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AUTHOR Mechling, Kenneth R.; Oliver, Donna L.
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ABSTRACT

Several research studies that can provide direction for improving elementary school science programs are highlighted. Selected results are summarized and suggestions given to elementary school administrators for translating research into action in their schools, action which can lead to improved teaching and learning in science. Studies are presented and discussed in seven sections, the first five sections focusing on: (1) current practices in elementary science; (2) the relationship of research and education; (3) the importance of the principal's leadership; (4) enhancing basic skills through science instruction; and (5) increasing performance with activity-based science, improving reading readiness, and effectiveness of hands-on science. Studies summarized in the sixth section focus on: the importance of the principal's leadership role; effective in-service programs; questioning and wait-time; the effects of student cooperation versus competition; developing positive attitudes toward science; the benefits of and strategies to develop critical thinking skills; what happened to National Science Foundation curricula; and exactly what is being taught in science (suggesting that principals find out what is being taught, at what grade levels, and for how long). The final section presents major conclusions and recommendations. One conclusion is that science programs based on manipulative materials are especially helpful in building reading/language readiness levels in elementary students. (JN)

HANDBOOK IV

WHAT RESEARCH SAYS ABOUT ELEMENTARY SCHOOL SCIENCE

by

Kenneth R. Mechling
Clarion University of Pennsylvania
Clarion, PA 16214

and

Donna L. Oliver
Sharon City School District
Sharon, PA 16146

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There is a Chinese proverb: one generation plants the trees...another gets the shade. During this project, trees were planted with the help of many people. It is our hope that elementary school children all over the United States will benefit from the shade.

The project, Promoting Science Among Elementary School Principals, began as an idea at the meeting of the board of directors of the National Science Teachers Association (NSTA), held in Dayton, Ohio in 1980. It was conceived as a joint effort of NSTA and the Council for Elementary Science International (CESI). We are grateful for the foresight, encouragement, and leadership of Don McCurdy, then president of NSTA.

Many people shared in the development of the project. Their efforts and ideas deserve our sincere appreciation. They include:

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Ken Mechling and Donna Oliver

DISSEMINATORS

Promoting Science Among Elementary School Principals

Dr. Bonnie B. Barr
339 Center Street
Slippery Rock, PA 16057

Dr. Lloyd H. Barrow
385 College Avenue
Orono, ME 04473

Dr. Glenn D. Berkheimer
2208 Heritage Avenue
Okemos, MI 48864

Dr. Lowell J. Bethel
7131 Wood Hollow Drive, #167
Austin, TX 78731

Mrs. Audrey H. Brainard
14 Glenn Way
Holmdel, NJ 07733

Dr. Betty Burchett
511 Marion Drive
Columbia, MO 65201

Dr. David P. Butts
Box 126, Deerfield Road
Bogart, GA 30622

Dr. Jan E. Calhoun
Supervisor of Elementary Education
State College School District
State College, PA 16801

Dr. Charles R. Coble
1505 East 6th Street
Greenville, NC 27834

Mrs. Doris R. Ensminger
2810 Falls Mont Drive
Fallston, MD 21047

Dr. Robert L. Fisher
1108 George Drive
Normal, IL 61761

Dr. Peter C. Gega
Elementary Education
College of Education
San Diego State University
San Diego, CA 92182

Dr. Stephen A. Henderson
Model Laboratory School
Eastern Kentucky University
Richmond, KY 40475

Dr. Phyllis E. Huff
7928 Hayden Drive
Knoxville, TN 37919

Dr. Gordon P. Johnson
3495 North 4th Street
Flagstaff, AZ 86001

Mrs. Sarah E. Klein
86 Roten Avenue
Rowayton, CT 06853

Sr. Patricia Lupo, O.S.B.
1256 Buffalo Road
Erie, PA 16503

Dr. Michael A. Magnoli
405 Bridle Path Way
Mobile, AL 36608

Dr. Donald W. McCurdy
7901 Avon Lane
Lincoln, NE 68505

Dr. LaMoine L. Motz
2890 North Lake Angelus Road
Pontiac, MI 48055

Mr. Joe Premo
5974 Quebec Avenue, North
New Hope, MN 55428

Mrs. Shelley Riggins, Principal
Windermere Elementary School
2283 Windermere Avenue
Akron, OH 44312

