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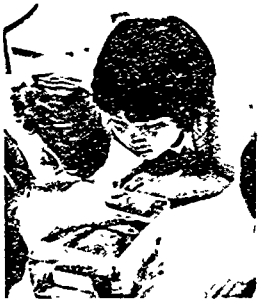
ABSTRACT

Children come to school with a foundation for formal learning from their early experiences with interactions of the natural and technological world. Failure of elementary schools to build on this experience can discourage children, especially those who do not identify readily with the science establishment (girls, blacks, Hispanics, and the economically disadvantaged), and filter them out from the stream of students that flows into the college science pipeline. This pamphlet, endorsed by educators, scientists, and industry, cites relevant research on elementary science education, and calls for renewed efforts to improve science education in elementary schools in the United States. (CW)

WANTED:

A Revolution in Elementary Science Teaching



A Revolution in Elementary Science Teaching

A statement endorsed by the participants, *The Importance of an Early Start for Science Education*; a conference sponsored by the Triangle Coalition for Science and Technology Education at the Spring Hill, (Minnesota) conference center July 28-30, 1986.

Science must join language and mathematics as a "basic" from the beginning of every child's school experience

Science must join language and mathematics as a *basic* from the beginning of every child's school experience. A quality elementary science experience contributes to the child's intellectual development and to the growth of an understanding of technology and the natural world, which is necessary for a productive, satisfying life.

Children come to school with 5 years of experience from interactions with the natural and technological world. These experiences, and the curiosity that drives and builds on them, are the priceless foundation for formal learning. Building on this natural resource can produce benefits beyond those to science.

. . . childrens early involvements with the substance of science and math can open gates for them into all the domains of knowledge and enjoyment . . . In this wider view of science education, the central aim is to contribute, quite generally, to the improvement of all education.[1]

Failure to open these gates for all our children, however, does more than raise a barrier to scientific literacy. Many girls, blacks, Hispanics, and the economically disadvantaged avoid science and technology courses whenever they can, because their experiences with elementary science are poor or nonexistent. These students are filtered from the stream that flows into the college preparatory science courses. With this filtering, the well of talent from which this nation draws its scientists and engineers has been traditionally white and male.

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- *Women make up nearly half of the work force but only 13% of U.S. scientists and engineers.*
- *Blacks make up 10% of the work force, but only 2% of U.S. scientists and engineers.*
- *Hispanics make up 5% of the work force, but only 2% of U.S. scientists and engineers.*

This well of talent, however, is drying up. Blacks and Hispanics are expected to constitute as much as 40% of the college age population by 1995. In many urban schools, "minority" students will be in the majority. To keep the well full, the gates that science education could open must swing wide.

Quality elementary science education could encourage rather than discourage those whose home environments are less rich. As Hawkins (ref.1) goes on to say.

. . . a basic assumption. to lead children into domains of science and math can presuppose less, by way of any prior richness in their educative backgrounds, than is needed for other essential parts of a school's curriculum.

If we follow this line of thought, we are led to the conclusion that there is more of the basic background

experience for mathematics and science in the life of every child than for most other subjects in the early curriculum. These are the daily phenomena of nature that surround us constantly, early and late, and about which we all accumulate a central store of experience—of light and dark and color, of heat and cold, of motion and rest, of forms of matter and of life.

... the doorways into these disciplines from the predisciplinary world of childhood are more widely accessible than others.

... childrens early involvements with the substance of science and math can open gates for them into all the domains of knowledge and enjoyment...

The task of providing door opening preschool and elementary experiences with science and technology should be high on the nation's priority list. *We need a revolution in elementary school science* reported Secretary Bennett in *First Lessons*,[2] the report on elementary education, which he wrote for the U.S. Department of Education. He goes right to the root of the problem.

There is probably no other subject whose teaching is so at odds with its true nature. We have come to think of science as a grab-bag of esoteric facts and stunts—the periodic table, the innards of frogs, the way to make little hot plates out of tin cans and wires. Worse, we have also given students the impression that science is a dry and arcane matter gleaned solely from the pages of a textbook. In three major studies, the National Science Foundation found that most science education follows the traditional practice. 'At all grade levels the predominant method of teaching was recitation (discussion) with the teacher in control, supplementing the lesson with new information (lecturing). The key to the information and basis for reading assignments was the textbook.'[3] If science is presented like this, is it any wonder that children's natural curiosity about their physical world turns into boredom by the time they leave grade school—and into dangerous ignorance later on?

Science is a way of thinking, a way of understanding the world. The term 'scientific method' has fallen into disfavor among educators, perhaps because it conjures up images of a white-coated man hunched over a petri dish. It ought to be restored. The scientific method is the method of thought, of reasoning, which applies not only to explorations of the physical universe but to all the realms of intellectual inquiry that require hypothesis, inference, and other tools of brainwork.

... the doorways into these disciplines (science and mathematics) from the predisciplinary world of childhood are more widely accessible than others.

Seen only as a laundry list of theorems in a workbook, science can be a bore. But as a 'hands-on' adventure guided by a knowledgeable teacher, it can sweep children up in the excitement of discovery.

The benefits attributed to the *hands-on adventure* have been demonstrated. Research conducted on the

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effects of three federally supported elementary science programs, ESS (Elementary Science Study), SAPA (Science. A Process Approach) and SCIS (Science Curriculum Improvement Study), demonstrates their positive effects on children's understanding of the natural world and on the development of scientific reasoning.

