responsibilities.

Q. 73. What characterizes the science coordinators who have responsibilities only for the elementary grades? How do they differ from coordinators who have other responsibilities?

A. 73. Nine percent of the systems in this state have a person designated as a K-6 science coordinator, a total of eighteen K-6 science coordinators.

Almost half of the eighteen coordinators spend more than 50 percent of their time on elementary science, and five of them spend 100 percent of their time on it. This is in comparison to the K-12 science coordinators, of whom only 9 percent spend half or more their tim. on elementary science.

Some comparisons about how they spend their time illuminate the differences: 57 percent of the time of the K-6 coordinators is spent in advising teachers, and 33 percent of their time is devoted to giving inservice work, while on the other hand, the K-12 science coordinators spend 24 percent of their time advising teachers and 20 percent giving inservice programs. The general (central administration) science coordinators spend only 12 percent of their time on inservice work and only 8 percent of their time advising teachers.

None of the K-6 coordinators buys materials, and only 11 percent of them report that they prepare budgets.

The principals who act as science coordinators spend 19 percent of their time advising teachers and 13 percent of their time on inservice work. On the surface, it would appear that there is little difference in the way a principal as science coordinator and a K-12 coordinator spend their time.

One out of every four of the most innovative systems -- those with NSF elementary science programs -- has a K-6 coordinator, and 80 percent of them have a K-12 coordinator.

In the least innovative systems -- ones that use a textbook approach and have no plans to try an NSF program -- we find that there are no elementary science coordinators, and only 20 percent of these systems have a K-12 coordinator. The least innovative school systems place the elementary science responsibility in the hands of a central administrator, a building principal or a principal in charge of many buildings.

Obviously, the presence of a K-6 coordinator is closely related to use of NSF programs, but which is the cause and which is the effect is difficult to determine. Very simply, there is a strong association between the innovative systems and the science coordinators spending much time with elementary teachers.

Q. 74. <u>What kinds of school systems get the most in outside funds for science?</u>

A. 74. We found that the systems that spend less per pupil on elementary science have received the least in outside funding for elementary science, and those that spend the most per pupil receive more outside funds. It is the chicken-and-egg problem, or a matter of priorities. If a system feels elementary science is important, it will take advantage of the existing sources of federal funds.

But the situation is more complicated. Some larger cities may receive large amounts of federal support for improving elementary schooling but expend most of it for reading programs. Small communities with less severe reading problems may be able to place a higher priority on science and accordingly seek outside funding to support the introduction of new science programs. In communities that spend less than $600 per pupil each year, new science curricula may not have a high priority.

Q. 75. <u>What responsibilities does the elementary teacher have for science?</u>

A. 75. The science coordinators reported that nearly half of the teachers in all of the elementary grades had full responsibility for their teaching of science with no help from either a specialist or a consultant -- and with little or no help from the science coordinator.

There is very little use of the specialist science teacher or consultant either in a one-school environment or in a multi-school environment. There is, however, some use of an individual teacher's special competance (32 percent) in the exchanging of classes with other teachers in the upper grades (grades 4 to 6).

It seems, then, that science at the elementary level is considered by most systems as a general subject which can be taught by any teacher.

Q. 76. <u>What inservice opportunities are provided by the systems?</u>

A. 76. Although 46 percent of the systems provide inservice or workshop training in the teaching of science, 67 percent provide the service in other subjects.

The major responsibility for workshops falls upon the science coordinators; over half of the workshops are conducted by the science coordinator. Only 20 percent of the systems used other school personnel to conduct workshops. There are a few instances where a publisher's representative conducts workshops. Somewhat less than half of the systems used science specialists or outside consultants for their workshops.

Although two-thirds of the systems allow release time for attending workshops and visiting other systems and half of them allow credit for workshops, financial remuneration for such "nonteaching" activities is not common. Even though there is a desire for more workshops by the coordinators (78 percent) and an indicated need for improvement of existing workshops (64 percent of the coordinators felt present workshops were ineffective), the system seems to provide little incentive to involve teachers in science workshops.

Inservice training in science was regularly available in only twenty-four school systems.

Q. 77. <u>Should elementary science be taught as a separate subject or integrated with the total elementary curriculum?</u>

A. 77. In nearly half the systems there is no policy expressed on this question. On the part of the coordinators themselves the issue was a toss-up. The systems seem unable either to look fully into the issue of integration or separateness or at the very least to make up their minds about which route they should like to take.

The science coordinators find themselves unable to agree on what should be done and therefore there is a laxity or an omission on the part of the curriculum developers either to provide fair direction for their curriculum as given or in the redevelopment of the curriculum to meet today's thrust in exploring more varied approaches in elementary education.

Q. 78. <u>Of the four NSF elementary science curricula, which, if any, is favored by the science coordinators?</u>

A. 78. No single NSF program (except for Minnemast, which is little used across the state) is more or less favored than any other. But is also seems that textbook series are favored by science coordinators when a textbook series is the sole program.

Q. 79. <u>In school systems with science coordinators who is responsible for introducting elementary science programs?</u>

A. 79. In a very few cases (15 percent), the science coordinator actually selected the program to be used. However, 54 percent felt they had had a legitimate advisory role in the selection process, while only 31 percent felt that they either had no special role in the selection process or were not directly involved in it at all.

The major cause for reevaluating science curricula was a dissatisfaction with the existing program (55 percent), although it is not clear who was dissatisfied. However, when asked if system personnel brought about a reevaluation, 42 percent of the science coordinators answered affirmatively. Very few instances of reevaluation were stimulated by other criteria, such as running out of books, new funding being available or a new person being assigned to elementary science.

The systems appear to recognize the need for change in elementary science; all segments of the school's professional staff evidently become aware of problems but there is no consistent decision-making pattern for solving the problems. This is substantiated by noting who was responsible for suggesting a change in elementary science: 30 percent were science coordinators, 30 percent were central administrators and 35 percent were teachers and elementary principals. Among the remaining 5 percent responsibility was unclear.

It is interesting to note that it was felt that the school committee had little or no role in stimulating interest in elementary science. In terms of continuing attention to, and support of, elementary science, the strongest people are, no doubt, the classroom teachers, followed very closely by the elementary principals. The school superintendents and other central administrators also appear to play significant roles.

Those outside of the school system, such as the PTA, parents, state and federal government personnel and professional consultants, play a minor role in drawing attention to elementary science. The exception among outside personnel is the publishers representative who may play either a major or moderate role.

In 90 percent of the school systems program reviews were conducted by ad hoc committees concerned only with elementary science, not by general curriculum review committees. These committees consisted primarily of elementary teachers and elementary principals. In less than 40 percent of the cases was the science coordinator or a science specialist a member of the review committee.

Q. 80. <u>What process, if any, was used to test or evaluate the curricula before full implementation?</u>

A. 80. The majority of science coordinators felt that it was desirable to use the new curricula on a preliminary bases--some label it a "trial". They did not feel that they lacked adequate information about the curriculum or that trials were a matter of system policy but that it was important to observe on a limited scale how teachers and students fared with a program and to learn how they felt about their experiences.

Q. 81. Who makes the final decision about the elementary science curriculum?

A. 81. Surprisingly enough, almost 40 percent of the science coordinators felt that no formal approval was necessary to adopt new curricula. In those systems where formal approval is necessary, they said the superintendent makes the final decision. Yet in more than half the systems (58 percent), approval is also required from the school committee.

In cases where school committee approval is necessary, half of the school committees give it cursory attention. Only 4 percent of the school committees review new programs extensively. No school committees give it a very extensive review. Basically, it appears that superintendents are making the final curriculum decisions, with the school committees automatically approving the decisions.

In short, there seems to be no real conflict over the power structure in curriculum choice. Either the school committees have delegated their authority to the superintendent, who in turn delegates that authority to someone else, or the individual teachers and groups of teachers may do as they wish. This has no relation to centralization/decentralization, but may be viewed as either a style of management or an abrogation of responsibilities.

Q. 82. In the eyes of the science coordinator what issues have been most important in the choice of elementary science curricula?

A. 82. The foremost issue was the concern by these people for the particular goals of elementary science in the system. Next most important was concern over the ability of the teachers to teach the program. The third most important issue was whether or not the pupils would like the program. The least important issue in the minds of the science coordinators is whether or not the parents will accept the program.

It is interesting to note that although we have found it very difficult to isolate particular goals in elementary science from the questionnaire responses, the coordinators find that these goals are most important to them. Few systems apparently have been able to identify their own goals.

It appears that in the choice of elementary science programs, the teachers come before the pupils; that is, it is more important to fit a program to the teachers' abilities than to pupils' likes and dislikes, or to a system's ability adequately to evaluate pupil learning. It is probably fair to be concerned over whether the teachers can use a program successfully but some caution must be exercised in setting teacher-pupil priorities in this direction.

Q. 83. How does the availability of financial support affect the functioning of elementary science?

A. 83. Only 35 percent of the science coordinators felt that money was not an issue in either the implementation or the choice of science programs.

There is, however, some cause for optimism here. In about one-third of the school systems, it seems, some more salient goals and criteria have been established to aid the decision-making processes in elementary science.

