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ABSTRACT

Science is often the stepchild among elementary school subjects-- something less than basic but not quite elective. This handbook encourages elementary school principals to begin thinking about science as a fourth "R" in their school's curriculum, a subject that teaches basic skills while enhancing those learned in other curricular areas. The handbook stresses the benefits of teaching science and identifies the basic skills that may be learned from science instruction. In addition, it relates science process skills to other areas of the elementary school curriculum and provides models for integrating and relating science to reading, language arts, mathematics, and other curricular areas. Issues are addressed in the 12 sections of the handbook under the following headings: (1) What are "basics?"; (2) What's so basic about science content?"; (3) What's so basic about science processes?"; (4) What's so basic about science attitudes?"; (5) Science promotes creativity; (6) Science encourages creative thinking; (7) Science with health; (8) Science develops math skills; (9) Science motivates art and music; (10) Science develops reading skills; (11) Science builds social studies skills; and (12) What happens when science isn't considered a basic? (JN)

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HANDBOOK I

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SCIENCE TEACHES BASIC SKILLS



Project for Promoting Science
Among Elementary School Principals

National Science Teachers Association
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KENNETH R. MECHLING and DONNA L. OLIVER

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HANDBOOK I

SCIENCE TEACHES BASIC SKILLS

by

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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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PREFACE

Science is often the stepchild among elementary school subjects--something less than basic but not quite elective. Handbook I, Science Teaches Basic Skills, encourages elementary school principals to begin thinking about science as a 4th "R" in their school's curriculum--a subject that teaches basic skills while enhancing those learned in other curricular areas.

Handbook I highlights the fundamental and lasting value of science learning. This ancient proverb expresses it well:

Give me a fish and I eat for a day. Teach me to fish and I eat for a lifetime.

We need to remind ourselves and those whom we serve that science is more than classes, reading, listening, tests and grades. It is more than giving out fish. Rather, science learning can be the key to better, more productive, happier lives. Skills like stretching the powers of observation, gathering information, collecting and analyzing data, communicating with words and symbols, and confronting problems in a rational way and solving them have significant value in one's life. These "fishing" skills, learned in an atmosphere which encourages positive feelings of self-worth, can help children keep learning throughout their lives.

Science Teaches Basic Skills stresses the benefits of teaching science and identifies the basic skills that may be learned from science instruction. It relates the process skills of science to other areas of the elementary school curriculum and provides models for integrating and relating science to reading, language arts, mathematics, and other curricular areas. Using Handbook I as a guide, principals can promote science as a tool for lifelong learning.

Ken Mechling and Donna Oliver

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OVERVIEW
SCIENCE TEACHES BASIC SKILLS

I. What Are The Basics?

There is a great deal of confusion among educators concerning the identity of the basic skills. The U.S. Department of Education Basic Skills Improvement Program and the Council for Basic Education both make strong cases against limiting children's education to the three "R's." The Department of Education and the Council for Basic Education believe that thinking skills, learning processes, and positive attitudes are basic to education. Elementary science education is a key to the basics because science promotes the development of the thinking skills, learning processes, and positive attitudes required for lifelong learning.

II. What's So Basic About Science Content?

A. Science Knowledge is Basic to Children's Lives

Science content is basic because it is part of kids' everyday lives. Children are surrounded by technology they must utilize and an environment with which they must interact effectively. Project Synthesis identifies four areas in which science touches children's lives in significant ways: besides helping them learn scientific ideas and processes it meets personal needs, it helps them become informed citizens, and it assists them in making career decisions.

B. Children Are Naturally Interested in Science

One of the reasons why science content is so basic is that children like it. Recent surveys show that science-related topics are often chosen by children for individual projects, and a high percentage choose science as their favorite subject.

C. The Integration of Science Content With Other Subject Areas

Science readily lends itself to integration with other curriculum areas. Investigating mealworms can lead to creative writing experiences, or measuring the growth of plants can give practical application for measuring skills. By integrating other subject areas with science, teachers and principals can wisely utilize learning time. Integrating also gives children the opportunity to use knowledge from many subjects to solve problems, make decisions and apply what they've learned to their lives.

D. Science Content and Standardized Tests

Science is a basic when it comes to standardized examinations. There are few publishers of standardized tests who do not provide measures of science content or processes. These tests can be used to assess a science program in a variety of positive ways. But even though a standardized exam can be an educational aid, it should not determine what content is taught--that decision should be made by those responsible for planning the science curriculum.

E. Going Beyond Content

Even though science content is important, the Council for Basic Education recognizes that science instruction must go beyond content. Science processes and positive attitudes are of equal importance.

III. What's So Basic About Science Processes?

A. Lifelong Learning Skills

Science processes are basic in children's education because these skills are lifelong learning skills. When kids work toward competence in using science processes, they are actually learning how to learn. The process skills taught through science education place an emphasis on thinking skills children use while in a classroom or in the future as adults.

B. Process Skills Relate to Other Subject Areas

Science process skills are basic because they integrate with other elementary school subjects. For example, classifying and sequencing are math skills; collecting data and interpreting graphs are essential to social studies. Science is a natural for teaching and reinforcing all process skills, especially that of scientific reasoning or problem-solving--a skill that is essential to all subject areas.

C. Standardized Tests Measure Process Skills

Principals will be interested to know that science process skills are a major component of many standardized tests. Process skills such as classifying, inferring, cause and effect, sequencing and interpreting data are measured. These skills are measured not only in the science portion of a standardized test, but also in other subject areas such as reading, math, and social studies.

IV. What's So Basic About Science Attitudes?

How kids feel about themselves when they are learning may be more important than all the facts they could possibly learn. A good elementary science program will get children involved, participating and contributing--all the kinds of things that will get them excited and feeling good about themselves. Principals are encouraged to promote curiosity, inventiveness, critical thinking, and persistence in their science programs. Positive attitudes in these areas will not only benefit the science program but all other parts of the curriculum.

V. Science Promotes Creativity

Formulating and testing hypotheses are at the heart of creativity and a good elementary science program. Creativity is also a basic part of every child. Examples of creative science activities and the types of questions that promote children's creative responses are cited for principals' reference.

VI. Science Encourages Creative Writing

Science experiences are rich with opportunities for kids to describe what they are doing or what they have observed. Principals will be interested to know about research which indicates that experience-based elementary science programs foster the development of language skills.

VII. Science With Health

Too often health in the elementary school is taught by textbook reading and teacher lecture. There are few participatory activities where kids can investigate how their bodies work. Principals are encouraged to help teachers integrate science and health content, teach health using science processes, and build positive health attitudes.

VIII. Science Develops Math Skills

Many science experiences at the elementary level provide opportunities to apply math skills. Activity-oriented science can give children the real world experiences they need to understand mathematical concepts such as fractions, subtracting, or number sequencing. Science/Math activities in the classroom also provide an atmosphere that fosters thinking and problem-solving skills.

IX. Science Motivates Music And Art

A. Science and Art

Integrating art activities with science experiences can give both science and art more meaning and interest. The sensory experiences kids have during science can be expressed through drawing, painting, sculpturing, etc.

B. Science and Music

Integrating science and music gives kids a chance to apply musical concepts in an experimental setting. Making musical instruments and writing nature songs are a few integrative activities principals can suggest.

X. Science Develops Reading Skills

A case is made in support of elementary science education as an important key to language and reading skills development. The subtopics in this section are:

- A. Reading Is Important
- B. Science Experiences and Reading
- C. Science and Reading Skills
- D. Science and Reading Readiness
- E. Science and Thinking Skills
- F. Reading About Science

These subtopics provide principals with supportive research and examples of how to integrate science and reading.

XI. Science Builds Social Studies Skills

Science processes and experiences can be the means kids use to gather data about the world around them. The accumulated information can then be applied to social studies issues. Examples are cited illustrating how social studies topics are integrated with science concepts and skills.

XII. What Happens When Science Isn't Considered A Basic?

Elementary science education has fallen to a lesser role in many schools. What happens when science isn't considered a basic? Principals will read what science educators, teachers, and other administrators have identified as the side effects of the "I don't have time to teach science" syndrome.

SCIENCE TEACHES BASIC SKILLS

I. WHAT ARE THE BASICS?

"Back to the Basics" is a cry we educators have heard before. We hear it when the economy slumps and budgets get tight. We hear it when the news media bemoan the fall of standardized test scores. We hear it when members of the community have an ax to grind with the schools.

"Back to the Basics" is one of the most ambiguous slogans ever coined. Ask people, "What are the basics?" and you will probably get answers that range from the ever-popular "reading, writing, and arithmetic" to "skills that are valuable to kids' lives." The "basics" often conjure up images of budget cuts; curtailment of curriculum; drill, recitation, and rote learning; ram-rod discipline; and the three "R's" as the curriculum that will put America back on its feet.

