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ABSTRACT

Included in this publication for parents and teachers are over 30 anecdotes that serve as suggestions for varied science activities for young people. The first section presents the objectives and organizing the learning environment. The second section presents a variety of ways to help children explore their environment. The last section suggests methods for evaluating children's science achievements. A selected bibliography is included. (RH)

The Child & Science

Wondering, Exploring, Growing

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The Child & Science

Wondering, Exploring, Growing

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Contents

Venturing into Science

Part 1

Curiosity

Tell me, tell me everything!
What makes it Winter
And then Spring?
Which are the children
Butterflies?
Why do people keep
Winking their eyes?
Where do birds sleep?
Do bees like to sting?
Tell me, tell me please, everything.

Tell me, tell me, I want to know!
What makes leaves grow
In the shapes they grow?
Why do goldfish
Keep chewing? and rabbits
Warble their nose?
Just from habits?
Where does the wind
When it goes away go?
Tell me, or don't even grown-ups know?

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Children bring their natural curiosity to science. They seem to have an unending stream of questions to ask as they go exploring: feeling the texture of damp soil, seeing an earthworm wiggle, feeling the wetness of water or the push of the wind, tasting the spray of the ocean, hearing the sound of thunder, watching changing cloud patterns, smelling new mown hay, seeing televised scenes of marine life.

How can we help children explore and thereby foster their curiosity and development? How can we create environments in which children feel eager and free to investigate? What can we do to overcome hesitancies about teaching science? In what ways can we, as adults, become informed and involved in science? How can we evaluate children's achievements based on the objectives of science experiences?

Identifying Objectives

Studies have identified processes such as observing, classifying, comparing, explaining, verifying, creating, hypothesizing, analyzing and predicting as important science skills. It is critical that we understand these process skills and encourage children to develop these skills as they explore their world.

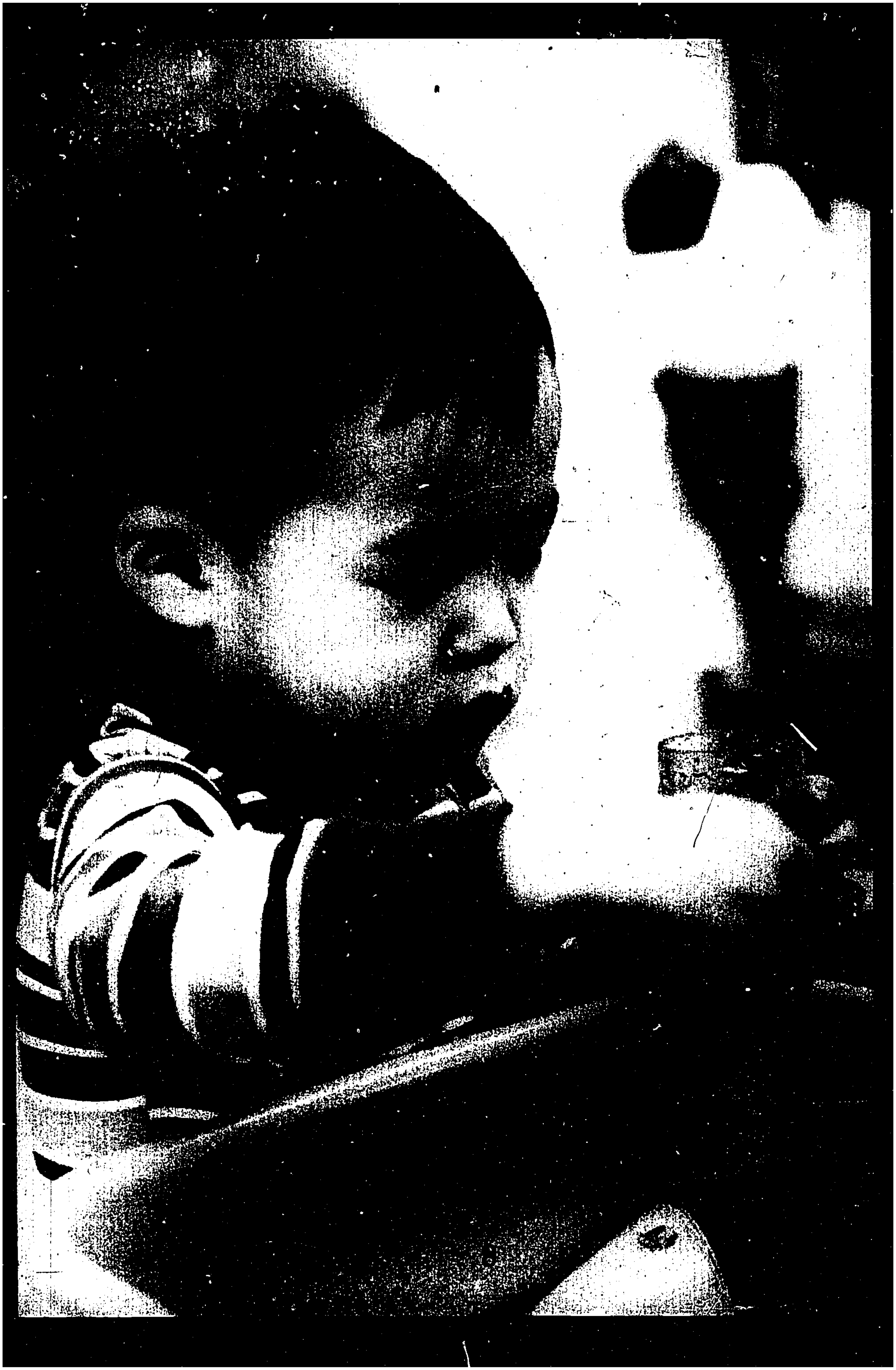
Through science, children can also develop their ability to discover meanings and develop concepts. The process of concept formation, continuing throughout life, is an open ended process in which one concept builds upon another. It begins in early infancy as children interact directly with things around them. When we provide a variety of learning opportunities, a concept becomes the child's idea through reinforcement. In the child's mind, the idea now has a strong power: when confronted with a new and different observation the idea can explain the observation or can become transformed into a new idea.