Q. 84. Which federal programs have been used to support elementary science?

A. 84. The majority of school systems (76 percent) took advantage of National Defense Education Act (NDEA) Title III funds. The Elementary and Secondary Education Act (ESEA) Title II was used to a significant extent with 64 percent of the systems taking advantage of this. The poorest showing (1 percent) was found in ESEA Title VII. Only 2 percent of the systems used Educational Professions Development Act (EPDA) funds.

Q. 85. Who provides information on new programs to the science coordinator?

A. 85. The source of information about new programs that is of greatest use to the science coordinators is the outside workshop or institute, and the second most useful source is the professional conference. Tied for third place as sources of information are professional journals and publishers' representatives.

The science coordinators find that information coming through the professional,personal sector is more important than that from the commercial sphere. (Presumably, the science coordinator responds better to experiences in the field than to commercialism.)

In the past few years more than 80 percent of the science coordinators have visited other systems to observe elementary science programs.

Q. 86. What are some of the factors that influence the success or failure of elementary science?

A. 86. In order to identify some specifics, the survey first asked if a particular school in the science coordinator's system emphasized science more than the others. If they answered "yes," the coordinators were asked to detail the reasons for this emphasis. The results showed that the teachers have the greatest influence on elementary science. The science coordinators felt that this emphasis on science in a particular school arose from the fact that the teachers liked teaching science and felt that science was important. The coordinators also felt that the principal's view of science, though not quite as important as the teachers', had a great deal to do with a particular school's emphasis.

Given the current attention to the adequacy of science facilities at the elementary level, it is worth noting that the least important factor influencing science programs (only 22 percent) was the availability of adequate facilities. At the same time only 23 percent of the science coordinators indicated that the lack of adequate physical facilities was a "great hindrance" to elementary science education. Good science facilities do not attract good science teaching and good science teaching is not dependent on adequate facilities.

About 50 percent of the coordinators felt that the lack of consultant specialist help was a great hindrance.

From the point of view of the science coordinators, the greatest hindrance comes from teachers feeling that they have had no voice in selecting the program. Yet from previous responses from science coordinators, it appeared that the teachers are the most important factor in the selection process. However, if the science program is not going well, the coordinator may be most likely to place the blame on the teachers' lack of involvement in the selection process. (This is confirmed by the teachers: only 12 percent helped to select the program in their system, and only 20 percent were involved in the program selection in their school.) From one point of view, then, the teachers are very much a part of the decision-making process and from another they may not recognize the part they play in it.

The science coordinators felt that principals, parents and the curriculum itself do little to hinder science education. The principal does not seem to exercise any authority and little direction in this subject. And parents, despite recent efforts to involve them in the life and work of a school system, have essentially no influence on science education. Ninety-seven percent of the coordinators have never experienced any problems with parents over elementary science; parents show almost no concern about the expenses, the activities, or the selection of science programs.

The curriculum itself peculiarly, does not cause many problems in the teaching of elementary science. The greatest hindrance associated with the curriculum by the science coordinators was that of excessive expense (yet only 18 percent expressed this view). Other hindrances associated with curriculum included such things as its requiring excessive teacher training, teaching time and teacher planning.

It is not the system, not the principal, not the parents, not the curriculum, not the sicence coordinator, but the teacher who is most influential in the success or failure of the program, according to the science coordinators.

Q. 87. <u>Do the various "hindrances" in the systems bear any relationship to one another?</u>

A. 87. Statistically, across the board, there is little or no relationship between one set on hindrances and another. In other words, the parents' involvement in the program made no difference, for example, to the principals' involvement. Each hindrance, whether it be the system, the teacher, the principals, the parents or the curriculum, acts quite independently of the other.

This tells a little about the power structure -- or lack of it -- in school systems. We're left with the question: Who's in charge of elementary science? And we cannot find anybody. This tells us two things: (a) the science coordinator is not casting a critical eye on the system; and (b) when he wishes to he has difficulty in isolating the hindrances because his role in the system apparently is so ill-defined. Without authority -- and the science coordinators appear to have, or to accept, little final authority -- their responsibilities are limited. There is a diffusion of nonpower; consequently, the hindrances facing a science coordinator are formidable.

Q. 88. Which NSF programs have been most successful, according to the science coordinators?

A. 88. The survey asked each science coordinator to rate on a sliding scale ranging from "excellent" and "disastrous" the new programs.

Program	Excellent	Satisfactory	Poor	Disastrous
SCIS	59%	30%	11%	0
ESS	40	51	8	0
AAAS	19	61	19	0
MINNEMAST	14	57	27	0
TEXT	29	53	17	0

If we look exclusively at the "excellent" column, SCIS is clearly the most successful program. However, if we add together the "excellent" and "satisfactory" columns, we in effect determine which of the programs is least likely to fail. In this respect the ESS program is slightly more successful than the SCIS program.

According to the science coordinators, then, if one is interested in insuring against poor results, one should adopt ESS; but if one is interested in achieving the highest degree of excellence (at the risk of some additional less than satisfactory results), one might adopt SCIS.

Q. 89. How does per pupil expenditure relate to innovation in science?

A. 89. For analysis of this data, the school systems were put into a number of categories. For our purposes we choose to compare the "most innovative" -- defined as those systems with complete NSF adoptions -- and the "least innovative" -- defined as those systems with textbook programs and no plans to review the NSF programs.

The mean cost per pupil was between $700 and $800, in all systems. Forty-three percent of the "least innovative" systems fell below the $700 level while only 21 percent of the "most innovative" systems fell below this level. Conversely only 8 percent of "least innovative" systems were above the $800 level and 48 percent of the "most innovative" systems were above the $800 level. There is an obvious correlation between per pupil expenditure and system innovation.

Q. 90. In terms of time spent, what is the role of the science coordinator in the "most innovative" system and in the "least innovative" system?

A. 90. The statistics show a strong correlation between time invested by the science coordinator and the degree of innovation in the system. Forty percent of the systems committed to NSF programs have a person responsible for elementary science coordination who spends at least 25 percent of his time on coordination. Only 9 percent of the systems using non-NSF programs have a coordinator who spends at least part of his time on coordination. This can be interpreted in one of two ways:

The "most innovative" systems result from a science coordinator spending much time in elementary science; or

The "most innovative" systems create the post of science coordinator.

For the previous judgments in our study, we feel that the second interpretation here is more accurate. The "most innovative" system produces the science coordinator, and he defines his own role.

Q. 91. <u>Is the degree of centralization related to having NSF programs?</u>

A. 91. We have found, using again the categories of "most innovative" and "least innovative," that there is little or no relationship, in the science coordinator's view, between degree of innovation and degree of centralization.

In the rare situation where the science coordinator felt there was a high degree of centralization, there is some correlation; the "most innovative" systems are somewhat more centralized and in this centralized environment someone is indeed in charge. As the science coordinator perceives it, in 39 percent of the "most innovative" systems somebody is making the decisions compared to only 11 percent in the "least innovative" systems.

Q. 92. <u>Are the classes smaller in the "most innovative" elementary schools?</u>

A. 92. No. Neither are they larger.

Q. 93. <u>Does the size of a system have anything to do with innovation in elementary science?</u>

A. 93. There is some relationship. Smaller systems (under 1,000 elementary pupils) tend to be least innovative and the medium-to-large (2,000 to 5,000 elementary pupils) to be most innovative. However, in the 1,000 to 2,000 category and for those systems over 5,000, there is little difference in their innovative style.

One might conclude that very small systems find change difficult (probably cost is a factor here). The greatest mobility of change in a system comes when the system is large enough to absorb change with little difficulty and yet manageable enough to allow innovation toward change.

Q. 94. Does the size of the system bear any relationship to the number of activities for which a science coordinator is responsible?

A. 95. The size of the system makes little difference. The science coordinator finds his responsibility not in regard to system size but rather in respect to his own temperament. It appears that the amount of activity a science coordinator is involved with is a result of his own personal job description and initiative.

Q. 95. What size systems have taken advantage of NDEA Title III and ESEA Title III funds?

A. 95. Less than one in five systems with fewer than 5,000 elementary students take advantage of NDEA Title III funds. Only 7 percent of the systems in the 5,000 to 10,000 range take advantage of such funding to promote elementary science. Yet 40 percent of those over 10,000 do this.

Fewer than one in seven systems of the under 5,000 range use ESEA Title III to help improve elementary science. No systems in the 5,000 to 10,000 range in our sample reported using ESEA Title III; and again, 40 percent of the very large systems (over 10,000) used this source of funding. Taking the two together, it is the 5,000 to 10,000 pupil system that appears to be suffering the most in the area of outside funding under these Titles.

Actually, the percentages are not very respectable for all sizes of school systems in seeking outside funding. School systems seem lax in scouting out and obtaining funds for elementary science programs.

Q. 96. Does the size of the school system make a difference in the arrangements for teaching elementary science?

A. 96. For the most part it does not. In no case did the cross-tabulation of size with aspects of the administration of elementary science programs produce a reply with statistical significance. There was some hint that the smallest systems were dependent on the resources of the classroom teacher alone and that the isolation of the classroom teacher decreased with increasing size, but, interestingly, she once again became the prime resource in the systems that were the very largest -- over 10,000 elementary pupils.

There was also some tendency for science teachers, or rather classroom teachers with science interests, to be available, often on a swapping basis, to take over the classroom during the science period in the larger systems.