Although the historical function of elementary schools has been to teach children to read, write, and do arithmetic, most attempts to define what is basic are trivial, atomistic, and joyless. In one city, the school board set 1,200 objectives in language arts alone, but none suggested that the students might read a book, write a page describing their understanding of a trip to a museum, or solve a mathematics word problem. And the arts, sciences, and social sciences were excluded--as were many other subjects(1).

So what are the basics? Unfortunately, there doesn't seem to be a definition, a phrase, or a list upon which everyone can agree. Educators, textbook companies, and citizens will all tell you what the basics are--according to their philosophies. What is basic to some will be a frill to others.

In a document entitled The Essentials Approach: Rethinking the Curriculum for the 80's, the U.S. Department of Education Basic Skills Improvement Program tells us what to avoid when trying to define the basics. We are encouraged to shun three simplistic tendencies:

...to limit the essentials to the three "R's" in a society that is highly technological and complex;

...to define the essentials by what is tested at a time when tests are severely limited in what they can measure; and

...to reduce the essentials to a few 'skills' when it is obvious that people use a combination of skills, knowledge, and feelings to come to terms with their world(2).

The Council for Basic Education has an opinion about the basics and, surprisingly, they do not view basics as the barebone technical skills of reading and simple arithmetic computation. Rather, this prestigious group of educators, a group committed to basic education, has a message for all of us--particularly elementary school principals. The Council's policy statement defines the basic intellectual disciplines as English (consisting of reading, writing, speech, and literature), mathematics, science, history, geography, government, foreign language and the arts. Not only do these subjects mean that pupils will learn content but more importantly, the Council tells us, they mean opportunities for developing thinking skills, learning processes, and developing positive attitudes(3).

Jencks, commenting on the back-to-basics movement, observes that:

Where problems appear, they are with more complex skills, with the students' desire or ability to reason, with the lack of interest in ideas, with a shortage of information about the world around them. If schools need to do anything... it is to get back to complexity, not to the basics. I submit to you that teaching students to think critically is basic. Students need instruction in inquiring, valuing, and decision making(4).

Science is basic to the elementary school curriculum because through it we can help children to learn to ask significant questions, to seek relevant answers, to apply problem-solving skills to everyday life, to think rationally, to test ideas, to make decisions, to investigate, to try and fail and try again. Through science we can and must help children sense the joy of making discoveries about their environment and about themselves. Through science we can heighten curiosity and excitement about learning and help children develop positive feelings about themselves. Through science we can help them to learn how to learn--for a lifetime. What could be more basic?

Science learned in an environment that invites and supports critical thinking, curiosity, decision making, investigation, and inquiry can provide a child with the knowledge of science content, the thinking skills, and the attitudes that will be useful today, tomorrow, and throughout life.

II. WHAT'S SO BASIC ABOUT SCIENCE CONTENT?

A. Science Knowledge is Basic to Children's Lives

Science content is basic because it is part of children's everyday lives. The way their bodies grow, the food they eat, the material in their clothes, and their electronic games are but a few examples related to science and technology. Children must understand scientific concepts and use them to make rational decisions and to solve problems in their lives.

Looking at the desired states of science education, Project Synthesis, a significant effort to improve science education funded by the National Science Foundation, identifies four areas in which science can touch the lives of elementary school children in a fundamental way:

1. Science can help children to meet their personal needs--help them maintain healthy bodies, make "smart" consumer decisions, and use a variety of skills to gather knowledge for personal use.
2. Science can help children to become informed citizens prepared to deal responsibly with social issues--prepared to vote intelligently on science-related concerns such as energy and the environment, to participate in responsible community action, and to recognize that solving one problem can create new problems.
3. Science can provide children with the opportunity to learn scientific ideas and processes from a wide variety of interesting topics selected from the life, physical and earth sciences. It can help them develop skills in gathering, categorizing, quantifying, and interpreting information.
4. Finally, science can help children to make informed decisions about careers related to science and technology--help them get a "feel" for jobs in these fields, become familiar with qualifications for entry, and recognize the role of scientific and technological careers in society and how their lives are affected by persons in those careers(5).

All four areas require that science content be learned, that it be included as a part of the child's science experiences.

We know that principals are sensitive to the role of science content in the elementary school curriculum. At a recent convention of the National Association of Elementary School Principals (NAESP), principals were asked about the role of science in the elementary school curriculum. Here is what they said:

Subject matter should not be an end in itself.

Content should be considered secondary.

In the beginning or primary grades, a science and technology curriculum should emphasize applications to the world around us. And there should be increased emphasis on the process of critical thinking to make use of the different facets of knowledge learned.

Subject matter should be the vehicle and not the end. Sometimes teaching can get too hung up on content(6).

The experiences and interests of children's day-to-day lives are the keys to your school's science curriculum development. Greater concern for content that is relevant to children should be considered in curriculum development. What science content do they come in direct contact with? What content affects their lives? What content surrounds them in their neighborhood, community, or state? What science content do they talk about?

Finally, the National Science Teachers Association provides us with insightful recommendations regarding content selection in science.

Elementary school children should have daily opportunities to relate science to their lives, concerns, and study of other subjects. Elementary science experiences should sustain and enhance children's natural curiosity and interest in the objects around them. They should help in developing science process skills, physical and life science concepts, and in providing children with opportunities to apply these skills and concepts to actual life situations. These skills and concepts may be learned through science programs that combine reading, discussion, and direct experience and support learning of other basic skills(7).

B. Children Are Naturally Interested in Science

One of the reasons why science content is so basic is that kids like it. They are interested in what's going on in the natural world, in their bodies, and in their environment. What science teaches them is exciting. If you question that statement, just look at this list of topics.

space	mermaids	wind currents
astronauts	microscope	spiders
wildlife	ocean life	computers
horses	bears	space craft
science experiments	chemicals	invention
dinosaurs	sharks	blood
mice	birds	Saturn
frogs	fossils	Earth
planets	electronics	animals
insects	whales	seasons

This list is from a recent survey given to elementary school children in western Pennsylvania to find out what they would like to study. The question asked was, "What things are you interested in and what would you like to know more about?"

It is significant that 66 percent of the responses for third grade were science-related, 60 percent for fourth grade, 64 percent for fifth grade, and 52 percent for sixth grade. The percentages clearly illustrate that science content is perceived as "basic" in the minds of children(8).

In a 1975 survey of 1,829 elementary pupils in 12 school districts in Pennsylvania, Mechling found that 76 percent of the children in grades two through six listed science as one of their favorite subjects. When 950 of their parents were asked if their children seemed to enjoy science, 82 percent said yes(9).

Survey results such as these show that children themselves provide strong support for considering science as a basic. If we really believe that one of our jobs in elementary schools is to sustain and enhance children's natural curiosity and interest, then it behooves us to teach science, for it is in science where so many of the children's interests lie.

C. The Integration of Science Content With Other Subject Areas

Another reason for considering science content as basic lies in its potential for integration with other curriculum areas. Science-related facts and concepts are read and discussed in all facets of the elementary curriculum. Here are a few examples:

<u>Science-Related Facts or Concepts</u>	<u>Subject Area</u>
animal stories and poems.....	reading/creative writing
science fiction stories.....	reading/creative writing
growth rates of plants or animals....	math problem-solving and measurement systems.
metric measurements.....	math problem-solving and measurement systems.
weather.....	social studies
geological forces.....	social studies
water cycle.....	social studies
vibration and tone.....	music
color and perception.....	art
energy.....	health
body systems.....	health
nutrition.....	health

Children seldom perceive the interrelationships among the content areas they study in school. English is English, and when we ask them to write clearly and spell correctly in science, we often get responses like "What's spelling have to do with science?" Or, in science when we talk about the economics of pollution, kids wonder whether they are in science or social studies.

Investigating mealworms in science can lead to creative writing experiences. Sampling populations of lawn plants in science can lead to measurement in mathematics. Studying weather in science can lead into a social studies unit on the effect of weather on people. Children are far better equipped to understand facts and concepts in other subject areas if they have experienced them in science or, better yet, if they study science in conjunction with other areas.

The Essentials Approach to education stresses the interdependence of disciplines. It recommends that disciplines meet in an interdisciplinary way so that children confront content from the perspective of two or more disciplines. For example, if a child is to read a science text with understanding, the child must learn about reading and about science. The study of the human skeletal

system in health can be joined with music in the singing of "Dry Bones." Or, mathematics and science can meet in experiences requiring measurement(10).