Among the more significant contributions to our understanding of cognitive development is the work of Jean Piaget. He and his associates at the University of Geneva propose that cognitive development occurs in four developmental stages, each stage characterized by the acquisition of particular concepts. Piaget identified the stages as the sensory-motor stage (ages 0–2), the pre-operational stage (ages 2–7), the concrete operation stage (ages 7–11) and the formal operation stage (ages 11. . .).

Interest in the cognitive development of children has accelerated over the past decade and has made an impact on many science curriculum projects. These include the *Science Curriculum Improvement Study* (SCIS), the *Elementary Science Study* (ESS), the *Illinois Studies in Inquiry Training*, and *Science—A Process Approach* (SAPA). These, as well as other federally-funded, experimental projects developed during the latter part of the 1950s and 1960s, influenced trends in science teaching. Most of the projects were concerned with developing process skills and with concept formation; they generally provided open-ended experiences in which each learner was involved in the discovery approach to science content. The curriculum designers often put greater emphasis on the processes, such as observing, classifying, predicting and experimenting, than on the science content. Developing mathematical skills, such as graphing, measuring and recording data, was integral to many of the projects. For the most part, however, the new programs developed selected science concepts, such as interaction, change, energy, matter and organisms, and included subject matter from both the life and physical sciences.

Many elements of these innovative science programs are found in today's classrooms. Recently, science educators have been drawing subject matter from environmental problems of concern to their students. Science ex-

Let's see how much water goes in this time.



periences are increasingly individualized and personalized. Science curricula have as objectives the acquiring of science concepts, the learning of process skills, and the development of attitudes conducive to positive interaction with others and with the environment.

Gaining Confidence and Acquiring Information

Today's objectives for science curricula present an awesome challenge to many classroom teachers. It is not surprising that teachers feel uneasy about teaching the subject as the following dialogue suggests.

"What are you planning to do with science? I have never understood what it's all about. Planning science lessons makes me feel so insecure."

"But science is happening all the time. Just being alive is science! Look, you just put a spoon in your coffee cup before you filled it with hot coffee. Isn't that science?"

"Can't you see me taking 30 cups and spoons into the classroom? That's a bit ridiculous!"

"I was just pointing out that we use science everyday."

"I don't have the time or energy to read and master all I need to know."

"But look at what you already know—your backyard garden is science; cooking is science. And you don't have to know everything; you can explore with the children."

"What do you mean explore? When the children ask questions, I'm supposed to have the answers."

"Much of what's important in science is the process of finding out. We need to encourage questions, help the children see that we don't have all the answers and guide the children to resources."

"I think I see what you're talking about. My nine-year-old daughter knows more than I'll ever know about space travel. When she asks me a technical question, I merely suggest some sources of information. But I couldn't possibly do that for all 30 children in my classroom."

"It's not easy to provide for so many individual interests. But we have many resources right here in our own community—the arboretum, the school district's science center, the National Park Service nature center. The list is endless."

"The school district is sponsoring a workshop on developing self-awareness through science. I wasn't going to attend, but now maybe I will. I guess I really need it."

After the science workshop. . . . . .

"The workshop was great. It focused on *us* and things *we* were interested in. The whole process of exploring was what was so exciting."

"Well, what kinds of things did you do?"

"Oh! There was so much. First we went to a nearby park. I noticed what I'd been too busy to see before. It was an experience in awareness. I became so involved that I wrote a poem just for myself."

"You were really getting involved in science. What else did you do?"

"We collected natural materials in the park and later created learning centers with them indoors."

"Did you arrange to have children use the learning centers?"

"No. The centers were for us. Each one provided an individualized science activity that integrated a variety of curriculum areas. We included music, art, language and movement by creating dances, developing art projects and making puppets. One person even composed a poem to accompany a science collage."