The largest systems, however, were distinct from the rest in that elementary science programs had been stimulated by people outside the school system, such as nearby college faculty or publishers' representatives or state department personnel. In no case was science cited as being stiumlated by parents.

Q. 97. How important is a satisfactory in-service experience?

A. 97. Evidently it is very important, since dissatisfaction with in-service experiences is associated with criticisms of the elementary science programs (for having inadequate facilities, insufficient funds, inadequate consulting help, inadequate distribution of materials and inadequate incentives for the teacher). Of course, this striking correlation may only be telling us that a good in-service training experience is the telltale symptom of a well-run science program.

Q. 98. How helpful are professional scientists in providing assistance to science coordinators? Are scientists a source of information?

A. 98. Scientists are the least used source of information; they are consulted by just one percent of the science coordinators!

Q. 99. What are the reasons science coordinators give for building science interest in the elementary school?

A. 99. The reason they give most commonly is that teachers like teaching science. Perhaps that is not so trivial an answer as it sounds: we have seen elsewhere that the enthusiast teacher is the first factor in making these elementary science progams go. So we are not surprised that another commonly given reason is that teachers feel that science is important. Science matters is also commonly cited.

Q. 100. Do science coordinators who sponsor different elementary science programs have dissimilar backgrounds?

A. 100. Yes. Almost half of those whose systems use a textbook series have little science background at all. There is a rough but real correlation between the extent to which an NSF program is used and the science coordinator's background in science.

Q. 101. Which NSF curricula have been discontinued?

A. 101. As we noted earlier, not very many of the NSF curricula have been dropped. Among the thirty-two school systems that have discontinued an NSF program in favor of one or more other programs, ESS and AAAS have been more frequently discontinued than the other programs.

Q. 102. What comments were offered by science coordinators whose systems are using AAAS?

A. 102. Out of 24 science coordinators who had something to say about AAAS, 16 mentioned its "structuredness." And 14 also associated it with "process education." Other comments were very scattered, although there was some complaint about the program's being expensive and time consuming.

Q. 103. What comments were offered about ESS?

A. 103. Of the 35 science coordinators who commented on ESS, 19 pointed out that it led to the children's being active. A common minority response was that to implement ESS there was need for teacher training and that the structure of the program seemed disorganized.

Q. 104. What comments were offered about Minnemast?

A. 104. Minnemast was being used in only nine school systems and in most of them it was a very new program. They noted that it was well-organized and easily integrated with other subjects.

Q. 105. What comments were made by the science coordinators about SCIS?

A. 105. Of the 24 science coordinators who discussed SCIS, a minority agreed that it led to the children's being active, and they pointed out that its content emphasized inquiry. The commonest and few complaints were that the materials were not especially durable and that the program was expensive.

Q. 106. What comments were made about the Concepts in Science program?

A. 106. The 16 science coordinators who commented on this program labeled it "process education: and half of them commented on the program's emphasis on concepts. But the rest of their comments about its strenghts and weaknesses showed no unanimity.

Q. 107. What comments were offered about Experiences in Science?

A. 107. Of the ten coordinators who commented on this program, five mentioned that it led the children to be actively involved. Five complained that the materials were not durable.

Q. 108. How do science coordinators who have tried the various NSF curricula rate their success?

A. 108. Almost always as "excellent" or "satisfactory"; only 12 percent of the trials were felt to have been poor.

BRIEF SUMMARY

We have already noted, and we emphasize it here, that the term "science coordinator" is a generic one. We have used it to designate the person in any given school system who is most responsible for elementary science. If all science coordinators were trained in science and spent most of their time working with teachers on science in the elementary school, then we would have a relatively complete picture of how this role works in all of the systems. That we do not have. We have three or four different groups of people most responsible for science, and in less than a quarter of the systems do we find full-time science coordinators designated by title with science responsibilities. In other cases, people hold this responsibility along with more pressing duties, from being principals to assistant superintendents for instruction. So, when we review the activities of the science coordinator and how the system supports this person, we cannot always speak with full knowledge.

Science coordinators have been in their present school systems for longer periods of time than they have been in that position. Most have administrative experience.

If a school system has a designated science coordinator, it will more likely have an NSF program; and if the coordinator is responsible for K-6 alone, then the system will surely have an NSF program. The more time a science coordinator spends on coordinating -- working with teachers, giving in-service programs, and the like -- the better science program a system will have.

The smaller systems and the very largest appear to suffer most from inadequate science programs. Medium-sized systems have the most NSF programs. This probably indicates a kind of educational inequality. A system spending less than $600 a year per pupil finds it difficult to obtain the necessary resources for a strong elementary program in science; if Boston, for example, decides that it wants to put an NSF program in every classroom, the system would have to spend $1 million or more to do so.

The science coordinators think there are distinct differences between SCIS and ESS and between Minnemast, AAAS, and the non-NSF approaches. SCIS and ESS coordinators appear to like what they are using more than the coordinators of the other NSF programs. This does not mean that these are better programs, but rather that the science coordinators using them reveal a higher degree of satisfaction.

Science coordinators as a group do not spend much time coordinating or working with teachers or giving in-service programs. Only one out of every four has been a science teacher in the past. Only 35 percent were science majors in college. The coordinators view with some skepticism after-school, academic year in-service programs, preferring instead summer workshops.

The position appears to be rather untenable but there is a great deal of freedom if a person chooses to exercise it. Most of the science coordinators' information about elementary science programs comes from workshops and professional conferences. How the science coordinator operates, what his priorities are, and how he spends his day, seem to vary greatly from system to system. In his role, he may have comfortable margins in which to help the system become more receptive to new programs. When he chooses to exercise his perogatives, the system benefits. But, except in those eighteen systems that have a full-time K-6 coordinator, it is not a well-defined position.

THE SCIENCE COORDINATORS' SUGGESTIONS

Q. 109. <u>What suggestions and advice do the persons responsible for implementing NSF curricula have to offer to others? What do they feel they have learned from their experiences?</u>

A. 109. Involvement, the goals of the system, sustained planning and commitment, and other considerations are important. But let's read what the coordinators wrote about this.

We asked the person responsible for elementary science in the school systems the following question:

One of our purposes is to help school systems that are implementing or plan to implement new elementary science programs, and we would like to draw on your experiences. Suppose a colleague in a school system very similar to yours was about to introduce and implement a new elementary science program. What lessons learned in your own system would you offer him as advice? What questions should he ask?

A selection of science coordinators in NSF systems replied:

"What is the consensus about the present program(s)?" Do they need basic and/or supplementary programs? Establish what may be the current attitude among principals, teachers, students, parents and central administration. How much coordination is possible within and without each school? Determine funding available in the light of what has been customarily expended. Who are the 'strong' science people in the system -- use them! Establish the positive aspects as well as the negative, of existing program(s). Request a committee. (Include a principal or two.)"

"Explore all possible programs to help decide program to be used. Look at cost figures and decide how much you may spend each year. If time is available for intensive in-service workshops, then plans can be made to implement total program, otherwise program will have to be placed a piece at a time. Most important, pick program that will be readily adapted to teacher preparations and interest even if it must be a moderately innovative one."

"1. Teacher committee for acceptance.
2. In-serivce workshop.
3. Pilot program for an interested teacher(s) and class(es).
4. Parent conferences.
5. Budget well -- plenty of supplies needed.
6. Work in schools interested in science.
7. Use as many outside resource people as possible, including those in your own community."

"It might be better to experiment with a limited number of schools (e.g., a 'cluster' of elementary schools feeding a particular junior high school). I would try to plan a program for each building rather than 'scattergun' several. I would always involve teachers in selecting programs they were to use. This enables teacher style to be considered. I would not adopt a single program on a systemwide basis. Always have in-service training for teachers prior to introducing a new program. Then provide these participants with materials."

"1. Begin only with enthusiastic, willing teachers who have better than average teaching skills.
2. Being slowly -- with above as teachers. Let this group serve as your pilot, providing considerable feedback at frequent intervals.
3. Provide as much time as possible for in-service help.
4. Teach the program somewhere yourself -- if only for two to three months."

"1. Develop an interest and show a need within the community for elementary science. (P.T.A. groups, Girl and Boy Scout groups, business organizations.)

2. Determine availability of funds for supplies and equipment.
3. Secure a commitment from the school committee for in-service credit or released time for teacher training.
4. Involve teachers and principal in an evaluation of various programs. Educate teachers and administrators as to difference between science and technology. Emphasize the new role that science education is taking in the elementary curriculum. Stress the process and conceptual skills that are adaptable to all areas of the elementary curriculum. Programs to be evaluated should be preselected by director of science based upon the philosophy of the total science programs, K-12.
5. Provide for adequate storage of materials.
6. Implement program at a rate that will guarantee proper supervision and administration.
7. Require teachers to submit yearly reports on evaluations and progress of the program.
8. Emphasize your role as a helper rather than an observer or critic."

"Provide extensive in-service training for teachers so they are thoroughly acquainted with the program, know how to teach it and know the materials involved. This has been the most important single factor in 'selling' science."

"Introduce materials very gradually, spread adoption out over several years, giving materials only to those teachers who desire them during the initial stages. Once the bugs are worked out, then these teachers can be used to train the rest if the materials look good."