The Essentials Approach points out that when subjects are integrated, dividends from learning time are compounded. More can be accomplished in less time. Learning to read science content yields the double return of increased reading skill and learned science content. Measuring the growth of plants allows children to practice measuring skills while learning about plant growth. Obviously, the elementary school curriculum is full of such opportunities. We must learn to take greater advantage of them, for increasing learning opportunities through integration makes wise use of our time(11).

D. Science Content and Standardized Tests

The public and many educators appear to have a great deal of faith in standardized examinations. For many, scores of the Metropolitan, the Iowa, and the Stanford are important. If our children score high, we puff out our chests and take the credit. If the scores are low, we retreat to foxholes to weather the attack which will probably come.

If the standardized tests measure the basics, as they are purported to do, then science must be considered a basic. There are few publishers of standardized tests who do not provide measures of science content or processes.

One of the most popular standardized tests is the Metropolitan. Here's what the teacher's manual says about science:

Both science and social studies education seek to develop three types of learning: knowledge and understanding (of concepts, generalizations, principles, etc.); intellectual skills and abilities (problem-solving, critical thinking, inductive and deductive reasoning, investigation and research skills, etc.); and attitudes. The prevailing philosophy, as expressed in most recent textbook series, curriculums, and professional journals, is that students learn and develop interest and curiosity when they become investigators or discoverers themselves; that is, when they become actively engaged in gathering and analyzing data

needed to answer questions they feel are important. This is the reason there is so much emphasis on the development of inquiry and discovery skills; i.e., why so much learning is problem-centered. The behaviors measured in the Science and Social Studies tests are: Knowledge, Comprehension, Inquiry Skills, and Critical Analysis.

The Science Test at all battery levels samples from three broad content areas: Physical Science, the study of matter and energy; Earth and Space Science, the nature, extent, and relationships of bodies in space, including geology and weather; and Life Science, the study of living things, including health science. These areas are universally covered in comprehensive textbook series at the elementary school level. Although the content emphasis in current science programs varies somewhat from grade to grade, the test at each level gives full recognition to the importance of each content area(12).

Science content is one of the basics measured by standardized tests, and there are many reliable standardized exams which can be used to assess your elementary science program. These tests can be used to measure student progress toward understanding science content, to identify content areas (i.e., life science, physical science, or earth science) in need of curriculum revision, or to assess how well your students stack up to national norms. One important note: you and your colleagues should decide what content should be taught in science and, if a standardized test is used, it should measure that content. Don't let a standardized test determine what content is important for the children in your schools. To do so would be like letting the tail wag the dog.

E. Going Beyond Content

While science content is important, that's not all there is to science teaching. The Council for Basic Education says it this way:

Obviously, content is highly important. Selection of appropriate topics, formulation of concepts in understandable terms, use of carefully chosen experimental materials that will reveal the significance of the content-- these are necessary but not sufficient

conditions. The challenge and the opportunity in teaching science exceed the bounds of content (13).

How should science teaching exceed the boundaries of content? The following sections address that question.

III. WHAT'S SO BASIC ABOUT SCIENCE PROCESSES?

A. Lifelong Learning Skills

When addressing the question, "What should science teach?", the Council for Basic Education acknowledges the highly important role of science content. But they go much further. They give equal weight to the development of positive attitudes and, particularly, to process skills. Here's what they say about processes:

Habits of thinking and positive attitudes should have equal priority. Rather than treating these objectives as only by-products of the more concrete content material and student activities contained in the course of study, the schools should focus attention fully on opportunities for practicing the processes of science: observing data, experimenting, hypothesizing, etc. (14).

Research evidence over the past ten years overwhelmingly favors the inclusion of science processes on an equal footing with science content. A healthy, well-balanced science program will have both.

Why are science processes considered to be basic in children's education? Essentially because process skills are lifelong learning skills. They are the tools which make any kind of learning in any subject area possible. There is an ancient proverb which says, "Give me a fish and I eat for a day. Teach me to fish and I eat for a lifetime." When we teach process skills to kids we are teaching them to fish and eat for a lifetime.

What are these process skills that have value throughout our lives? Science education texts list the following skills:

observing	interpreting graphs
describing	recording
classifying	controlling variables
following directions	inferring
communicating	analyzing
designing investigations	making judgments
synthesizing	generalizing
measuring	predicting
sequencing	hypothesizing
recognizing relationships	using spatial relationships
organizing graphs	

These process skills are the basics of lifelong learning. They are the thinking skills that are woven through all subject areas--the common threads of education. Kids learn how to learn while acquiring these skills. Competence in using them provides children with the ability to apply knowledge, not only to science and other subjects in their classrooms, but outside the classroom in their everyday lives as well. They are the same skills that will serve them as adults, when they measure their floor for a carpet, try to figure out why their automobile didn't start, or decide which presidential candidate to vote for. These are the thinking skills they will use when separating evidence from opinion while listening to someone's side of a story, or when looking for evidence and contradictions in written or spoken opinions. They are the science processes children will use as adults to separate inferences from evidence in a systematic way.

The idea that children should be taught to think is not new. It was as important to Plato as it is to us. The Educational Policies Commission of the National Education Association (NEA) has said it well, "The central purpose which runs through and strengthens all other educational purposes--the common thread of education--is the development of the ability to think"(15).

The development of thinking skills as a foremost goal of education is a familiar idea to school principals and superintendents. Twenty years ago the United States Office of Education conducted a nationwide survey of school administrators. They were asked to rank the importance of a number of science teaching objectives. The two objectives that received top priority were:

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

Help children learn how to think critically(16).

Ten years ago, in a survey of Pennsylvania school principals and teachers, the same two objectives still held top priority and another had been added: "Help children develop problem-solving skills"(17).

Thinking skills and problem-solving skills are dependent upon the development of process skills such as observing, communicating, and hypothesizing.

The process skills are basic to what learning is all about. They lead us to ask pertinent questions. They help us to think critically. They are the intellectual raw materials for problem-solving.

Science is particularly valuable because many problem-solving situations do not result in exact answers. Teachers don't have the answers all the time. The educational value of science is not limited to having the teacher or children always knowing a specific answer. Instead, the value is the process of problem-solving--observing, inferring, communicating, analyzing, sequencing, etc.

The process skills taught through science education place an emphasis on the thinking skills children can develop. With these skills, children can learn as much content as they are able to learn or as much as they desire to know. The use of these skills is a process that continues for a lifetime. As a recent article in Educational Leadership points out:

The crucial tools of today's human living include not only the familiar three "R's," but also those skills that allow us both to adapt ourselves to our environment--to live with uncertainty and tolerate ambiguity--and to adapt our environment to ourselves--to analyze, synthesize, and hypothesize. These "process-oriented" basics cut across subject matter lines to give the person a capacity for response in a range of situations(18).

When should science processes, as well as content, begin to be taught? As early and as often as possible, according to an article in Principal. Here's what one elementary school principal says:

Science should be taught early since it is a thinking process. It is important how it is taught--at early ages, it should be done simply, at children's interest levels and in terms that they can understand. Environmental objects can be used(19).

B. Process Skills Relate to Other Subject Areas

Science process skills are basic because they cut across all subject areas--they can be readily integrated with other school subjects. These skills are the same skills which are necessary to achieve competence in other subjects. For instance, comparing, classifying, and sequencing are math skills. Social studies relies on collecting data and interpreting graphs, while creative writing uses communication and synthesizing skills. In fact, almost any process skill can find a niche in almost any subject area. The beauty of science is that it provides an excellent vehicle for teaching and reinforcing processes. By teaching processes in the context of science we are combining content that kids like with thinking skills that are relevant to their lives.

The Essentials Approach to education tells us that:

If learning is to be of long term benefit, educators must teach processes. Further, these processes must be taught in a manner that ensures their future use. Students must be taught how to learn in and outside the classroom--with and without the assistance of formal instruction. While it is often easier to teach and measure factual learning, research demonstrates that teaching processes pays off tremendously(20).

One study found that manipulative science programs stressing process skills had the following effects on the entire elementary school curriculum. They

- ...increased language and general knowledge
- ...developed measuring skills
- ...increased mathematics concepts
- ...increased number skills
- ...increased social studies skills
- ...improved visual perception skills
- ...served as a reading readiness program for early primary-grade children(21).

One of the processes that children should be taught is scientific reasoning--it is an essential problem-solving skill. The Essentials Approach to education tells us what scientific reasoning includes, when it should be taught, and how it can be related to other subject areas:

The process of scientific reasoning and experimentation consists of many subprocesses, including identifying factors and levels, controlling variables, formulating and testing hypotheses, making inferences, and systematically collecting and recording data. There is no grade level or subject that does not lend itself to teaching the fundamentals of scientific reasoning and experimentation. Whether the student is a second-grader studying the effects of sunlight and water on freshly planted bean seeds, a senior conducting a complicated experiment as a part of an advanced chemistry exam, a fifth-grader figuring out how to best protect his or her new bicycle from vandalism, teachers should encourage each to use these processes.