Dr. William Ritz
12092 Argyle Drive
Los Alamitos, CA 90720

Dr. Walter S. Smith
National Science Teachers Association
1742 Connecticut Avenue, N.W.
Washington, DC 20009

Dr. Greg Stefanich, Professor
Coordinator of Early Adolescent Education
Education Center 616
University of Northern Iowa
Cedar Falls, IA 50614

Dr. Gilbert Twiest
R. D. #1, Box 171B
Clarion, PA 16214

Dr. Leon Ukens
325 Old Trail
Baltimore, MD 21212

Dr. James R. Wailes
4513 Navajo Place
Boulder, CO 80303

Dr. Robert E. Yager
Science Education Center
University of Iowa
Iowa City, IA 52242

Project Staff:

Dr. Ken Mechling
Chairman, Biology Department
Clarion University of Pennsylvania
Clarion, PA 16214
Office: (814) 226-2273
Home: (814) 226-9508

Miss Donna L. Oliver
1057 Linden Street
Sharon, PA 16146
School: (412) 981-0980
Home: (412) 981-6710

In a recent article in Today's Education, author John H. Hollifield explains why education research has never captured the minds--much less the hearts--of many educators. Most of the reasons relate to the perceived irrelevance of research to education practice (1). Although we know a great deal about how children learn and how teachers teach effectively, research will simply not improve education unless the knowledge derived from it is translated into practical applications that educators can use. That is what this Handbook is about.

In Handbook IV, What Research Says About Elementary School Science, we shall highlight several research studies that provide direction for the improvement of elementary school science programs. We shall summarize selected results and provide suggestions to elementary school administrators for translating research into action in their own schools, action which can lead to improved teaching and learning in science.

Handbook IV is not intended as a comprehensive compendium of research related to science education at the elementary school level. Rather, it is a glimpse at existing research and a guide post for turning documented knowledge into action. For more information relating research in science education to practical applications in schools, readers are encouraged to consult other publications like the National Science Teachers Association series What Research Says to the Science Teacher, or the research articles featured in the journal, Science and Children.

Ken Mechling and Donna Oliver

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I. THE STATE OF THE ART

The state of the art in elementary school science, say researchers Robert Yager and Ronald Stodghill, can be summarized by one word--textbook. Not only does the textbook determine the content but also the order, the examples, and the application of that content. "The influence of teachers occurs in the choice of a textbook--apparently the most important decision in establishing the curriculum or curriculum component identified by a given course," say Yager and Stodghill.

"Teachers appear to have 'faith' in the textbook," lament researchers Robert Stake and Jack Easley, "if the right one could be found." In many schools then, the science curriculum is little more than a set of knowledges and skills rooted in the various disciplines of science and packaged in textbooks (2).

Donald L. Wright elaborates on the theme. "Fifty to eighty percent of all science classes use a single text or multiple texts as <u>the</u> basis for instruction...for students, knowing is more a function of reading, digesting, and regurgitating information from the textbook or lab manual than it is of analyzing, synthesizing, and evaluating" (3).

Although there is widespread belief that problem-solving and thinking skills should play an important role in children's science experiences, observations of classrooms reveal that children seldom practice these skills. Unfortunately, teaching methods so frequently recommended by science educators are not often found in actual instructional practice in schools. And while two of our most-professed goals are to help children develop the ability to solve problems and think critically, evidence of reaching those goals is scanty indeed (4). The results of the National Assessment of Science clearly support that view. They indicate that most students at ages 13 and 17 are most deficient in just those higher level thinking skills (e.g., analysis, synthesis, evaluation) which are components of reflective thinking and problem-solving (5). Unfortunately, there is wide disparity between what should be happening in elementary science classes and what is happening.