"1. What are your objectives (skills, concepts, etc.)?
2. What is your rationale for science instruction?
3. Stay away from <u>all</u> textbook series.
4. Observe new programs in action -- look for 'turned on' kids and teachers.
5. Seek NSF, NSTA information and publications.
5a. Attend conferences, conventions and workshops.
6. Committee review (including teachers).
7. Small-scale trial.
8. Adopt nothing across the board until you see if it works for you (7 above).
9. Cost consideration, including replenishment of expendables."

"Attend EDC workshops. Attend NSTA workshops. Attend ESS, SCIS workshops. Buy lots of frog eggs and supplies. Gather many plastic dishes. Include teachers in planning. Keep principals informed. Visit other schools. Keep parents informed and involved. Involve civic improvement groups, if possible. Check federal, other funding. Integrate with other curriculum areas. Take field trips often. Use outdoor study areas. Read professional journals."

"1. Contact teachers interested in science and those who have been part of the decision procedure.
2. Select teachers who are respected in their schools and have <u>them</u> present the program with opportunity for teachers to 'try,' with the contact teacher in the building as a resource person. If other aid is needed, call others, with necessary background (from Science Curriculum Committee) to consult and hopefully, answer problems.
3. Be sure the materials a teacher needs are available when they volunteer to 'try' a program.

4. The best advertising is a teacher who tells other teachers about the enthusiasm the pupils have with the program."

"Involve the teachers who will teach the program in the decision, give them an intensive in-service program on the program selected and taught by a well qualified consultant who has been successful elementary school teacher but who also knows science education."

"1. Have the committee represent all interests, if possible. This should include teachers, principals, interested and/or competent parents and students.
2. Figure out approximately how long the task will take, then add six months!"

"Appoint a well versed, qualified, fulltime science coordinator to:
1. Institute continuing workshops for new teachers to system.
2. Coordinate all grades and schools.
3. Visit and observe and help teachers.
4. Evaluate the science program.
5. Maintain a resource center of science materials that teachers may borrow from or obtain help or instruction from in maintenance and minor repair of some items.
6. Maintain an inventory, assess needs for the next year.
7. Compile a budget."

"Provide much teacher training before, during and after program implementation. Support of various building principals is necessary for success of implementation. Resource person or persons quite necessary."

"Make sure all principals undergo some training or are required to attend an in-service program dealing with philosophy, teacher's role, student role, supplies of materials, and how to collect objective data to assess the program."

"Move slowly with the staff of a school that seems reluctant about the program, even though it was approved and recommended by a committee. I would have a tendency to bypass this school until the staff starts to make inquiries about the program because of the PR the other schools may be receiving, teacher enthusiasm and student and parental pressures."

And, finally, one coordinator said simply, "Pray!"

VIII

"IN KINDERGARTEN WE WENT OUTSIDE AND CAUGHT A BUTTERFLY"

CHILDREN AND ELEMENTARY SCIENCE

We had two goals in mind when we interviewed a selected group of children and gave them questionnaires to answer. Our goals were (1) to find out the children's attitudes towards and interests in science; and (2) to explore the relationship between the teachers' attitudes and interests in science and their impact on the attitudes and interests of the children whom they taught.

In developing the sample of teachers and children, we started with a random group of 800 elementary teachers in Massachusetts, one-quarter of whom taught in the fifth and sixth grades. We selected the fifth and sixth grade children because they are more articulate than younger children. We had about two hundred teachers to choose from, but this group was further limited to those who had indicated a willingness to cooperate with us in seeking further information for the study.

We ended up with a group of 21 fifth and sixth grade teachers, ten women and eleven men. These teachers are not a random sample of teachers in the state, but they represent a diversity of personal and academic backgrounds and they include both NSF and non-NSF teachers from small and large, urban and suburban schools. They teach a total of 712 children in nine different communities. Eight of the teachers used traditional, non-NSF programs; thirteen used NSF (ESS or SCIS) or NSF in combination with a textbook series.

Two-thirds of this sample of teachers liked teaching science more than teaching other subjects; 14 percent liked teaching science less than teaching other subjects. Forty-eight percent felt that their teaching skill in science was better than it was in other subjects.

All the children responded to the questionnaires. From them we selected 18 groups of children representing four teachers (two male and two female) to interview personally, four or five at a time. All of the students interviewed were using ESS in one form or another. One-third of the children interviewed came from poor urban communities, one-third from wealthy suburban communities, and one-third from middle income communities.

Q. 110. Do children like science?

A. 110. Yes, very much. Science is the second most popular subject (next to mathematics) among fifth and sixth graders, but only a small majority of the children liked mathematics more than science as their favorite subject. Forty-five percent of the children liked science more than their other subjects; 38 percent liked it the same; and 17 percent liked it less.

Only 6 percent of the children in our sample selected science as a subject they liked least. (Twenty-four percent of them chose mathematics as the subject they liked least.)

More than half of the children liked science very much this year compared to only about a third who liked it as much the preceding year (in either the fourth or fifth grade).

Slightly more than half of the children are already making plans to take some science courses in high school. Although 44 percent have not yet decided about taking science in high school, only 5 percent have been throughly turned off and expect to take no high school science courses at all.

Q. 111. Do children like doing experiments?

A. 111. More than half the students thought that doing experiments in science was "more fun than hard work" and more than two-thirds of the students (71 percent) reported that they enjoyed doing experiments. We found no differences in the responses from boys or girls in either the fifth or sixth grades.

Almost all of the children questioned were doing experiments of one sort or another; they most frequently reported their enjoyment of these ESS units (i.e., they remembered them): Peas and Particles, Bones, Stream Tables, Mystery Powders.

Some of the children said: "I like subjects where you do something: science and art." "I like science this year because we get to do things." "I like working with kits; it's like a game. You learn more and get more interested."

Q. 112. Do girls like science less than boys?

A. 112. Our information reveals that the differences in science interest are more likely to occur in the sixth grade than in the fifth grade. In the sixth grade boys tend to be significantly more interested in science, as indicated by the children's considerations of future jobs, favorite subjects, best grades, and plans for study in high school.

Sex roles appear to play a crucial role at this stage. The interest of girls in science drops off in the sixth grade; until then there are closer levels of interest among boys and girls. Only 14 percent of the children -- boys and girls -- felt that people wanted girls to be scientists; but fifth grade girls felt more support from their world than did sixth grade girls. Can schools do something to keep intact the interest of girls in science?

Q. 113. <u>What are some of the major influences generating interest in and attitudes toward science in children?</u>

A. 113. There are many sources from which children can hear about science, including television, books and the home. Of the children sampled, 37 percent said they first learned about science in school from a teacher. Eleven percent first learned about science from television, and 6 percent learned about science from parents. But 36 percent of the children could not remember exactly what source was responsible.

Here are some comments of children about when they first learned about science:

Boy: "I never really learned; I always sort of knew about science."

Girl: "First grade."

Boy: "In kindergarten, we went outside and caught a butterfly."

Girl: "I always liked science. My brother got me interested. I watched him developing pictures."

Girl: "I watched my brother with his chemistry set. That's how I learned."

Some of the evidence reveals that girls are more likely than boys to have first learned about science from a teacher; boys are more likely than girls to gain this knowledge initially from a book or television. For the girls in our sample there was not much encouragement of interest in science in the home, and significantly this is true for all the communities in our sample.

Children do not view parents as that important in the early formation of science attitudes and interests. Only two out of ten children reported that they ever asked parents questions about science and only one out of ten children agreed that their parents thought that science was the most important subject.

The parents' professions ranged from unskilled and unemployed to highly paid professionals and business people, from artists to clerks to housewives. There was no significant relationship between a father's occupation and the interest of a child in science. The father's occupation was significant only in relation to the child's potential involvement in science as a career. But children whose families were in the middle and upper income economic strata were more likely to report that they received their best grades in science. Fathers who were in the lower economic stratum had children who planned to take many science courses in high school, while upper stratum children were more likely not to know or to be in the small group that planned to take no science courses in high school. Possibly science is seen as a way toward upward mobility. If you are the first in your family to go to college, you go to learn something practical and useful.

A mother's occupation seems to have more impact on a child's interest in science than the father's. Children -- both boys and girls -- whose mothers were in semi-skilled or unskilled jobs, or who were housewives in any economic stratum, were likely to like science more this year and to like it more than other subjects. Children of mothers in professional positions, including bank tellers and artists, were more likely to be in the small group of children that selected science as the subject they liked least. The mother's occupation was not associated with any attitude factors.

For the girls who favored a career in science or in other traditionally male professions, there is more of a relationship with their father's occupation than with their mother's Upper and lower strata mothers tend to have "liberated" daughters; i.e., girls who choose science or male-related professions, such as being a jet pilot or policman. The "non-liberated" daughters tend to come from the middle stratum families.

Q. 114. <u>Do the attitudes and interests of teachers toward science make a difference?</u>

A. 114. Certainly. On all of the indicators of interest and attitude in our interviews with children, it appears that the individual teacher makes a significant different in the attitudes and interests of the children toward science. One boy said: "I never heard of fun science 'til this year." Another said: "Last year the teacher was a bore. She didn't teach you anything. This year's teacher teaches me something." One girl said: "We have a good teacher this year. If you like the teacher, you like the subject." Another said: "Last year we had a better teacher and I liked what we learned better."