Students should be encouraged to experiment systematically with their musical instruments, drawing, story-telling or composition style, study habits, playground activities, and so forth. The primary, elementary, secondary, and college teacher must each assume responsibility for contributing to the development of this complex, all-important process. Children can be asked to predict the outcome of a story, to order alternative ways and to explain the reasonableness of the groupings, and to tell why they think (infer) so-and-so did such-and-such. Children in pre- or primary school are not too young to be asked to discover the number of small blocks needed to fill the same amount of space as that filled by six large blocks, to find which of three types of paper is best for watercoloring, or to identify which primary colors when combined make green.

Research indicates that when children are guided properly, they are capable of solving relatively difficult scientific problems and of doing so in a systematic way(22).

C. Standardized Tests Measure Process Skills

As principal, you are held accountable for the learning that occurs, or doesn't occur, in your schools. Standardized tests may be a

critical part of the accountability. You will be interested to know that science process skills are a major component of many standardized tests. Student performance on these examinations may be linked to their ability to demonstrate science process skills.

For instance, the primary objective of The Comprehensive Test of Basic Skills is to measure achievement in those skills common to all curricula--the basic process skills of learning. Student results are categorized by processes--recognition, classification, quantification, interpretation of data, prediction from data, hypothesis evaluation, and design analysis(23).

The reading tests (note: READING) of the Iowa Test of Basic Skills are designed to measure the following skills: understanding factual details relating to classification; inferring underlying relationships; understanding cause and effect; understanding functional relationships, time, and sequence and so on(24). If these skills sound familiar indeed they are! They are the same basic skills that can be taught and reinforced in science.

You may find it enlightening to review the standardized examinations used in your school. Don't be surprised to see the objectives of the test and many of the items leaning strongly toward the measurement of process skills which characterize a good elementary science curriculum.

IV. WHAT'S SO BASIC ABOUT SCIENCE ATTITUDES?

Attitudes formed during science instruction may be the most important basic of all. How kids feel about science and about themselves when they are learning may be more important than all the facts they could possibly learn. Benjamin Bloom came to that conclusion after studying data from research involving children in seventeen countries around the world. He found that the amount of learning in a science classroom depends on the initial interest and attitudes brought to the classroom. It is interesting also that this relationship is cumulative; that is, success breeds success. As children develop more positive attitudes and more interest in science, their achievement increases(25).

A good elementary science program is a natural breeding ground for success. Children develop good opinions of themselves when they have had opportunities to feel good about themselves. In a science program

where children are involved, participating, and contributing, there are many opportunities for them to feel excited, to like what they are doing, and to feel good about themselves.

A recent article in the Elementary School Journal reviewed 30 studies comparing three elementary science laboratory approach programs--SCIS, ESS, and SAPA-- to more traditional science teaching approaches. One of the areas measured in these studies was attitude. Here are the findings:

Four of the seven studies that assessed changes in attitudes found significant advantages for the laboratory approach. Again in laboratory programs, the mean ratings on attitudes of the group were never lower than the mean ratings of the group taking part in the nonlaboratory program. It appears to be a case of heads you win, tails you don't lose, at least in the meeting of objectives(26).

In developing good attitudes, it is important that children feel they are not constantly under the judging eye of a teacher, peer, or principal. They must feel their observations about guppies are good ones; or the data they collected were helpful to the class; or their experiments are important because they are their own-- they've done it themselves and they're proud of it. The development of positive attitudes is possible in a science curriculum that encourages children's curiosity, inventiveness, critical thinking, and persistence.

The characteristics just mentioned are four of the major attitudes in science as identified by the Science Curriculum Improvement Study. When encouraged, they result in positive attitudes not only toward science, but toward learning in other curriculum areas. For example, curiosity heightened in science can raise curiosity in reading.

How would you recognize such attitudes in a science classroom? Here are a few things you could look for.

Curiosity

Children use several senses to explore organisms and materials.

Children ask questions about objects and events.

Inventiveness

Children use equipment in unusual and constructive ways.

Children suggest new experiments.

Critical Thinking

Children predict the outcome of untried experiments.

Children investigate the effects of selected variables.

Persistence

Children repeat an experiment in spite of apparent failure.

Children continue on a task even though their frustration is evident(27).

Positive attitudes developed with the help of your elementary science program will benefit the whole curriculum. Many research studies tell us that if children have positive learning experiences, they are likely to develop positive attitudes about learning and about themselves. Research has also shown that there are opportunities in science programs to affect those attitudes significantly, to help them like science, school, and themselves. Don't let good opportunities pass you by.

V. SCIENCE PROMOTES CREATIVITY

Dr. Paul Torrence, a recognized authority on the subject of creativity, defines creative thinking as "the process of sensing gaps or disturbing missing elements; forming ideas of hypotheses; and communicating the results, possibly modifying and retesting the hypothesis"(28).

Although Torrence's definition is meant to apply to creativity, it also applies to science. In fact, formulating and testing hypotheses are at the very heart of science. These important skills can be taught and learned in elementary school classrooms. What better place to propose and test ideas than in science? What better place to encourage creative thinking? Abraham Maslow tells us that "All teachers, not just a few, and all courses should strive to develop creative ability"(29). It is clear that science class is a natural place for promoting creativity.

Fostering creativity is an essential part of what a good elementary science classroom is about. Promoting creativity through elementary science experiences is a matter of providing an investigative atmosphere conducive to creativity. Look for signs such as these in your science program.

1. When children are brainstorming ways to discover the identity of four unknown white powders, the teacher accepts all ideas and provides opportunities for the kids to test those which they believe most feasible.
2. When the teacher and children examine possible reasons why some plants grow larger than others, they have a two-way conversation. The teacher is open to suggestions and the conversation is child-centered. The children are talking with each other and reacting to each other's ideas.
3. Science projects are based on the kids' interests. The teacher suggests ideas, but the children are free to accept or reject them. Substituting their own ideas is encouraged. The children evaluate their own projects, they evaluate each other's projects, and the teacher also evaluates them.
4. In an experience in which groups compare results from a "bouncing ball" investigation, comparisons are made of the heights of bounce of different types of balls and how bounce heights differ on a variety of surfaces. Results vary and the teacher encourages the children to think about how these variations have occurred. He asks, "What variables are involved?" The teacher does not judge what is right or wrong but lets the children test their ideas.
5. In another investigation, the teacher gives each person in the class a piece of fishing line, a board, and some nails. The kids are challenged to create an instrument that makes sounds. Individual ideas are welcomed and the children are encouraged to try their ideas. Some children are off working by themselves, while others are combining ideas and/or resources.

Another way of promoting creativity through science is by asking questions that encourage responses which reflect the use of creative thinking skills. For instance, given 50 soda straws and 50 pins as building materials, the children are asked, "How tall a structure can you build?" Other questions to promote creative thinking might include: "What are different ways you

could pack an egg so it won't break when it's dropped? Why do you think the water in the aquarium turned green? How can you test your idea?

Encourage your teachers to use creative science activities. Children can be involved in activities such as role playing to show a famous scientist making a discovery, drawing posters to express their feelings about animal care, making filmstrips about science topics, taking photographs as part of a science project, constructing learning puzzles and games, or publishing a science newspaper for the school.

Creativity is a basic part of each child. Science can be the environment in which creativity is given a chance to grow.

VI. SCIENCE ENCOURAGES CREATIVE WRITING

Children who are involved in science activities have a rich bank of experiences to draw from when they think and write. Your teachers can capitalize on those science experiences by encouraging creative writing.

In times when basics are emphasized, science is often considered as unworthy of the title "basic." However, research indicates that experience-based elementary science programs foster the development of language skills. Reporting on a study relating science activities and creative writing, Knight states, "...demonstrations conducted as prior stimuli result in significantly more creative writings"(30).

Kids write about things they know about and like. They seldom stop to think that perhaps the words they are using are not in their spelling or reading books. They don't give a second thought about whether a word has two, three, or four syllables. What is important is that they are thinking about their thoughts. They are in a class where writing words on paper is interesting and purposeful, not academic drudgery in English usage.

Jenkins describes his experiences with children's writing, "...students' writing scores go away up after they've been writing their own reading materials"(31). He also states he often hears that if science, social studies, art and music were dropped from the first three grades and teachers just taught reading, the children would learn to read better. "But that's not true," Jenkins replies,

because when you ask kids what they want to write for their own reading, the major things they write about are science and social studies. We've classified words beginners like and 40 percent are from science, 22 percent from social studies, and 12 percent from fantasy(32).