Three in-depth National Science Foundation studies of precollege science education confirm 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 the basis for reading assignments was the textbook" (6). Data from these three studies suggest that the textbook's domination "tends to discourage use of inquiry techniques which require students to do more than look up information in the text and then recite or record it." "Activity" is apt to be the filling in of workbook exercises (7).

F. James Rutherford, Chief of Education Programs for the American Association for the Advancement of Science, sums up the current state of affairs, "At the elementary school level, instruction in science has almost ceased, being no more in most classrooms than a few minutes each week of reading from textbooks" (8).

If this is the overall picture of elementary school science, then it is hardly surprising to encounter mounting concern over its quality. You, as principal, should determine just how accurately these accounts describe science in your school. If they come close, you should be using the findings of research as solid clues for building a better science program.

II. RESEARCH AND EDUCATION

Science and modern technology depend on research. The next time you climb into your automobile, remember that its engine was constructed from ideas growing out of eighteenth and nineteenth century research on heat. The telephone had its origins from Hans Christian Oersted's discovery of electromagnetism in 1820. Even the microcomputer traces its roots back a century to the algebra of logic as done by British mathematician George Boole together with research on the nature of electromagnetic waves.

The truth is that modern technology is built upon research. Any business or industry worth its salt knows that if capital isn't set aside for research, chances for long-term survival are diminished. Our weapons of war, medicines for curing illness, the cars we drive, the food we eat, even the shape of the chairs we sit in--all have been shaped by research.

Although the results of research pervade almost every aspect of our lives--from sex to space exploration--education staunchly ignores it. Somehow, research and education seem strangely incompatible. While research has an aura of respectability, front-line educators tend to view it with considerable skepticism. Oh, we remember the weighty research papers of graduate school or the sweat of defending a dissertation, but the results of research seldom seem to trickle down to our elementary schools, where they could do some good. If the medical profession disregarded the results of research, as we seem to do in education, practitioners might still be drilling holes in heads to vent evil spirits.

The irony of it all is that while educational research goes forth in relative obscurity, the results, if known and used, could make a difference in improving the way science is taught and learned. Knowing and applying those results has the potential for enabling elementary school administrators to become more effective school leaders while enhancing the teaching-learning process which lies at the heart of what we are all about. How can the results of research help improve the science program in your school? Let's begin by examining research about you, the principal.

III. FOLLOW ME!

If you want science to succeed in your school's curriculum, you, the principal, must take an active leadership

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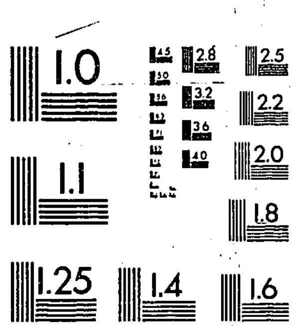

a dominant role in decisions about selection of instructional materials and in program planning and evaluation; and emphasized academic standards (14).

Evidence from research strongly supports an active leadership role by you, if you wish to achieve an effective program of science instruction. Your importance is summed up succinctly in a report from a series of National Science Foundation (NSF) case studies in schools around the United States:

> The principal serves a unique role of boss, shepherd, and manager all rolled into one. He or she is usually the major factor in the school's operation ...(15).

Or as one principal was overheard to say while discussing the role of the principal at a recent National Fellows Program of the National Association of Elementary School Principals at the Florida Institute of Technology, "There ain't nothin' going to happen in science unless we make it happen." And so it is. Research shows that if science programs are to succeed, you the principal, have to lead.

IV. SCIENCE ENHANCES BASIC SKILLS

As principal, no one has to remind you that you're held accountable for the learning that occurs or doesn't occur in your schools. High on your list of priorities, probably number one, is that the children should learn basic skills in reading and mathematics. There is considerable research which shows that science skills enhance reading and math skills, particularly if the science skills are learned in a program that emphasizes processes and provides children with first-hand experiences with objects and events.

Ruth Wellman cites 18 studies which found that direct first-hand manipulative experiences in science enhanced the development of process skills in young children in kindergarten to 3rd grade and had a positive correlation with their success in beginning language and reading achievement (16).