Q. 115. <u>Does it make any difference if a child has a male or female teacher of science?</u>

A. 115. A distinct difference, apparently. We learned that children -- boys and girls in both fifth and sixth grades -- tend to like science better if their teacher is a man. We should be wary of drawing any far-reaching conclusions from this discovery, especially in view of the fact that most elementary teachers are women and, that being the case, students are likely to prefer men teachers -- in science or any other subject -- out of sheer desire for novelty.

BRIEF SUMMARY

Children like science. That they like it a lot is an overarching factor in our consideration of how it is possible to bring more satisfying experience to more students. For they like it despite the difference in intensity of the generating forces that first stimulated their interest in science, whether it be the home, television or books.

According to the children, schools play a very important part in stimulating their science interest. Individual teachers can and do make a difference in children's interest and attitudes toward science. Parents, on the other hand, play a relatively minor role, according to children, in stimulating interest in science.

Through the fifth grade, girls apparently are as interested in science as boys, but a change takes place in sixth grade. In this grade, they are no longer as interested in science as boys are. However, since only 14 percent of the children -- both boys and girls -- felt that people wanted girls to become scientists, we can see how the sex roles in our society suddenly are reflected in the society of the school. Girls do not like science less than boys. But society tells girls that the profession of a scientist is not a woman's profession. By the time a girl has finished the sixth grade, she has begun to formulate her adult feminine identity; thus, at this stage, she may be more sensitive to society's prescriptions about what a girl ought to do. It may be that schools can counter this tendency by providing support and encouragement to girls in their science programs.

Children like science, they like to do experiments, and many consider science worthy of further study. Half the children are already making plans to take some science courses in high school. Only 5 percent of the children had decided to take no high school science courses. Clearly, science makes a difference to children; they are already eager and able to approach science positively and enthusiastically. Are the schools ready, eager and able to respond?

IX

SUMMARY

The first efforts of national curriculum development groups in the middle fifties were directed at preparing new high school science courses in physics, biology and chemistry, and in mathematics. Supported by the National Science Foundation, these groups developed the Biological Sciences Curriculum Study (BSCS), Chemical Education Materials Study (CHEM Study), Harvard Project Physics (HPP) and the Physical Sciences Study Committee (PSSC). The rate of adoption of these new programs and acceptance by high school science teachers increased at a substantial rate in successive years. Reform efforts in elementary science started in the early sixties; three of the four new major NSF-sponsored programs have been commercially available to the schools for several years. Yet it appeared to some observers that the rate of adoption by the schools was somewhat lower than could be expected. This study grew out of the interest of the director of the Massachusetts Advisory Council on Education and his colleagues. They wanted to learn what was happening with the new elementary science curricula in Massachusetts schools, and in the spring of 1971 they invited Dr. Dean K. Whitla, director of the Office of Instructional Reserach and Evaluation, at Harvard University, to direct the study. Dr. Whitla then recruited a committee of nine to join him in planning and conducting the research.

The members of the study committee wanted to draw upon samples of respondents who were representative of all of their peers in Massachusetts schools and to design questionnaires that combined the virtues of sharply-formulated, pretested, multiple-choice items on the one hand and open-ended expression of opinion on the other. Questionnaires were designed separately to be mailed to statewide samples of elementary school teachers, science coordinators, principals, superintendents with elementary school enrollments, and 5th and 6th grade students. In addition, classroom visits and personal interviews were carried out in forty system. A description of data collection methods and responses is given in a footnote.*

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* The data from the questionnaires was coded for computer analysis; descriptive statistics, such as frequency distributions, were made available for every variable; and hundreds of relations between variables that seemed of interest were examined by means of contingency tables and analyses of variance.

Some of the statistical works has also been used in separate technical papers that focus on particular issues of interest to members of the committee. The summary offered here is an overview of all of the data and reported without excessive statistical details. (If our conclusions interest researchers among our readers, the computer data will gladly be shared with them.)

The first questionnaire was sent to 244 superintendents in December 1971. Responses were received from 214 superintendents (88 percent) whose systems represent 90 percent of the elementary schools in the state, 92 percent of the teacher population and 96 percent of the student population. We heard from 100 percent of all of the systems with more than 2,000 elementary student populations.

From the research we have gained a comprehensive picture of the extent to which the NSF elementary science curricula are being used in Massachusetts schools, and we have learned also a great deal about the manner in which students, teachers, principals, science coordinators and superintendents are affected by them. We have found far fewer obstacles to using these programs well in the schools than we anticipated when we began our study, and there is some reason to feel confident about the continuing acceptance of them. The people who use the NSF curricula find in them a capacity to make classroom instruction lively and interesting. This was as apparent from our research as it was from our classroom observations. The NSF programs -- offering an abundance of materials by which students and teachers may gain a firsthand, investigative experience in science -- give schools a vehicle and a subject area that can transform a static classroom into a lively one and can make possible a shift from the didactic lecture method to an interactive class mode, from reading about science to doing science. According to teachers and students, the new curricula tend to be agents of change in themselves, and rather spiritless classrooms can become energized when laboratory experiences are possible.

Yet there are important problems that should be considered in examining the introduction of new elementary science curricula, and some of these problems may persist even following a system's commitment to the new curricula. Unlike the high school science courses, there is not a small cadre in the elementary school of specialized science teachers. Ninety percent of the elementary teachers teach science, along with their other subjects. Hence it is difficult to provide teacher education opportunities for the beginning elementary teachers as well as for experienced teachers, and to provide such opportunities on a sustained basis. And science is a relatively low priority item in the elementary school curriculum; the concept of scientific literacy has little saliency at the elementary level. Further, it must be recognized that science materials and programs are relatively high budget items considering the instructional expenditures in elementary schools.

Science coordinators in 244 systems next received questionnaires, and 158 coordinators (65 percent) responded. The respondents represented 71 percent of the total number of elementary schools in the state, 79 percent of the elementary school teachers, and 77 percent of the elementary student population.

We then sent questionnaires to a teacher sample. We mailed a total of 2,100 questionnaires and we heard from 822 teachers (39 percent) who represented 73 school systems and 1,000 classrooms in 248 schools. They were responsible for teaching 25,000 students, K-6. NSF curricula and non-NSF curricula were about equally distributed in the teacher sample. Fifty of the NSF teachers (17 percent) were using a combination of NSF programs; 104 teachers (28 percent) were using Science Curriculum Improvement Study (SCIS); 26 teachers (7 percent) were using Minnesota Mathematics and Science Teaching (Minnemast); 89 teachers (24 percent) were using American Association for the Advancement of Science (AAAS); and 99 teachers (27 percent) were using Elementary Science Study (ESS). One hundred and forty-six teachers were in systems with over 5,000 elementary school students; 407 in systems ranging from 2,000 to 5,000 students; and 225 teachers were in systems with less than 2,000 students.

Principals were the next group to be surveyed. There were 208 respondents (53 percent) from a total of 380 who received questionnaires. The 208 respondents worked in 60 school systems; half of the principals used NSF curricula

Are there compelling reasons to overcome these obstacles? Even though we do not fully subscribe to all of the Jencks' conclusions, we do agree with him that schools should be satisfying places in which to teach and learn and that pleasurable experiences should occur in them. Where we found problems they tended not to be in operational areas; e.g., classroom management and discipline, nor in the curricula themselves. Rather, the problem areas concerned in-service training, consultant help and storage space. The elementary school, however, can be a sufficiently flexible institution to accommodate the problems of teacher specializationa and training, and we believe that it can become even more responsive to science teaching needs. Instituting any new program, especially those with equipment, can be expensive, and the NSF programs are not cheap. These programs are also filled with expendible items, such as batteries and bulbs, and they too cost money. But the costs relative to school benefits are very minimal and appear from all the data we have been able to collect worthy of the cost.

The summarization of the findings is grouped in different ways: following our initial reporting on the use of the NSF programs in Massachusetts schools there are paragraphs dealing separately with topics of common concern, such as pupil progress in science, classroom preparation and the adequacy of teaching guides. Teacher training, science coordinators, principals, financial considerations and sex-role stereotyping are delineated at greater length. We conclude the summary information with teachers' perceptions about the NSF curricula and with two tables, one showing some of the differences between systems committed to NSF curricula and those using textbooks, and the other showing how science coordinators view the strengths and weaknesses of the NSF curricula. Then follow our recommendations.

At least 13 percent of Massachusetts public elementary school children -- or 78,000 children out of a total elementary population of 600,000 -- studied science in NSF programs duing the academic year 1971-1972. This is higher than the national estimate of 4.6 percent for the same year. Furthermore, 54 percent of the systems using NSF curricula in limited or trial use indicated that they planned to expand their use in the future. One hundred and sixteen system (48 percent) are using NSF curricula, ranging from limited trials in a few classrooms to full adoption in the system. One hundred and twenty-eight systems (52 percent) are using non-NSF programs. Some of these non-NSF programs, including the "Concepts in Science" series (used in 13 systems) have optional laboratory equipment. Only 12 systems in Massachusetts have either used and discontinued NSF programs or have considered and rejected their use.