Science experiences are rich with opportunities for kids to describe what they are doing or what they have observed. They use new words to help them build concepts. These words find their way into children's creative writing.

Relating creative writing to science may take many forms. (See the Packet of Attachments.) Children's imaginations can be set free with lessons about the moon, dinosaurs, or snakes. Science concepts can be reviewed or introduced with creative story writing. Similes such as busy as a bee, filthy as a pig, or bald as an eagle can be researched for accuracy. Kids can even make up their own similes. Children can write books about animals that visit the class. Energy jokes and riddles can be written, or kids can elaborate on science concepts to create science fiction stories. Poems, such as haiku, sijo, and cinquain can be written to express science facts or children's feelings. For instance, here is a poem written by an elementary school youngster after she had observed and investigated a mealworm.

Pity the poor mealworm
He is not an ideal

worm

In fact, he's not a real
worm,

But a bug,

Ugh

And when he sought the bran
He couldn't escape my scan
No matter how hard he ran,

what a bug,

Ugh(33).

Or consider the lines written by a little girl who investigated a hermit crab in her third grade classroom.

A crab, looks, yuck

Oh so hairy,

He makes me feel a little scary(34).

In most cases, knowledge and attitudes gained from experiences in the science curriculum will show up in creative writing. Anyone reading children's literary expressions will be able to identify what science has been taught and how children feel about it. Science and writing are a dynamic duo and combining them increases skill development in both areas(35).

VII. SCIENCE WITH HEALTH

"In my view," wrote Thomas Jefferson in 1814, "no knowledge can be more satisfactory to a man than his own frame, its parts, their functions and actions." Unfortunately, many elementary school children do not share Jefferson's view. Rather, considerable evidence exists to show that health, as it is often taught, is boring, repetitious, and irrelevant to the problems of today's youth(36). When it is taught, and all too often it is not, it is taught by textbook reading and teacher lecture only. There are few activities in which students actively investigate their own bodies and how they work(37).

Good health is important to everyone. Yet there is a real need for effective health education programs. This is evidenced in the lack of student interest and the inability of existing programs to build positive health attitudes(38).

During 1979 a telephone survey, conducted in 11 randomly selected school districts in western Pennsylvania, revealed a wide variety of health education practices. The most significant finding was that when 11 principals and 22 teachers were asked to describe activities that students participated in while studying health, not one named an activity in which a student participated directly in an investigation of his or her own body(39). As one sixth grader remarked when she was asked how she liked health; "Boring, boring, boring. We drew pictures of the eyeball in fourth grade, fifth grade, and we're drawing them again this year."

But health does not have to be boring and repetitious. By eliminating areas of overlap and reinforcing health concepts through science activities, we can teach more effectively, utilize school time more wisely, and increase pupil interest. Health and science are natural partners. Let's look more closely at several connections.

First and foremost, much of the subject matter we normally expect to find in health class is also found in science. Concepts in Science, which the Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education notes is the "...most commonly used elementary science textbook program in the United

States," includes several topics closely related to health: height and weight, food and nutrition, health and disease, most of the human body systems, and human inheritance(40). A close look at other elementary science programs will reveal similar topics and almost always, human body systems. Such content similarities are not unusual. The distinctions between health class and science class become blurred when children study how their heart works, how bacteria cause disease, and how pollution affects the environment and living things. It may not matter whether this commonly-shared subject matter is taught in science class or in health class. What does matter is that it is taught--and taught in a way which is both educationally sound and economical of curriculum time.

While the content of health may be taught in either class, science class is certainly the natural place for integrating health content with science processes. Involving kids with science processes makes health a get-up-and-find-out-about-yourself subject. Kids can

count and record pulse rates before and after exercise

compare reaction times to sight, sound, and touch stimuli

formulate and test hypotheses concerning factors which affect lung volume

predict, measure, and record external body temperatures at various locations on their bodies

design investigations to observe the effects of exercise regimens on muscular strength

simulate nutritional choices and predict effects on their bodies

design experiments to test peripheral vision

collect and analyze data on local and regional sources of environmental pollution

Activities such as these combine the content of health with the processes of science. It is here, in this meeting of health and science, that children can sharpen their science skills while finding out for themselves how their bodies work. It is here where they learn to practice thinking skills and decision-making processes applicable to their own health.

Health taught in a hands-on, child-centered, activity-oriented science class can provide the spark needed to make health interesting for kids. Children need to be involved themselves in order to learn about themselves.

Foundations can be laid for positive attitudes toward self and toward school. Learning health becomes important to the children because they see its relevance to their lives and enjoy studying it.

One other advantage of integrating health and science should be noted. In many elementary schools, science is not taught every day in every grade. In many cases it is scheduled three times per week, for example 1:30 to 2:10 p.m. on Monday, Wednesday, and Friday. On the alternate days the 1:30 to 2:10 p.m. time period is often devoted to health. In other schools science may be taught for one-half of a year and health for the other half. Such block scheduling offers an excellent opportunity for integrating science and health, a time to teach content common to both areas, while learning science processes and building positive self-images. Integrating science and health is not only educationally wise, but it may also be time efficient. The subjects can complement each other in content, processes, and attitude development. Teachers and principals would be wise to take advantage of these integrative opportunities.

VIII. SCIENCE DEVELOPS MATH SKILLS

When children are actively involved in science, they are often involved with math at the same time. When they grow plants, they measure and weigh the plants. When studying weather, kids read a thermometer daily and graph the temperatures. When kids find their resting pulse or heart beat rates, they count, record time, and calculate averages. When guppies are born, kids add them all up. When guppies die, they subtract. Histograms are made to show the type and number of leaves found on a field trip. Science and math can and should be integrated because they are interdependent.

Arithmetic can be difficult for children. It is a subject based on abstractions. Regrouping, fractions, subtracting, or number sequencing can be confusing to youngsters without hands-on activities and real-world experiences. Activities can help children to understand and apply mathematical skills. The motivations, hands-on materials, and real world experiences can come from science. For example, what child wouldn't be more motivated to learn how to calculate percentages if it

involved keeping records of the amount of food consumed by animals of different sizes kept in the classroom, rather than calculating home loan interest rates? Math skills are likely to be much more meaningful when applied to situations the kids can actively participate in and relate to. Those immediate situations can be science activities.

Picture the following science classroom situations. Some children are weighing objects and sequencing the weights from lightest to heaviest. Others are predicting and measuring, using weights and an equal arm balance. Another group is graphing the increase in weight of a paper towel partially immersed in water while another group graphs a wet paper towel's decrease in weight from evaporation. Another group is finding one-minute breathing rates by counting the number of breaths in fifteen seconds and then multiplying by four. Still another is collecting data on the amount of rainfall in a given month and then computing the daily average and monthly range. In these examples the relationship between science and math is clear. Because of the supportive nature of science with math and vice versa, many of the science experiences at the elementary level provide opportunities to apply math and develop mathematical reasoning skills.

At the 1977 National Convention of the National Association of Elementary School Principals, a large group of elementary and middle school principals were asked to react to questions dealing with science, math, and technology curriculum content. One question asked, "Should the mathematics curriculum be integrated with the teaching of science and technology?" Here in summary is what the principals said:

Emphasis should be on the math curriculum with its relationship to the science and technology areas (math as related to science).

Yes. Science and math cannot be separated, and technology is a tool of implementation.

Mathematics is applicable to the ideas of science and technology; it is the language of science and technology, but there are principles and concepts that do not have a real-world application(41).

Such comments from principals lend credibility to the science and math partnership at the elementary school level. An NSTA Curriculum Committee adds this support:

One cannot speak realistically of a sound science curriculum without considering the important role played by mathematics. Just as science itself could not have developed to its present stage without mathematics, so it is unrealistic to think the true character of science can be portrayed without mathematical reasoning. Mathematics is the language by which one describes the order in nature and which in turn leads to a clearer understanding of that order(42).

When monitoring your math and science curricula, ask yourself and your teachers whether children use math skills to substantiate science facts and whether they use their discovered science knowledge to show how math works. As Bruner points out:

To instruct someone is not a matter of getting him to commit results to memory. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on the subject, but rather to get a student to think mathematically for himself(43).

Integrating math with science experiences is an excellent way to accomplish Bruner's goal.