Among children in grades 4, 5, and 6, strong activity-oriented science programs also seem to strengthen the development of language arts and reading skills. Wellman cites a dozen studies which point to benefits children can derive from science instruction (17). Included are vocabulary enrichment, increased verbal fluency, increased ability to think logically, and improved concept formation and communication skills. For a summary of Wellman's work and how science contributes to the development of reading skills, see Handbook I in this series, Science Teaches Basic Skills (18).

Barufaldi and Swift note that the deficit in science teaching in the elementary school is often the consequence of teachers' sincere, but misguided, notion that they are too busy teaching more important things, such as reading and language arts. If they knew that the results of research indicate a positive relationship between children's participation in activity-centered science programs and the development of oral language skills and reading readiness, perhaps science would get a greater share of their attention (19).

Language arts skills seem to fit naturally into science experiences. When pupils are asked to define problems, locate information, organize information in graphic form, evaluate findings, and draw conclusions--they are performing skills concomitant with those of a well-developed reading program. The critical ingredient seems to be pupil involvement in science experiences.

Science experiences are also primary contributors to intellectual development. Jean Piaget stresses that as pupils mature mentally, they pass sequentially through four major stages of development. The stages are sensory-motor, preoperational, concrete operational, and formal operational. Maturation, physical experience, social experience, and equilibration are four major factors that influence mental development. Piaget's research clearly mandates that the learning environment should be rich in physical experiences. Involvement, he stresses, is the key to intellectual development, and for the elementary school child, this includes direct physical manipulation of objects, the kind of manipulation so easily achieved in science lessons (20).

The relationship between science and mathematics also seems linked to Piaget's research. After reviewing numerous studies relating science experiences to mathematical performance, Kren concluded that science can and does assist children in making transitions from one Piagetian level to the next (21). And, since a child's level of thought influences his/her achievement in mathematics, as demonstrated by Almy and others, there seems to exist an indirect, beneficial relationship between science and math (22).

After an extensive review of the literature, Esler concluded that science activities do, indeed, enhance the performance of children in the basic skills of language arts, mathematics, and other subjects (23). He noted further that teachers often find science a near-perfect vehicle to help children develop thinking skills...a goal which is high on everyone's list for what should be happening in our nation's schools.

V. RECIPE FOR SUCCESS

Place twenty-five kids in an elementary school classroom. Mix them with science materials. Add a teacher with a dash of enthusiasm and the skill to guide "hands-on" learning, and presto--another successful science class.

Unfortunately, read and tell science classes, filling in workbook blanks, and fact-cramming still seem to be the standard fare of science classes these days, even though twenty years worth of research has shown that activity-centered science is the key to effective science programs.

One of the earliest studies, done by Regan Carpenter in 1963, used fourth-grade pupils to compare the textbook-recitation method with the problem-solving or activities-oriented approach. He found the problem-solving way brought the most gains in content learning. Slower learners, demonstrated by Almy and others, there seems to exist an indirect, beneficial relationship between science and math (22).

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B. Improving Reading Readiness

Researcher John Renner found another advantage to hands-on science classes: they can sharpen reading-readiness skills. He took two groups of thirty elementary students each and tested them in science process skills--observation, classification, measurement, experimentation, interpretation, and prediction. Group I had followed the hands-on Science Curriculum Improvement Study (SCIS); Group II had been exposed only to a read-and-recite approach. The SCIS program, he concluded, led the children to develop scientific literacy or the ability to apply science in everyday life (26).

In another study, Renner compared four experimental classes of five-year-olds with four control classes. The experimental group had used Material Objects, an activity-centered SCIS unit. Activities for the control group had been limited to nature walks, a science table, and science-related stories. Data showed the activity-centered group outscoring the other group on every basis of comparison.

A third Renner study divided selected first-grade classes in Ada, Oklahoma, into experimental (using only the SCIS Material Objects unit) and control (using a commercial reading-readiness program) groups. The experimental group made the greater gains in word meaning, listening, matching, alphabet, and numbers. Renner concluded that hands-on science experiences in the early primary grades out-performed a reading readiness program when compared on reading readiness standards.