. . . researchers have studied the impact on learners of 'hands-on science' during the last 20 years. One hundred and five experimental studies that dealt with the effects of 'new curricula' on students performance were analyzed quantitatively. These studies involved over 45,000 students. Results indicate that students exposed to new science curricula performed better in general achievement, analytic skills, process skills, and related skills (reading, mathematics, social studies, and communication) than did students in traditional courses.[4] These researchers compared the performance of students in ESS, SAPA, or SCIS classrooms with that of students in traditional textbook-based classrooms. The average student in ESS, SAPA, or SCIS classrooms performed better than 62 percent of the students in traditional classrooms across all performance criteria measured—a 12 percentile point gain.

Research by Bredderman[5] involving 13,000 students in 1,000 elementary classrooms showed the same kinds of results with the greatest differences shown in measures of science processes, creativity, attitude, perception, and logical development.[6]

These programs had certain elements in common, and these elements exemplify the characteristics of high quality elementary science programs. All of these programs provided children with opportunities to engage in direct experiences with the natural world and to discuss these experiences with their peers under the guidance of an informed teacher. The successes of these programs, which were developed cooperatively by scientists and teachers, illustrate the importance of direct experiences with the physical world in the development of an understanding of scientific concepts and scientific ways of thinking. The nature of the experiences is critical. They must be direct, but increasingly disciplined and be accompanied by developmentally appropriate opportunities for children to compare and discuss their observations and interpretations. Talking and writing about science are essential characteristics of excellence in children's science programs.

Another, less scientific form of evidence about the effectiveness of experience-based programs, which is no less compelling, is the testimony of teachers who report the intense satisfaction and depth of understanding that their students gain from the opportunity to engage in personal exploration of the natural world.

We can conclude from these and other studies that

an early childhood and elementary science program of high quality:

- Is an enjoyable, developmentally appropriate experience for the child.
- Engenders positive attitudes toward science.
- Complements the language arts and mathematics programs.
- Has positive effects on quantitative reasoning and spatial conceptualization.
- Facilitates the development of critical thinking, scientific reasoning skills and builds understanding of scientific method.
- Provides a databank of physical experiences from which the child can build an integrated information system.
- Builds skills in the use of scientific equipment.
- Builds strategies for disciplined interactions with the natural world (for example, strategies for asking the right questions and assessing the quality of the answers).
- Broadens the range and quality of the child's experiences with the natural world.
- Supports respect for the unknown and for creative approaches to problem solving.

The scientific method is the method of thought, of reasoning, which applies not only to explorations of the physical universe but to all the realms of intellectual inquiry that require hypothesis, inference, and other tools of brainwork.

Unfortunately, most students do not have the opportunity to enjoy these benefits. Many elementary schools do not have elementary science programs. Far too many of the existing programs limit childrens' experiences to reading about science and writing definitions of scientific terms. Participation in school science by all but the college bound is minimal; achievement is generally poor even for better students. Lack of opportunity to learn and the generally poor quality of elementary science constitute the most serious barriers to achieving a scientifically literate citizenry.

Evidence from a recent NSF study showed an alarming amount of scientific illiteracy in this country. In a study of 2,000 adults Jon Miller found that about 40% of the adults give some credibility to astrology, 46% question the premises of evolution, and 70% showed no clear understanding of radiation.[7] These deficiencies have serious consequences for the conduct of our democracy as well as for our ability to compete economically in the world market.

A strong commitment of resources is necessary to provide all children the opportunity to experience science in the early and elementary years. Do the outcomes justify the expenditure of resources necessary to achieve them? Viewed in terms of its potential contribu-

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tions to personal fulfillment, economic productivity, and reasoned social decision-making, the answer is yes.

The Triangle Coalition for Science and Technology Education and its member organizations accept the challenge. The revolution is beginning. It is our goal that every student know science as a "hands-on adventure," and that all students live with the natural world and work with the technological world in the comfort and enjoyment that knowledge allows.

We challenge those who teach in, administer, and provide support for the nation's elementary schools to join in the revolution that Secretary Bennett describes. It can spread beyond science and help revitalize all of education. And in the end, the knowledge and world view made possible by early development of the skills and scope of science may serve a purpose beyond *scientific literacy* and *filling the talent well.* David Hawkins, again, says it well:

. . . the evolution of science since the sixteenth and seventeenth centuries has transformed our working relations with nature and has brought us, as a single biological species, to dominate—but also to destabilize—the whole of our planetary world. We can learn to love it as a potential Second Garden or, by the turn of the screw, destroy it, and with it, ourselves. The love cannot come as a belated afterthought; it must begin in our early years with the onset of knowledge and wonder, of nature closely observed, observed first in detail and later conceived in powerful generality.

It is the goal of the Triangle Coalition member organizations to work with schools and teachers, to provide them the resources—material and human—which they will need to carry out this revolution. We are working in all the nation's communities to forge alliances between concerned educators and the scientists, engineers, business people, and others who want to help. We ask you to join in the task.

For further information on the Triangle Coalition for Science and Technology Education and its local alliance network project, please contact Dr. John M. Fowler, Director, Triangle Coalition for Science and Technology Education, c/o NSTA Special Projects, 5112 Berwyn Road, College Park, Maryland 20740. (301) 220-0871.

1. David Hawkins, "Nature Closely Observed," Daedulus, Volume 112, #2, Spring 1983.

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7. "Some new Measures of Scientific Illiteracy," a paper presented by Jon D. Miller, Northern Illinois University, at the Annual Meeting of the American Association for the Advancement of Science, Philadelphia, Pennsylvania, May 28, 1986.

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