Hopefully, we are on our way to convincing you that there is a real opportunity for a partnership between math and science. Perhaps you have always had that intuitive feeling. Now you must be an advocate and win teachers, other principals, and parents to your side. Here are some integration examples you can use:

1. Math through Science Experiences - The children want to find out whether water is necessary for seeds to sprout. Two groups are planted: one receives water, the other does not. The children then discover that water is necessary, but they don't know how much water caused the seeds to sprout. Math is needed to show quantitative evidence. In the next experience, the children plant seeds and decide on various amounts of water to use. Those amounts are measured by the children each time the plants are watered.
2. Math with Science to Show Relationships - The children measure their height and arm span to discover a relationship about themselves.
3. Math with Science in Interpolation - The youngsters weigh a hamster seven days after it is born and again after fourteen days. On the seventh day, the weight is ten grams, on the fourteenth

day it is 20 grams. From the data collected the kids then interpolate the point at which the hamster weighed 15 grams. And since baby hamsters don't usually come in "ones," all the babies are weighed periodically to calculate an average weight gain.

4. Math with Science in Extrapolation - The children are investigating how a plant hormone solution will affect the growth of pea seeds. Some are dipped in the hormone solution, some are dipped in water. They measure growth in both groups every twenty-four hours for five days and plot points on a graph to indicate that growth. After examining the data, the children are asked to extrapolate, go beyond, what they observe on the graph and predict how high the plants would be on the seventh day.
5. Math with Science in Problem-Solving - The children are given a variety of materials to determine which are the better insulators. The kind of investigation the children design, what steps they include in the procedure, what tools are used for measuring, how data is recorded, and what conclusions are reached are a few of the processes kids use to solve this science problem. You have probably noticed that the same processes are used in solving math problems.
6. Math with Scientific Objectivity - The youngsters are investigating the reaction times of first, second, and third graders. They find they need a "language" to communicate what they are doing. Identifying the exact number of children tested is better than saying "some" or "a group," and an exact reaction time is better than saying some kids were faster and some were slower. The children also question the accuracy of some results and decide to duplicate a part of the reaction time investigation. Knowing the number of kids tested and how they were timed allows them to duplicate the investigation to check its accuracy.
7. Math with Science and the Metric System - The class measures the temperature each morning in degrees Celsius. Their readings are then placed on a large class graph. Later on in the day the children estimate and record the weight of small objects they have brought from home and then weigh them to find the actual weight.

These integrative examples point out how the children are using higher level thinking skills. Unfortunately, the back-to-basics approach in mathematics has been extremely narrow, centering on computational skills rather than problem-solving(44). Science/math experiences in your teachers' classrooms can provide an atmosphere to foster thinking and problem-solving skills.

A final analogy can be drawn from all the evidence which supports the integration of science and math. Schwartz and Zacharias make that analogy:

We like to regard the relationship between real content and intellectual processes as the relationship of the working fluid of an engine to the engine itself. A steam engine requires water, heats it to create steam and its pressure, condenses it at the far end, and forces it back into the boiler. The sciences can provide the working fluid for the mathematical engine(45).

IX. SCIENCE MOTIVATES MUSIC AND ART

A. Science and Art

Once there was a class studying mammals. One day the teacher said to the class, "I'd like each of you to take a piece of paper and draw a picture of a horse." And the children said,

"Oh, I can't draw a horse."

"I'm not a good drawer."

"What color should I make the horse?"

"What color are horses' eyes?"

"Are horses' tails long or short?"

"Can I draw just the head or do I have to draw the whole body?"

"I don't like it - it doesn't look like a horse!"

"Are you going to put these up?"

Of course the teacher encouraged, praised, guided, and coerced until the pictures were drawn. Days later, the class went to a farm and actually got close to a horse. So close that they could touch its tail and mane; feel its hair; see the muscles, ears, feet, mouth, and tail move; hear

the sounds the hoofs made; hear the snorting and neighing sounds; watch it run, walk, jump, and kick; watch the horse being saddled and ridden; and they even got to sit on the horse. There were also lots of different kinds, colors, sizes, and ages of horses for them to see.

The next day the children were still talking about the horses. The teacher then said, "I would like you to take a piece of paper and draw a picture of a horse."

"What color are you going to make yours? Mine's going to be brown with black like the one we saw yesterday."

"There, the tail is about that long."

"Look, I put the knees in. I didn't know horses had knees."

"I'm drawing my horse in the paddock."

"This is the baby horse and this is its mother. The baby has really long legs."

"See, I tried to make the ears look like they're moving."

"Can't we please take our pictures home?"

The teacher encouraged the children to talk about how their first picture was different from their second one.

This brief story illustrates how an art activity can be integrated with a science experience and increase in meaning and interest, because it is based on real experience. As Hans Hoffman, a German artist and teacher once said, "Nature is always the source of the creative impulse" (46).

Science activities which involve sensory experiences can be the raw materials for art activities. Field trips to zoos, pet stores, museums, and parks are exciting. Such trips help children make mental pictures of the world around them--pictures which can be translated into art.

The most obvious place for science activities which, by the way, is often the most overlooked is your own school ground with its trees, leaves, patches of lawn, bushes, and pavement. Science-related field trips to places such as these give

children the opportunity to observe and interact with their environment. Drawing, painting, collaging, paper sculpturing, and other art forms are all ways kids can express what they have observed.

Do the kids ask "What can I make?" or "What can I draw?" If they do, then what they manipulate and observe during science class can give them the answers. Capitalize on children's natural wonder at dinosaurs, the solar system, or those critters in the classroom. Have them keep picture records of their investigations with electricity and magnetism. Using construction paper, clay, pipe cleaners and other miscellaneous items, have them "invent" plants which are adapted to certain environmental conditions. Or have them make "animals" of painted vegetables and hide them in the environment to simulate animal camouflage.

Try listing several activities suitable for integrating science with art. Here are a few ideas to get you started:

1. Symmetry in nature can be observed when kids study butterflies, clams, birds, or their own faces. Fold paper in half and cut out butterflies, clams, or birds. Another symmetry activity involves photographing children's faces when each has half of his/her face covered. Then photograph everyone's other half face. Each child can then compare both photographs.
2. Send children outside to collect objects from nature that are rough, smooth, round, rectangular; shiny, fuzzy, or lumpy and make texture collages.
3. Have the children observe a pineapple. Sketch what it would be like from the side and from the top. Then have them visualize and sketch what it would look like cut in half from top to bottom. Cut the pineapple and compare it to the drawings.

Can you think of others? Ideas for integrating art and science are limited only by the imagination. Combining them into a single activity provides an opportunity to enhance learning in both.

B. Science and Music

Music can also become part of science experiences. In the Elementary Science Study units "Whistles and Strings" and "Musical Instrument Recipe Book," children make instruments with tubes, string, wood, bottles, and a variety of other materials. They discover what it's like to create vibrations, sound, pitch, intensity, musical scales, and even writing their own music.

Here are some ideas for activities which integrate science and music.

1. Give the kids bottles and water to make musical scales. Challenge them to use two bottles to illustrate an octave.
2. Have the children stretch rubber bands of four different widths around a shoebox. Encourage them to pluck the bands to note differences in sounds. Ask them to arrange the bands from high tones to low ones.
3. Have the children make their own musical instruments from natural objects...such as flutes from elderberry branches, whistles from willow twigs, reed instruments from blades of grass, etc. Have them form a "nature band" and play a tune.
4. Let the children pick familiar melodies and have them rewrite the words to the songs. Lyrics can be written about food chains, mealworms, the water cycle, or volcanoes. The possibilities are endless.

Combining music and science enables the children to learn concepts and skills from both. Such integrated experiences provide opportunities for the children to apply what they have learned and have fun too. We must encourage our teachers to take advantage of such opportunities.

X. SCIENCE DEVELOPS READING SKILLS

A. Reading is Important

There is no other subject in the elementary curriculum that has had so much attention as reading. Elementary teachers have spent countless hours taking inservice courses to improve their ability to teach reading. Parents are most concerned that their children learn to read. Tests

whether standardized or curriculum-related, are strongly weighted toward assessing reading skills and language. Textbook publishers try to maintain the integrity of their products by demonstrating that readability studies prove their books are written on or below grade level. The Federal Title I remedial reading program has been successful in helping millions of children overcome reading difficulties. More hours of the elementary school day are spent on the teaching of reading than on any other subject. There is no doubt that if teachers prioritized the elementary subjects in order of importance, reading would hold the number one spot.

With reading commanding such attention and high esteem, you would assume that teachers and administrators would be cognizant of what educational research and articles in the literature are saying about the positive relationship between reading and science. Unfortunately, that is not the case. Although the effects that science has on reading during the elementary school years has been documented in study after study, educators seem unaware of the value of integrating science and reading.

B. Science Experiences and Reading

Let's begin with a story. Do you remember the story of Peter Rabbit? Here's another version.

THE TALE OF PETER AND THE RABBIT

"Class, look at this picture and tell me what you see," said the teacher. Hands went up, but the teacher called on Peter, whose hand had not been one of them. "Peter, what is it?"