Still another Renner investigation involved 115 fifth grade pupils from two elementary schools. Forty-six pupils from a school using a hands-on science curriculum were compared to sixty-nine students from another school not using hands-on science. Academic achievement in mathematics and social studies was measured by the Stanford Achievement Series. Findings included:

> ...the activity-oriented science group scored significantly better in manipulating data in problem-solving situations.
>
> ...the activity-oriented science group scored significantly better in interpreting graphs and tables, reading maps, and interpreting posters.

Renner concluded that any school teaching science with the activity-oriented SCIS model is teaching more than just good science. Reading, mathematics, and social studies are also being enhanced.

C. The Winner and Still Champ...Hands-On Science

The more recent Shymansky study revives an old controversy by asking how effective were the hands-on science programs of the 1960s (27).

Shymansky and others surveyed research studies comparing elementary student performance in three hands-on, activity-based science curricula--Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), and Science--A Process Approach (SAPA)--to their performance in traditional, textbook-based science programs. Students in the activity-based curricula out-performed their counterparts in the textbook-based classrooms on every criterion measured--academic achievement, attitudes, process skill development, and performance in related school subjects.

In twenty studies comparing academic achievement in science content, the activity-oriented science groups percentile scores ranged from four to thirty-four points higher than the textbook-oriented science groups.

Twenty studies compared attitudes of students in the two approaches to science teaching. Attitudes toward the newer science curricula, toward science in general, and toward self were measured. Positive gains in attitudes favored the activity-centered programs, with scores ranging from three to twenty percentile points better.

Process skills like observing, measuring, interpreting data, inferring, and graphing are important for children to develop in all science programs. In thirteen studies which included measures of process skill development, students in the hands-on curricula scored eighteen to thirty-six percentile points better than those in the traditional, textbook-oriented science programs.

Finally, from thirty-one studies that compared student performance in the development of related skills, specifically reading and arithmetic computation, students in the activity-based curricula scored four to eight percentile points better than those in the traditional, text-oriented classes.

Shymansky and his colleagues concluded that the results of the research clearly showed that students in the hands-on science curricula "achieved more, liked science more, and improved their skills more than did students in traditional, textbook-based classrooms."

How science is taught in your school can determine whether you have a good program or one that simply has the children marking time. If your teachers give the kids a steady diet of "read and tell," your program is probably less than effective. In the face of such compelling research evidence how can we afford to have less than activity-centered, hands-on science experiences for our pupils?

VI. POTPOURRI

Other research findings may be relevant to your science program. Here are just a few.

A. Seeing the World Through Rose-Colored Glasses

Teachers may view your instructional leadership in science differently than you do. One study of 82 elementary school administrators in Texas public schools found that 81% of the principals saw instructional leadership as their most important priority, but only 30% of their teachers thought the principals had actually made it a top priority (28). Make science one of your instructional priorities and let your teachers know about it.

B. Rx for School Improvement

In the November 1981 issue of Phi Delta Kappan, Shoemaker and Fraser reviewed ten studies of effective schooling. Although none of the studies set out to examine the role of principals, most concluded that principals were clearly important in determining the effectiveness of schools. They concluded that principals can make a difference (29).

For instance, in one study of four successful urban schools, Weber found that one of the contributing factors was that all had clearly identifiable instructional leaders--in most cases, the principal (30). In another in-depth examination of two elementary schools, one characterized as high-achieving and the other as low-achieving, researchers found that the factors associated with the high-achieving school included positive principal/teacher interaction;

frequent informal classroom observations by the principal; and attention to an atomsphere conducive to learning (31).

Based on their survey of research, Shoemaker and Fraser concluded that principals can do four things to improve schooling: (1) provide assertive, achievement-oriented leadership; (2) maintain an orderly, purposeful, and peaceful school climate; (3) set high expectations for teachers and pupils; and (4) establish well-designed instructional objectives and evaluative systems (32). All four recommendations can be applied to improve science teaching and learning in your school.