Seventy-three systems are using Elementary Science Study (ESS); 44 systems are using Science Curriculum Improvement Study (SCIS); 39 systems are using American Association for the Advancement of Science (AAAS); and 9 systems are using Minnesota Mathematics and Science Teaching (Minnemast).

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in their schools and half used non-NSF programs. The respondents' schools taught about 66,000 students.

The sample of students totalled 712 fifth and sixth graders in nine school systems, in varied socio-economic settings.

Of the systems using a particular program the percentage of use by grade is given in the following table:

GRADE	SCIS	ESS	AAAS	MINNEMAST (K-3 PROGRAM)
K	27%	34%	51%	67%
1	80	53	95	67
2	80	58	90	67
3	64	63	74	44
4	41	81	44	0
5	34	81	28	0
6	5	85	8	0
TOTAL SYSTEMS	44	73	39	9

An additional table shows the number of systems using the NSF curricula, and the number of classrooms and buildings using these programs:

	SCIS	ESS	AAAS	MINNEMAST
SYSTEMS	44	73	39	9
BUILDINGS	218	374	212	36
CLASSROOMS	910	2,680	1,230	159

Do the NSF curricula represent an improvement over other programs and other ways (that are now commonly practiced in the schools) of introducing science to children in the elementary school? Our answer is that they do for the following reasons:

PUPIL DIFFERENCES

The NSF programs allow teachers to become more responsive to a wider range of pupil differences than the non-NSF programs. Forty-two percent of the NSF teachers reported that their programs were "very suitable" for use by all students, while only

23 percent of the non-NSF teachers felt this to be the case. In an NSF program the slow learner can be reached more readily while the ablest child is simultaneously being interested and challenged.

PUPIL PROGRESS

Since elementary science has a low priority in elementary education, it is assumed by some observers that children do not make as much progress in science as they do in their other subjects. We learned that 62 percent of the non-NSF teachers felt that their children made less progress in science compared to their progress in other subjects; yet only 38 percent of the NSF teachers felt the same way about the progress of their children in science.

STUDENTS' LIKING OF SCIENCE

In the analysis of the responses from teachers, we found that a larger proportion of NSF teachers (61 percent) than non-NSF teachers (54 percent) felt that their students liked science more than other subjects. In the analysis of student data, we learned that more of them chose science as their favorite subject (27 percent) than any other subject. Seventy-six percent of them like science either the same or more than their other subjects. (Only 5 percent reported that they liked science the least.)

'DOING' SCIENCE AND 'READING' ABOUT SCIENCE

NSF classrooms more frequently offer opportunities to "do" science and not just "read" about it than non-NSF classrooms, according to the teachers. This is hardly unexpected considering the supply of materials that come with NSF programs. Although there are no significant differences between the two in the writing of reports and making collections and displays and models, other science activities show a difference. NSF classrooms do more experiments and record data from them than non-NSF classrooms. Apparently one effect of being more active is to encourage independent learning: we found that activities such as taking home science materials and supplementary readings, and the like, occurred 25 percent more frequently in NSF classrooms than in non-NSF classrooms.

TEACHERS' LIKING FOR SCIENCE TEACHING

We found that there is neither an overwhelming liking for science teaching nor an overwhelming dislike for science teaching in the elementary grades. One-fourth of the teachers in our sample as a whole reported that they liked teaching science more than other subjects; another quarter said they liked science teaching less. And one-half the teachers reported that they liked science teaching the same as teaching other subjects. However, we learned in another place in our survey that once a teacher begins using an NSF program the odds were improved: a higher percentage of the NSF teachers (79 percent) liked teaching science more or the same than the non-NSF teachers (62 percent).

ADEQUACY OF TEACHING GUIDES

More NSF teachers (80 percent) felt that the teachers guides were adequate than did non-NSF teachers (65 percent).

CLASS SIZE

There is no difference in class size between schools using NSF programs and schools using other programs.

EFFECT ON STUDENTS' ATTITUDES TO LEARNING

According to the teachers, the effects of science instruction on students' attitudes to learning were that students showed curiosity, asked questions, participated actively in conducting experiments and enjoyed science. The NSF programs were more effective in bringing about these conditions than non-NSF programs by ratios higher than 2:1.

CLASSROOM PREPARTION

A higher percentage of the NSF teachers (38 percent) feel that their programs require "much preparation" than do the non-NSF teachers (22 percent).

TIME FOR ELEMENTARY SCIENCE

More time is spent on science in each succeeding grade. Science is given more emphasis in the upper elementary grades, 4 to 6, then in the primary grades. Only 76 minutes weekly are devoted to science in the first grade; 157 minutes weekly are devoted to science in the sixth grade. (There is no significant difference between the time spent on NSF curricula and non-NSF programs.) The average time per week spent on science in all of the elementary grades is 108 minutes.

SCHOOLS CAN BE THE DIFFERENCE

In our sample of children the data revealed striking significant differences about the role of the school and the teacher in stimulating the interest of children in science. Despite socio-economic differences and despite parental occupations, ranging from the unskilled to the well-to-do professional, the home apparently plays a minor role, and the school a major one, in introducing science to children. Thirty-eight percent of the children first learned about science from a teacher and only 6 percent reported that the source was a parent or a brother or sister (5 percent). Eleven percent of the children reported that they first learned about science from television and 5 percent from a book. (Thirty-one percent said they didn't remember where they first learned about science.)

CLASSROOM MANAGEMENT AND DISCIPLINE

Some observers believe that interactive classroom environments -- especially those that may be encouraged by the availability of materials that allow each child to engage in his own experimentation and to discuss his work with his peers -- create classroom management and discipline problems. Yet from our data we can infer that the NSF curricula do not create undue problems. A larger percentage of NSF teachers (60 percent) than non-NSF teachers (46 percent) felt that the "noise" and activity in their classrooms was in no way disruptive of teaching and learning. Teachers prefer, apparently, to see students involved and working with one another in busy, active classrooms. (At the extreme, only 4 percent of the NSF teachers and 3 percent of the non-NSF teachers felt uncomfortable.)

SHARING IDEAS

Thirty-seven percent of the NSF teachers meet together informally and often to discuss science, while only 18 percent of the non-NSF teachers do.

SCIENCE SPECIALIST HELP

Thirty-one percent of the systems committed to NSF curricula have some specialized science teachers. Only 19 percent of the non-NSF systems provide this kind of help. The customary teaching approach in 51 percent of the NSF systems is a classroom teacher with no assistance from an elementary science specialist or consultant. This percentage rises to 94 percent in non-NSF systems.

TEACHER INVOLVEMENT IN INNOVATION

Seventy-six percent of the teachers felt the need for a new program (whether NSF or text) before they began using the current program, but only 12 percent of the teachers helped select the new program in their system and only 20 percent in their schools. Forty-one percent were among the first teachers in the system to use the new programs and thirty-nine percent volunteered to use the new program.

COMMUNITY INVOLVEMENT IN ELEMENTARY SCIENCE

Teachers, science coordinators and principals reported that parents play next to no role in elementary science, neither aiding nor hindering what the people in the schools want to do.

STORING MATERIALS

Forty-one percent of the teachers reported that they stored materials in the classroom where children can easily get them. Twenty-three percent said they kept materials in a storage area until they were needed for a specific lesson, and 8 percent stored materials in the classroom but "safely out of reach." (Various other accommodations were made by 28 percent of the teachers.)

EDUCATION AND TRAINING OF TEACHERS

Teachers with strong science backgrounds are more satisfied with teaching science than those with weaker backgrounds, and there are no differences in the undergraduate science preparation between NSF and non-NSF teachers. Twelve percent of the teachers in the sample had taken more than six undergraduate science courses. Only 3 percent of the teachers have not had at least one science course as an undergraduate.

Most elementary teachers feel that their undergraduate science education was not as helpful as it should have been, and some were extremely critical of their science methods courses. Seventy-three percent of the teachers had science methods courses, but only one teacher out of every four thought that methods courses were helpful.

Most science workshops apparently are conducted in a manner antithetical to the aims and philosophies of the new curricula. Eighty-four percent of the teachers reported that the workshops they attended consisted of demonstrations and 54 percent reported that the workshops seldom or never dealt with the units they were teaching, and 68 percent of the teachers said that the workshops seldom or never gave them the opportunity to try out materials with children.

Teachers who have participated in science summer workshops like teaching science more, in general, than those who have not.

Forty-six percent of the systems offer in-service work in elementary science. Sixty-seven percent offer it in other subjects, in mathematics and the language arts.

Seventy-three percent of the NSF systems offer workshops in elementary science. Only 23 percent of the non-NSF systems do.

Two-thirds of the teachers (66 percent) who attended science workshops in the summer rated their teaching skill in science as either better or the same as their skill in teaching other subjects. Slightly more than half the teachers (51 percent) who did not participate in summer workshops felt this way about their skill. This might indicate that summer workships simply increase a teacher's confidence generally; but perhaps it also helps to have some special help in planning next year's activities.

Twenty-nine percent of the teachers have attended science workshops, institutes or courses held outside their systems -- at a college or university or another school system; 71 percent have not.

An average of 22 hours was spent by teachers over the preceding three years attending science workshops held either in the system or outside of it.