"It looks like a rat."

The class laughed. Someone said, "Peter is so stupid. He doesn't know a rat from a rabbit."

The teacher said, "Peter, what's the matter with your eyes? Can't you see that it has long ears?"

"Yes," said Peter weakly.

"It is a rabbit, isn't it?"

"Yes," he said.

"Today's story is about a rabbit," said the teacher, pointing to the picture and then the word. "It's a story about a hungry white rabbit. What do you suppose a rabbit eats when he's hungry?"

"Lettuce," said Mary.

"Carrots," said Suzy.

"Meat," said Peter.

The class laughed. Someone said, "Peter is so stupid. He doesn't know what rabbits eat."

"Peter, you know very well that rabbits don't eat meat," said the teacher.

"That depends on how hungry they are," said Peter. "When I'm hungry, I'll eat anything my mother gives me, even if I don't like it."

"Don't argue, Peter," said the teacher. "Now class, how does a rabbit's fur feel when you pet him?"

"Soft," said Suzy.

"Silky," said Mary.

"I don't know," said Peter.

"Why?" asked the teacher.

"Cause I wouldn't pet one. He might bite me and make me sick like what happened to my little brother the time one got on his bed when he was sleeping."

The class laughed. Someone said, "Peter is fibbing. He knows his mother doesn't allow rabbits in bed."

After the class had read the story and had recess, the teacher said to the supervisor, "I hate to sound prejudiced, but I'm not so sure that this busing from one neighborhood to the other is good for the children."

The supervisor shook his head sadly and said to the teacher, "Your lesson lacked one very important ingredient."

"What was that?" asked the teacher.

"A rabbit," said the supervisor(47).

The major point of the story, as you have probably inferred, is that children need participatory experiences before they are asked to talk about those experiences. Children need things to happen to them so they can talk or read about those things with confidence and understanding.

Here's an example in experience-based reading:

The batsmen were merciless against the bowlers. The bowlers placed their men in slips and covers. But to no avail. The batsmen hit one four after another with an occasional six. Not once did a ball look like it would hit their stumps or be caught.

Let's try a simpler version of that same story.

The men were at bat against the bowlers. They did not show any pity. The bowlers placed their men in slips. They placed their men in covers. It did not help. The batsmen hit a lot of fours. They hit some sixes. No ball hit the stumps. No ball was caught(48).

Was the second passage easier to understand? Probably not, unless you happen to be British or know the game of cricket. Simplifying the content doesn't help much if you have no prior experience with the ideas in the passages. Children react the same way when given reading material about things beyond their realm of experience.

But there is a solution to the problem. The solution has been well documented and proven to work in elementary classrooms. The answer is an activity-oriented curriculum, in which kids are doing math, doing science, doing social studies, and doing activities in all curriculum areas.

~~It's in the doing and thinking about it that~~ kids develop the concepts and vocabulary to read, speak, and write. Give them the experiences first, then ask them to read, speak, and write about them. Too often the process is reversed, with experiences coming last or not at all.

Activity-oriented science can bridge the gap between experience and language. It gives the teacher and children an opportunity to share experiences and discover ways of expressing that experience together. The children have the opportunity to hear and use language through direct exploration. Definitions of words are invented after children have had experience with the objects or concepts that the words represent. It is through science activities that children can enhance their reading skills.

C. Science and Reading Skills

Recent research indicates that experience-based elementary science programs foster development of language and reading skills(49). In addition, studies show that elementary science instruction may not only increase achievement scores in reading and language arts, but may actually offer alternative teaching strategies to motivate children with difficulties in these areas(50).

In a recent report funded by the National Institute of Education, Ruth T. Wellman synthesized research evidence and concluded that science helps children develop language and reading competencies. She reports that:

1. Active experience with science helps language and logic development;
2. Science instruction appears especially helpful for children who are considered physically or culturally "different;"
3. Selected science activities accelerate reading readiness in young children;
4. Science activities provide a strong stimulus and a shared framework for converting experience into language;
5. Reading skill development stems from language and logic development, which comes after concepts are formed from repeated encounters with objects and events through science activities(51).

Wellman also found evidence that science instruction improves reading skills in grades 4, 5, and 6:

Some of the benefits that intermediate-grade children have been found to derive from science instruction are: vocabulary enrichment, increased verbal fluency, enhanced ability to think logically, and improved concept formation and communication skills(52).

Others agree:

Elementary teachers often say they do not have time to teach science. We believe teachers cannot afford to overlook the opportunity to develop language arts skills in the context of an almost ideal setting. Most children are naturally curious and are fascinated by science activities. When science and language arts are presented together in the same lesson, both disciplines profit(53).

D. Science and Reading Readiness

The Council for Basic Education reports that "There is impressive evidence that hands-on science increases achievement in reading and math in early grades"(54). This statement has been supported time and time again. The manipulation of objects in science provides the opportunity for kids to match, reproduce, recall, discriminate, describe, sequence, and classify. These skills and many more are needed for reading readiness.

The goals of activity-centered science programs emphasize reading readiness skills. When science is not included in the primary grades, children miss out on experiences which can help them develop readiness skills. The results of research in science education indicate

...a positive relationship between children's participation in nationally recognized elementary science programs and the development of oral language skills and reading readiness(55).

Studies have been done to compare the effect of hands-on, activity-oriented science experiences with science taught through reading and teacher telling. The results show "...that children having science experiences scored significantly better on reading readiness...better on listening, vocabulary, matching, alphabet, and numbers. The science reading-teacher telling group did better on copying"(56). The summarizing statement concludes, "Although specific aims and outcomes of

research studies differ, a definite trend emerges which indicates that science experiences enhance reading readiness skills and oral communication skills among children"(57).

This is evidence that we as educators and principals cannot afford to disregard. We must use it to our advantage--using experiential science as a means of improving reading communication skills in our schools.

E. Science and Thinking Skills

Another similarity between science and reading also exists. They both emphasize the same intellectual skills. This similarity presents an opportunity for a wise curriculum planner. Use the motivation, natural interest, manipulative materials, outdoor activities, field trips, and discovery opportunities in science to make the thinking skills and processes of reading come alive for children. For instance, in reading, a list of vocabulary words can be introduced, defined, and then tested. Vocabulary words introduced with science activities will have experiences to back them up.

Let kids experience activities with magnets, water drops, balls, magnifying lenses, salt, and blocks. Vocabulary words such as attraction, repel, magnify, absorb, vertical, dissolve, evaporate, crystals, square, tallest, rounded, corners, edges, etc., will then have mental images.

When teachers involve kids in science processes, they are helping them develop reading processes. Table 1 shows the skills common to both science and reading.

TABLE 1

SKILLS IMPORTANT BOTH TO SCIENCE AND READING(58)

Examples of Problem-Solving Skills in Science

Corresponding Reading Skills

Observing

Discriminating shapes.
Discriminating sounds
Discriminating syllables and accents

(Continued on next page)

Identifying

Recognizing letters
Recognizing words
Recognizing common prefixes
Recognizing common suffixes
Recognizing common base words
Naming objects, events and people

Describing

Isolating important characteristics
Enumerating characteristics
Using appropriate terminology
Using synonyms

Classifying

Comparing characteristics
Contrasting characteristics
Ordering, sequencing
Arranging ideas
Considering multiple factors

Designing investigations

Asking questions
Looking for potential relationships
Following organized procedures
Reviewing prior studies
Developing outlines

Collecting data

Taking notes
Surveying reference materials
Using several parts of a book
Recording data in an orderly fashion
Developing precision and accuracy

Interpreting data

Recognizing cause and effect relationships
Organizing facts
Summarizing new information
Varying rate of reading
Inductive and deductive thinking

Communicating results

Using graphic aids
Logically arranging information
Sequencing ideas
Knowledge of technical vocabulary
Illuminating significant factors
Describing with clarity

(Continued on next page)

Formulating conclusions

Generalizing

Analyzing critically
Evaluating information
Recognizing main ideas and
concepts
Establishing relationships
Applying information to
other situations

The key to the whole relationship between thinking skills in science and reading is in the child-centered activities science can provide. For instance, when kids work with bouncing balls--dropping them from different heights, bouncing them on different surfaces, working with different kinds of balls--they experience cause and effect. Then when they have to identify cause and effect in a paragraph, they have that prior skill experience. If kids learn to classify objects, they then have that experience as a basic for classifying action words and object words. If they interpret data from a science investigation with plants, they are better equipped to interpret data from a paragraph they have been asked to read.

The skills taught in science can enhance and extend the skills taught in reading, and vice versa. It is up to us to help teachers see the benefits derived from integrating science and reading.