C. Overcoming Those Inservice Blahs

Inservice education for teachers is one of the primary ways administrators can assist teachers in becoming more effective instructors of science. Donald C. Orlich reviewed Education Resources Information Clearinghouse documents which pertained to inservice education findings related directly to elementary school science projects. He identified eight general traits that characterized effective elementary science inservice education programs:

1. Effective inservice programs have a specific focus, goal or set of objectives.
2. Effective programs use curricula which serve as exemplars.
3. "Hands-on" experiences are most obvious, i.e., effective inservice allows teachers to use concrete teaching materials.

4. Laboratories, field trips, museums and sharing of experiences are structured into the effective projects.
5. Effective inservice projects reflect an adaptive behavior of university faculty. They do not simply teach the usual fare of courses.
6. All effective inservice projects are job-related to the real world of the participants.
7. Participants are taught how to utilize knowledge, not simply to gain new information in effective programs.
8. The most effective inservice programs are apparently related to continuous programs, not just a one-shot activity (33).

The message is clear. Teachers of science want inservice programs that are activity-oriented, practical, and related to their needs (34). You can get rid of those inservice blahs by designing inservice programs to meet the needs of your teachers of science.

D. Questioning Wait-Time

Science classes are especially good places for questions. Mary Budd Rowe has done an extensive study of the questioning behavior of teachers. In her analysis of classroom discussions, she discovered most teachers on an average wait less than one second for students to reply to their questions. However, some instructors wait an average of three seconds for students to reply. Comparing the student responses revealed that teachers with longer wait-times, three seconds or more, obtained greater speculation, conversation, and argument from students than those with short wait-times.

Rowe also found that when teachers are trained to wait more than an average of three seconds before responding, the following occurs:

1. The length of student response increases 400-800 percent.
2. The number of unsolicited but appropriate responses increases.
3. Failure to respond decreases.
4. Confidence of children increases.
5. The number of questions asked by students increases.
6. Slow students contribute more--increases ranging from 1.5 to 37 percent more.
7. The variety of types of responses increases. There is more reacting to each other, structuring of procedures, and soliciting. Speculative thinking increases as much as 700 percent.
8. Discipline problems decrease (35).

Analyze your teachers' wait-time. Encourage them to pause three or more seconds, then watch the results!

E. <u>Cooperation Versus Competition</u>

While competition among students is the dominant interaction pattern in most schools, research indicates that a cooperative interaction pattern with students working in small groups is effective in building positive attitudes toward science (36). Problem-solving, critical thinking, laboratory investigations, and divergent thinking are all processes that benefit from student-to-student interactions (37). Since cooperative learning differs from the usual whole class, lecture/recitation method, most elementary teachers must be encouraged to use cooperative learning methods. Hands-on science classes are natural places for sharing and cooperating.

F. Mixed Feelings About Science

In a 1976-77 study involving 72,000 students, the National Assessment of Educational Progress measured students' attitudes toward science. Almost two-thirds of the nine-year-olds stated that they were happy with science and over four-fifths said they were interested in science.

However, only about half of the children felt excited or successful in science, while only six percent ranked science as their favorite subject. Mathematics and English were clearly the frontrunners.

Nine-year-old boys have more positive feelings about science than girls, with girls' interest in science beginning to drop off around third grade (38).

Teachers' attitudes toward science and the way it is taught most likely determine children's attitudes toward science. But, teachers' attitudes can be affected by your attitudes. If you stress science, your teachers will stress science. If you show an interest in science, they will likely be interested, too. The messages about science your teachers receive from you will likely be passed along to their pupils. How you feel about science can make a difference in your school.

G. Turning Kids On to School

Activity-centered science instruction may help children feel better about school. In a well-controlled study of 150 second, third, and fourth graders comparing those taught by an activity-oriented approach to those in a text-reading approach, Jaus found that after 12 weeks, the children who participated in the activity science made significant gains in their attitudes toward science and toward their school environment (39). Want to turn kids on to school? Try involving them in high-interest science activities.

H. Thinking About Thinking

Most people agree that schools should help kids learn how to think. According to the Educational Policies Commission of the National Education Association, "The purpose which runs through and strengthens all other educational purposes--the common thread of education--is the development of the ability to think" (40).