PRINCIPALS

Principals with NSF curricula in their schools are more satisfied with the science activity (50 percent) than are principals with non-NSF curricula (30 percent). Two out of three NSF principals would like to supplement their present supply of materials.

Principals rank science third or fourth in importance in the elementary curriculum, far behind mathematics and reading and sometimes slightly lower than social studies. Only 54 percent ranked science third or higher. (Ninety-nine percent ranked reading first.)

Fifty-seven percent of the principals considered their present science facilities either inadequate or totally inadequate.

Twenty percent of the NSF systems offer workshops in science for elementary principals. Nine percent of the non-NSF systems offer them. Many principals would like to participate in science workshops, if principals and teachers from their own schools attended the workshops with them.

In the following order are ranked the principals' needs to improve or change the facilities for teaching science: Storage space (52 percent of them needed storage space or additional storage space); a special science room (45 percent); sinks (37 percent); electrical outlets (34 percent); movable furniture (18 percent); better lighting (7 percent); and windows (5 percent).

Three out of every four principals reported that they had been able to obtain replacement and consumable materials; one out of every four could do this only with great difficulty or not at all. Yet 39 percent reported that their budget requests for science were approved in full and only 4 percent said their requests were usually rejected. Fifty-three percent of the principals reported they have little or no petty cash or discretionary funds for science: 21 percent had less than $50 to spend a year. Nine percent had more than $250. Eleven percent had between $50 and $100, and 5 percent had between $100 and $250.

According to the principals, the quality of science instruction in their schools was rated excellent (17 percent), satisfactory (49 percent), fair (28 percent), and poor (6 percent).

Grades are given in science in 73 percent of the principals' schools, but 59 percent of the principals felt that grades should not be given in science.

Principals neither spend very much time in maintaining the science activity in their schools nor do they see themselves having played a key role in encouraging the use of new curricula. The elementary science coordinator (80 percent) and the classroom teacher (44 percent) play larger roles in their opinion than they do themselves (42 percent). Only 3 percent said that parents played a major role. (Only 5 percent of the principals work directly with children in the classroom and only 7 percent spend a lot of time assisting individual teachers.)

Principals reported that there were no overriding hindrances to effecting change in elementary science. There were only three factors in which over 25 percent of the principals reported as being great hindrances. None of these involve the curriculum itself, but rather that other subjects have a higher priority (31 percent); there is inadequate consultant or science specialist help (27 percent); and there is inadequate in-service training (25 percent). The following factors were considered to be some hindrance: teachers do not know methods of teaching science (64 percent); they are afraid of science subject matter (55 percent); and teachers are reluctant to try new methods and materials (53 percent). About half the principals felt hindered by inadequate room facilities, insufficient funds, and an inadequate system of maintaining and distributing materials and equipment. Inadequate in-service training (45 percent) and inadequate consultant help (36 percent) were considered to be of some hindrance.

Only 5 percent of the principals felt that their personal interest was the most important factor in the success of science instruction in their school. They felt that the enthusiasm of the teacher (68 percent) and the teacher's skill (17 percent) were the most important factors.

Only one out of every seven principals has ever taught science full-time, and less than 10 percent of them attend National Science Teacher Association meetings or have attended NSF workshops.

SCIENCE COORDINATORS

In 90 percent of the systems program reviews were conducted by ad hoc committees concerned only with elementary science, not by a general curriculum review committee. These ad hoc committees consisted primarily of elementary teachers and some elementary principals. In less than 40 percent of the cases was the science coordinator or a science specialist a member of the review committee, and in only 28 percent of the systems was the initial suggestion for program change or review made by a K-6 or K-12 science coordinator. Nevertheless, school systems with a designated full-time science coordinator, either K-6 or K-12, are more likely to have NSF curricula than systems that give the responsibility for science to a person who has other duties, such as a principal or an assistant superintendent for curriculum and instruction. Forty-five systems (23 percent) have designated science coordinators and of them 27 systems (14 percent) have K-12 coordinators and 18 systems (9 percent) have K-6 coordinators. Each of the systems with K-6 coordinators uses NSF curricula. Eighty percent of the systems committed to NSF curricula have a K-12 coordinator.

On average, the "person most responsible for science" in a system spends only 20 percent of his time coordinating science activities. But we found that almost half of the K-6 coordinators spend more than 50 percent of their time on elementary science, and five of them spend 100 percent of their time on it. Only 9 percent of the K-12 coordinators spend at least half of their time on elementary science.

Both the K-6 and K-12 coordinators spend significantly more time advising teachers and giving in-service workshops than do other ranks in the system who are given science responsibilities along with other duties. Persons with science responsibility in the central administration spend only 8 percent of their time advising teachers and 12 percent of their time on in-service work. (The least innovative systems in elementary science; i.e., those using textbooks and with no plans to consider using NSF curricula, place the elementary science responsibility in the hands of a central administrator or a principal. None of these systems has a K-6 coordinator and only 20 percent of them has a K-12 coordinator.)

Science coordinators conduct most of the in-service programs. Only 20 percent of the systems used other personnel in the system, or consultants outside of it to conduct workshops.

In-service training is regularly available in only twenty-four systems. Seventy-eight percent of the science coordinators would like to have more workshops, and 64 percent of them feel that the present workshops are ineffective.

Eighteen percent of the coordinators have never visited another school to observe innovative work in elementary science. Forty-eight percent made from one to three visits in the past few years. Thirty-four percent of them made four or more visits. However, 44 percent of them reported that personnel from other systems had never visited their systems regarding elementary science.

Most systems first began interested in the new curricula in the sixties (70 percent), according to the science coordinators, and only 30 percent of the systems later, beginning in the academic year 1969-1970.

The science coordinators reported that the teachers' fear of science (45 percent), the teachers' reluctance to try new methods and materials (30 percent), and inadequate consultant help (30 percent) were great hindrances to making innovations in science. The curriculum itself did not appear to be a great hindrance: only 12 percent of the coordinators felt that it required too much teacher planning, 15 percent felt that it required too much teacher training, and 8 percent felt that the curriculum was not clearly articulated from grade to grade. And 12 percent felt that principals' not helping teachers plan or improve the curriculum was a great hindrance.

Teachers play a major role in stiumlating change in elementary science, according to 60 percent of the coordinators. Only 6 percent felt that teachers played a minor role.

Only 23 percent of the coordinators in the 60 percent of the systems that have trials as policy felt that they themselves lacked sufficient information about the merits of a new program to implement one without a trial, but 88 percent of these coordinators reported the primary reason for having a trial as wanting to see how teachers and students fared with the new programs.

Thirty-five percent of the science coordinators majored in science as undergraduates. Only 4 percent reported that they had studied little or no science. Before assuming a position of science coordinator 65 percent had been elementary teachers and 47 percent had been elementary principals. Five years ago, 60 percent of them were not science coordinators.

FINANCIAL CONSIDERATIONS AND INNOVATION IN SCIENCE

A striking correlation exists between per pupil expenditures and the use of NSF curricula. Ninety percent of the systems using these programs spend more than $900 per pupil. Only 30 percent of the systems spending less than $600 per pupil use the new curricula.

The average amount spent on elementary science materials in the systems is less than $1 per pupil yearly. Systems using NSF programs spend $4.

The more per pupil expenditure on elementary science, the more outside funding that system receives, and with the exception of National Defense Education Act Title III funds (76 percent of the systems) and Elementary and Secondary Education Act Title II funds (64 percent), little use has been made of federal programs to support elementary science activities. Twenty-two percent of the systems have used Elementary and Secondary Education Act Title III funds to help establish supplementary science centers and innovative programs. Thirty percent of the systems have used Elementary and Secondary Education Act Title I funds to organize innovative science programs for the disadvantaged. Twenty-four percent of the systems have never used any outside federal funds to allay the costs of science innovation. The proportion of systems using local funds and general state aid to the use of federal funds is 84 percent local and state to 16 percent federal.