F. Reading About Science

We don't want to leave you with the impression that the actual reading of printed words should be minimized. Elementary children should be involved in reading about science. As adults, they will need to read about how science and technology affect their lives. Children will not be able to experience everything. They will have to read to expand upon their experiences.

But content reading can make a whole lot more sense to children when they relate their reading to their experiences. The teacher's role is then one of reminding the children of their experiences rather than spending precious time explaining what abstract content is supposed to mean.

Children's trade books can serve as a valuable reading resource. A year-long study done by a librarian in New York shows that science books are the second most popular books among children.

Most popular are fiction books, and some of those include science or science fiction(59). Using trade books also allows the teacher to select a variety of reading material appropriate for the reading levels of the children. Trade books can serve many purposes--ranging from recreational reading to information gathering.

A final word: science is the key to classroom experiences. Instead of pushing science aside with the idea that kids will get it in later grades when they can read about it, do science now in grades K-6.

XI. SCIENCE BUILDS SOCIAL STUDIES SKILLS

A close examination of elementary social studies books will illustrate how integrated science and society really are. Perhaps you have seen social studies books when working on textbook selection committees. Think back, for a moment, as to the titles of some of the units in those books: Our Earth, Mapping the Earth, Where We Get Our Food, Industry in the U.S., Our Pioneer Ancestors, Ancient Cultures, The Geography of Our Land, Climates of the World, Going from Place to Place, Our Neighbors to the South, etc.

For every unit, there is one or more science concept or skill woven into the social studies topics. For example, Our Earth includes measurement systems for the earth--linear, volume, temperature and weight measurements. Mapping the Earth incorporates inferring, spatial relationships, and land forms. Industry in the U.S. involves geologic formations, changes in matter, and forest management. Ancient Cultures includes the problems of flooding, growing crops, and superstitious beliefs about weather, geological forces, and the human body. Examples of science and social studies integrations are extensive. As long as there are people to be studied, there will also be people's science and technology to study whether it be pre-historic human being's discovery of fire or twentieth century human being's invention of the computer.

A recent National Science Teachers Association policy statement adds support for integrating science with social studies.

Science and technology influence every aspect of our lives. They are central to our welfare as individuals and to the welfare of our society. One has but to examine the immediate environment to identify clear examples of the importance of science and technology for production of food,

water, shelter, clothing, medicines, transportation, and various sources of energy. This examination reveals an increasing number of science and technology-related societal problems as well as increasing societal benefits. This position--that science and technology are central both to our personal and cultural welfare and many societal problems--presents a strong case for insuring adequate science education for all citizens(60).

We think that science experiences and social studies can go hand-in-hand in the elementary school curriculum. DeVito and Krockover support this view:

The natural sciences and social sciences cannot be divorced from one another. The study of human activities, coupled with climate, vegetation, soils, and landforms, makes social studies a truly integrated topic(61).

Science experiences can be used as the vehicle for kids to gather data concerning the world around them. The analysis, synthesis, and evaluation of data aids children in understanding science concepts. And when they do understand science concepts, kids have real information upon which to base facts, opinions, and solutions to problems in social studies. In other words, science experiences can be the raw materials needed to build social studies lessons.

For instance, let's consider how a class might deal with a problem related to a local sewage treatment plant which dumps improperly treated sewage into a local creek. The children could visit the creek to collect water samples to test for pH. Plants and animals found in and along the bank of the creek can be collected, classified, and identified. Microscopic organisms can be used to indicate water quality. To find the changes that have occurred in the stream, kids can interview or survey people who have lived along the stream for many years or people who use the stream for fishing or recreation.

After collecting this science information, the children can then visit the sewage plant to observe and ask questions about the plant's operation. Questions concerning the cost of treatment, benefits to the community, sewage treatment procedures, sewage treatment in the past and future, and the plant's methods for environmental protection can be investigated. The kids could also survey the community to sample attitudes toward the sewage problem.

Freshwater ecology, surveying community attitudes, and a community sewage plant can all be integrated into one unit of study. A sense of how things happen in the real world has been created by integrating science and social studies.

Esler and Esler sum it up this way.

In the integration of science with social studies, experimental science activities should be conducted prior to the use of the library as a research tool. When this is done, the science activities can serve to stimulate student interest and to provide data to be added to and clarified by that data gathered through library research. In this way investigations into the principles of science and technology related to the topic under study are made more meaningful. The basic skill subjects can be easily incorporated into any project for they serve as a means of gathering, analyzing, and storing information(62).

XII. WHAT HAPPENS WHEN SCIENCE ISN'T CONSIDERED A BASIC?

Elementary science education, once a top priority and the source of a great deal of national enthusiasm and federal funding, has fallen to a lesser role in many schools. Concern for improved student performance in the basic skills--reading, writing, and mathematics--and state mandates for minimum competencies in these areas have forced teachers to ignore subjects not considered "basic" or covered by statewide testing programs. In fact, elementary science instruction has been abandoned in many local school districts or given low priority(63).

The sorry state of science at the elementary school level was driven home hard by the National Science Foundation status studies of the late 1970's. Stake and Easley in their case studies of elementary school concluded:

Although we found a few elementary teachers with a strong interest and understanding of science, the number was insufficient to suggest that even half of the nation's youngsters would have a single elementary school year in which their teacher would give science a substantial share of the curriculum and do a good job of teaching it(64).

We have said many things about why science content, processes, and attitudes are basic for the elementary curriculum and children's lives. We have also quoted

many well-known science educators and cited a variety of research and literature sources that support science as a basic. We hope you, as an elementary principal, will support the view of the Council for Basic Education when they say, "Basic education without science is inconceivable. A person can neither be basically nor liberally educated today without science"(65).

What happens, though, when science isn't considered a basic? What have science educators, teachers, administrators, and education researchers found so far to be the effects? What are the side effects of the "I don't have time to teach science" syndrome?

Responses to those questions have serious implications for science education. Some are noted here because of their implications for elementary children and the people who educate them.

According to a study commissioned by the White House in 1980, America is headed "toward virtual scientific and technological illiteracy." The report states that our nation has lost the momentum of its post-Sputnik commitment to science education, adding that unless "the current trend toward scientific and technological illiteracy is reversed," many important national decisions will be based upon "ignorance and misunderstanding." Students who are turned off to science at an early age find out too late that science is the key to success in other academic areas and in many careers(66).

"Problems arise," according to the National Science Foundation and the U.S. Department of Education, "when the acquisition of 'basic skills' becomes the curriculum, rather than simply a foundation upon which students can build their ability to deal with more complex situations and problems. Science is not generally viewed as a 'basic,' so its role is diminished in such programs..."(67).

A disadvantage of "back to basics" that Brodinsky foresees is the increased emphasis on "testing, testing, testing," with the probable result that many teachers will teach the test and not the subject matter. But of even greater importance to many concerned educators is the possibility that public education is in the process of losing its "great generating power" by dehumanizing the learning process and "placing it under rote and autocracy"(68).

Preoccupied with preparing students for basic skills tests, some districts give science lower teaching priority. This is ironic in view of studies showing

that science, when creatively taught, can be an excellent way to teach the fundamentals of reading, writing, and math(69).

Constance Tate, science coordinator for the Baltimore City Public Schools, agrees. Cutting science, she says,

...demonstrates what happens when the public fails to understand that science is involved with more aspects of daily life than any other discipline. And because it's such a good way to teach fundamental reading, writing and math skills, science is a key to school improvement. I'm convinced the only way to get our citizens involved in education is to get them involved in science. Otherwise, we're going to end up with people who know science against those who know nothing about science(70).

And finally, a report from North Carolina summarized both the low status and high potential of science.

Primary grade teachers report they spend less than an hour per week in science studies. They would like to devote more time to science, but the heavy pressures they feel to teach even more reading and mathematics force them to spend nearly all of the class time in those areas. We believe there is reason to be concerned about over-emphasizing the elementary curriculum in the "three R's" to the exclusion of other disciplines. Ironically, there is sufficient evidence available to support the contention that improvements in reading, language development, and math result from teaching more science rather than less. Much of the gains that occur in elementary reading and math seem to be related to the hands-on experiences a strong science program can provide(71).

As principal, you can help teachers to see the importance of science. You can encourage them to teach it. You can show them how to combine and integrate science with other subject areas. Without your leadership skills and support, science will never become an important part of the elementary school curriculum, and the loss of science will be a serious loss to the children's lives. With your support, science can enhance the elementary school curriculum. It can teach basic skills--it can provide a vehicle for applying what children learn in other subject areas; it can increase interest in school and promote better self-concepts; and perhaps most importantly, it can equip children with a love for learning that will drive their intellectual engines throughout their lives. What could be more basic?

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