Historically, school officials have agreed. In 1961, when school officials were asked to rate the importance of a number of science teaching objectives for their schools, the two at the top of the list were:

Help children develop their curiosity and ask What, How, and Why questions.

Help children learn how to think critically (41).

The same two objectives were still important ten years later in a survey of Pennsylvania public school principals and teachers, but also included:

Help children develop problem-solving skills (42).

Hands-on experiences in science provide opportunities for children to engage in problem-solving experiences that develop thinking skills. Bruner maintains that it is through problem-solving and discovery that students actually learn to discover or think for themselves. He further notes that the more one utilizes or practices discovery, the more likely one is to generalize what is learned into a means of inquiry applicable to a myriad of problem-solving situations. Bruner states that four benefits result when children investigate and discover for themselves. These are:

(1) An increase in intellectual potency.

(2) A shift from extrinsic to intrinsic rewards.

(3) Learning the heuristics of discovery.

(4) As an aid in memory (43).

What is more basic to school than learning how to think? Science can help children develop thinking skills that are valuable in school and out--skills that will last a lifetime.

I. Whatever Happened to Those NSF Science Curricula?

For more than 25 years the National Science Foundation funded development and dissemination of instructional materials in mathematics, social science, and science. Yet even in 1976-77, those instructional materials were not in widespread use.

At the K-6 level, only thirty percent of the school districts in the United States had used the NSF-developed science materials. Further, only seven percent of the K-6 teachers had ever attended NSF-sponsored science meetings (44). While considerable time, effort, and money were devoted to the development and implementation of new science curricula, it appears that the innovations never achieved the critical mass required for widespread adoption. It should also be noted that many of those curricula, particularly the Elementary Science Study (ESS) and the Science Curriculum Improvement Study (SCIS), are still being used successfully by numerous school districts in the United States. These NSF curricula, and others like them, have also contributed to the development of many of the second and third generation programs currently available.

J. Exactly What is Being Taught in Science?

A school district's adopted scope and sequence chart does not always give the true picture of what is happening in an elementary science classroom. Such were the findings of English when he compared the Little Rock, Arkansas School

District's K-6 formal scope and sequence chart with the curriculum as it was actually being taught in classrooms (45).

He discovered that many major science concepts were not being taught at the grade level for which they had been identified. In addition, some science concepts were being taught in every grade level from K-6.

Other results revealed that of the 273 concepts found on the scope and sequence chart, 97 had to do with life sciences, 73 to earth science, and 103 to physical science. But the average amount of instructional time per day spent in these three areas was indeed surprising. Eighteen minutes were spent on life science, seven minutes on earth science, and only two minutes on physical science.

You as the curriculum leader in your school should find out what is being taught, at what grade levels, and for how long. Give your science program direction by either enforcing the scope and sequence or revising it to fit your children's needs. Make sure life, earth, and physical sciences are given "equal time."

VII. CONCLUSIONS

The research on science as a means for helping children learn basic skills is massive and convincing. Science programs based on manipulative materials are especially helpful in building reading and language readiness levels in primary pupils. First-hand experiences in science expand pupils' vocabularies and reading comprehension at all levels. Similar growth is found in mathematics as children work with various geometic forms and measure real objects and events. Evidence continues to mount showing science as a natural vehicle for teaching thinking and problem-solving skills.

Now that you're acquainted with the results of some research in science education, what can you do with it? Certainly, it is more than "nice-to-know" information. A curriculum-wise principal will use the results to forge a blueprint for action, bridging the gap between research and what happens in schools. Research provides road signs for your trip to a successful science program. It provides direction and justification for assertive leadership. It provides clues for improving science program implementation; inservice programs for teachers; and building positive attitudes toward science and toward school. The results of research can make a difference in your school.

Get the word out to your professional staff. Call pertinent research results to their attention. Encourage your teachers to read research summaries in journals such as the National Science Teachers Association's Science and Children. Help them to see how research findings apply to their teaching and their classes. Without your leadership and action, research will continue to have little relevance to schooling. Use it to improve your science program, your school, and your effectiveness as a curriculum leader.

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