SOME DIFFERENCES BETWEEN SYSTEMS COMMITTED TO NSF CURRICULA AND THOSE USING TEXTBOOK PROGRAMS BASED ON RESPONSES FROM SCIENCE COORDINATORS

	NSF System	Non-NSF System
System provides workshops in science for teachers	73%	23%
System provides workshops in science for principals	20	9
System has a person responsible for elementary science who spends more than 25 percent of his time on coordination	40	9
System has designated K-6 or K-12 science coordinator who spends more than 25 percent of his time on coordination	33	5
System has some specialized science teachers	31	19
The common teaching approach in the system is a classroom teacher with no help from an elementary science specialist	51	94
System performs many coordination activities at the central administrative level as opposed to the building level. These activities include purchasing materials, training, budgeting, purchasing and evaluating.	38	14
System's policy provides a relatively high degree of support for released time for workshops and visits, and credit and renumeration for workshop attendance	38	23

SOME PERCEIVED STRENGTHS AND WEAKNESSES OF THE FOUR NSF PROGRAMS
BASED ON RESPONSES FROM SCIENCE COORDINATORS USING THE PROGRAMS

Program	Strengths and Weaknesses	% of Respondents
American Association for the Advancement of Science (AAAS)	Strengths	
	● well-organized and structured	67
	● emphasizes development of process skills	58
	● provides for active involvement of children	38
	Weaknesses	
	● requires too much time to teach it	29
	● too structured	25
Elementary Science Study (ESS)	Strengths	
	● provides for active involvement of children	50
	● encourages development of skills of inquiry and learning by discovery	38
	● student-centered, enabling children to pursue their own questions in their own ways	28
	Weaknesses	
	● requires too much time to teach it	27
	● does not specify a sequence of skills and concepts for each grade level	26
Science Curriculum Improvement Study (SCIS)	Strengths	
	● provides for active involvement of children	54
	● emphasizes development of conceptual framework	41
	● well-organized and structured	33
	Weaknesses	
	● living specimens difficult to keep alive	33
Minnesota Mathematics and Science Teaching Project (Minnemast)	Strengths	
	● easily integrated with other subjects	62
	● well-organized and struc-ured	37
	Weaknesses	
This program is used in only nine systems.	● no build-in means of evaluation	--
	● may be too structured for some teachers	--
	● program goes only through third grade	--

A NOTE ON SEX-ROLE STEREOTYPING AND CHILDREN'S INTERESTS IN SCIENCE

While 76 percent of the children in a sample of fifth and sixth graders liked science the same or more than their other subjects, and they liked the participatory-experimental mode of learning which is typical of the NSF programs -- our data revealed that only 14 percent of the children in these grades felt that society wanted girls to become scientists. Children's attitudes about science as well as the assumption that girls cannot do experimental work appear to be generated in the elementary years. And, further, that the feeling of the lack of support for science as a possible career is markedly more evident among sixth grade girls than among fifth grade girls.

If elementary teachers want to maintain the interest in science among girls, they may want to address the issues of sex-role stereotypes -- both as the stereotypes influence their own behavior and expectations and as they limit the options among their children. Not surprisingly, teachers were found to have an impact on their students' interest in science. The teacher and classroom characteristics which tended to produce positive science interests were: a positive attitude toward science; a responsive, flexible teaching style; the use of experimental activities that encouraged individual experimentation; and the belief that an interest in science and the ability to perform science experiments are not sex-linked functions. When teachers -- men and women -- had these characteristics and were using science programs that encouraged individual experimentation, then girls had attitudes toward science which were as positive as that of boys.

By encouraging classroom discussions about sex-role stereotypes in science and by offering programs that allowed individual experimentation, teachers can help to offset the traditional view that virtually compels elementary school students to question the ability of girls to do science as well as the propriety of their being scientists.

X

RECOMMENDATIONS

In the long run, the schools will be responsible for their own strengths and weaknesses. In reflecting upon the sharp downturn in federal support and encouragement for innovative practices and programs, it seems wisest for us to make recommendations that may assist teachers and administrators to utilize their own strengths and to suggest strategies that can make them more self-reliant.

There are many paths to excellence and many routes to innovation; we do not feel that we should recommend a single strategy for introducing the NSF curricula or for expanding their use. Indigenous methods should be derived from the interests and objectives of each school in each system. No one program or combination of programs appears to have overriding advantages over any other program or combination of programs, except to the people using them. Each school system must make its own choice and in our handbook information is given to help them better determine that choice. But there is one choice that we can make: the evidence of the advantages of the new programs is so clear that we recommend their continuing and expanding use in Massachusetts schools.

Because education is an experiment and by its nature an incomplete one, we suggest that school systems exploring the new programs do so in successive, discrete steps, allowing for individual reactions and evaluation, and that they organize for continuous master planning and not develop one master plan. In investigating the NSF curricula a system should look for the ones that reflect its own design for learning and its own educational goals and policies.

Some of the parameters of each program or combination of programs that can help in arriving at a compatible selection concern the following: the degree of structure and flexibility in the curriculum; specified sequences of activities or many options; the degree of teacher training and support required for successful implementation; conceptual and process structures or open-ended discovery; behavioristic orientations and non-restraining orientations; pupil differences and the capacity to reach a wide or narrow range of interests and abilities; subject matter balance in the physical, biological and earth sciences; evaluative schemes and philosophies in each of the programs; which programs require more storage space, more facilities, more administrative support; opportunities to engage in experimentation; adaptability of the materials to fit varying teaching styles; the effect of a program on the student's attitude to learning; teaching time required; class preparation; costs; and adequacy of the teaching guides.

In shaping its search for the more effective program selection and accommodation, the system should encourage its teachers, students and administrators to learn by experiencing the curricula to discover those that best suit them.

We like to think of the course content improvement activity initiated by the National Science Foundation as a continuing search for finding ways to become more responsive to the interests and needs of students and teachers. Because teachers and students are partners in the search with those outside the classroom, we feel that our recommendations must not be intransmutable.

We make the following recommendations:

RECOMMENDATION: Systems should consider the role of the designated science coordinator for this is a critical role in introducing and implementing successfully NSF curricula. Systems that now have designated science coordinators can enhance their effectiveness in this position by allowing them to spend a major portion of their time working on science activities with elementary teachers and principals.

RECOMMENDATION: In-service training in science appears to be perhaps more important than preservice training, and it should be regularly available in the system. In-service training is an important component of successful curriculum implementation in elementary science, as it is in the new high school science courses. In-service training should take account of: (a) knowledge of subject matter; (b) knowledge of some of the inhibitions caused by teaching methods; (c) knowledge of children. (If a system wants to try to remove sex-role stereotyping, another component of training would deal with teacher attitudes in this regard.)

These should be integrated in an appropriate training mix, unifying <u>what</u> is taught with <u>how</u> it is taught.

RECOMMENDATION: Summer workshops, with children attending are an effective way for teachers and administrators to become initially immersed in the philosophies and techniques of the new curricula. NDEA Title III funds can be used to allay up to fifty percent of the costs of workshop materials in science.

RECOMMENDATION: An effective atmosphere for innovations in elementary science can be fostered by the co-alignment of decision-making at two levels, the administrative and the faculty. It seems desirable at this time for the administrative decision to be that NSF curricula will be used in the system; once this decision has been made, then the teaching faculty -- possibly at the individual building level -- should decide, following experiences with the curricula, which ones they would like to use and how they would like to use them. This recommendation, to a certain extent, recognizes a customary but inexplicitly-formulated policy. To formally recognize this procedure can lessen the confusion, resistance and frustration that sometimes result from not having an operative policy, with decision-making shared by the two groups.

RECOMMENDATION: Planning teams in systems that are considering adopting new science programs should consist of administrators, teachers and the person responsible for elementary science. The team members can select programs they wish to use and develop specific plans on how the new programs will be introduced and extended in the system. The key factors are continuing responsibilities of the planning team throughout the implementation process, from program selection, monitoring trials, arranging feedback, and devising a flexible long-range plan.

RECOMMENDATION: The change effort can be strengthened by discarding the trials of new curricula in only several classrooms in many schools and by concentrating the trial effort throughout the individual school or several schools. This practice can remove some of the isolation a trial teacher has by increasing the opportunity for teachers in a building to share their experiences with a new program.

RECOMMENDATION: Teams of principals should meet together at least a half-day every six weeks to discuss their common problems and to learn from one another how science is going in their own schools. Where this practice has been followed in elementary education -- West Hartford, Connecticut public schools, for example -- the results have been beneficial.

RECOMMENDATION: Procedures and instruments for evaluating pupil progress in elementary science should be based to some extent on the evaluative schemes suggested by the NSF programs, but they must be geared to the school's educational goals and how the teachers use the various units. National assessments and standardized tests in elementary science are pitifully weak and irrelevant to the aims of the NSF curricula.

RECOMMENDATION: Systems might start teachers' centers in which the teaching faculty might find the time to talk with each other in an informal way, examining and perhaps solving some of their common problems in science (and in other subjects). Pittsfield has started a teachers' center and other systems might do the same.

RECOMMENDATION: Reduced-cost alternatives in teacher training and staff development may be possible in new confederations of school systems that want to share their expertise in elementary science. It is suggested that a number of School Science Collaborative Programs be started by the schools. The purposes of this program are to encourage the wider use of the new curricula in systems that are now using them and to assist in the sound introduction of the new programs in systems that presently are using traditional approaches. The focus of the program is on staff development in a shared role among groups of five or more cooperating school systems beginning with summer workshops and carrying on during the school year. The program is modelled somewhat on the League of Cooperating Schools in California (18 systems work together on staff development in elementary schools). These could become regional instruction centers in the schools and work in voluntary partnership with the university scientist and members of certain groups, such as the Massachusetts Association of Science Supervisors. The organizational development of the program and possible sources of partial funding are delineated in our handbook.

RECOMMENDATION: Thirty or more science demonstration schools could be identified in this state to serve as intensive teacher training centers and as observation centers at which school board members could see exemplary science in the classroom.

RECOMMENDATION: Industrial firms that employ scientists and science faculty in universities could contribute to the schools by giving informal science workshops for elementary teachers. These workshops or seminars -- held in the plant, university or school -- would not deal with NSF programs, but rather on science.

RECOMMENDATION: During the course of our visits to school we were struck by the apparent shortages of basic educational materials in quantities sufficient for each student to have his own. This appeared to be the case in most elementary subjects, including social studies, mathematics and the language arts. So we suggest the enactment of legislation that would require books or their equivalent for each child.

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