"You have just illustrated that science can be a part of everyday living."

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"Yes, I understand—now that I've gotten involved. I even have more self-confidence to experiment. I can hardly wait to help the children do the kind of exploring that I've been doing. And I want to encourage other teachers who may be hesitant."

TO: All interested teachers

FROM: A teacher who discovered the excitement of science

SUBJECT: Science resources for personal development

Botanical gardens	National Aeronautics & Space Administration
Museums	National Geographic Society
Arboretums	National Wildlife Federation
School-district science centers	Audubon Society
Lakes, streams, ponds	TV documentaries
National Park Service	Local industries
University and college resources	Pictures
Tide pools, beaches, oceans	Senior citizens
Observatories	Libraries
Films	Records
Books	

and Children

Organizing the Learning Environment

Warren, aged 5, seemed negative, asocial, private and uncooperative. However, he loved reptiles, especially dinosaurs, turtles and snakes, and had a large collection of books, records, pictures and models of reptiles.

The kindergarten teacher was perceptive and encouraged Warren's interest. She even obtained a real live snake—the ultimate resource—for Warren. Warren responded by showing social leadership. He involved everyone in building a cage of blocks to house the snake. When the children asked what kind of snake it was, Warren pointed to a small labeled picture in his reptile book. Warren turned to the teacher, "Here it is—the name of my snake! Please read it to me!"

The teacher's understanding of how children grow and develop provided the basis for her organization of the learning environment. She provided activities that would promote the total development of each child.

Integrated Curriculum The teacher integrated science with reading, math and social development. Warren "read" the pictures of snakes and asked that the teacher read the words. Constructing the snake's cage required mathematical problem-solving. Warren's leadership role and the cooperation of his classmates were directly related to the science activity.

Individualized and Personalized Learning Warren's interest in reptiles provided the catalyst for the learning experiences. The teacher encouraged this interest by introducing Warren to a variety of resources

including the snake. Warren's interest in the learning situation allowed him to develop at his own pace and in a positive manner. As a result, the other children learned about snakes, too, and accepted Warren as a part of the group.

One morning the urban 5-, 6- and 7-year-olds noticed the tadpoles in the aquarium. "What are those?" "Where did they come from?" "Do they have to stay in the water?" "What will they eat?" "How do they move?" "Why is the body so big and the tail so small?" "How big will they get?"

Days passed. Observations continued. Finally there was a change! "The tadpole's got its back legs!!!" How did the classroom organization facilitate this enthusiastic process of inquiry?

Multi-age Grouping The children sparked each other's enthusiasm; their cooperative work sustained this interest. The 7-year-olds provided leadership and gave the younger children individual attention. As they made observations and asked questions, they developed self-confidence.

Learning Centers The tadpoles in the aquarium, the many picture books, and other resources composed learning centers that stimulated the children's open-ended investigations. The children gained an understanding of metamorphosis because they were able to observe live tadpoles and thereby confirm their own discoveries.

"New Island in South Pacific! Volcano Erupts." Spurred by this headline in the newspaper, a group of 10-, 11- and 12-year-olds decided to investigate volcanic activity. The children had many questions. "How does a volcano make an island?" "How do you predict an eruption?" "What other volcanic islands are there in the world?" The teacher allowed the children to design their own investigations; the approach of the teacher and children created an open environment in the classroom.

How hot is lava? What makes it cool?
Will anything grow on lava?

Multiple Organizations The classroom was the scene of "volcanic" learning experiences. The teacher creatively combined multi-age grouping, learning centers, integrated curriculum and team teaching to create an environment in which current events and science were integrated. The children used a variety of resources: books, magazines, films and photographs. The young investigators visited a science museum and consulted with geologists and other knowledgeable professionals. Working together, the children constructed a model of an erupting volcano from papier-maché, paint, vinegar, baking soda, food coloring.

SUGGESTED GUIDELINES

Preparing for Science Adventures

Get ready to venture into science teaching by—

- ☐ letting the "whys" and "hows" of your science teaching emerge from your philosophy of education.
- ☐ obtaining a foundation of scientific information drawn from community and other resources.
- ☐ identifying desired objectives, suitable activities and methods of evaluation that assess the extent to which the children achieve the objectives. (Also be aware of unanticipated outcomes that are so important to children's learning.)
- ☐ selecting activities that foster children's development of attitudes, concepts and process skills—from the life and physical sciences.
- ☐ checking that the activities include multi-age grouping, learning centers, integrated curriculum, team teaching, as well as individualized and personalized learning.
- ☐ showing an attitude of inquiry, of eagerness to learn, and encouraging this attitude in children.
- ☐ recognizing that learning about science trends and innovations is an ongoing process that continues through workshops, inservice meetings, books, films and television.

Helping Children Explore

Part 2

Children should be led to make their own investigations and draw their own inferences. They should be told as little as possible.

Herbert Spencer, EDUCATION: INTELLECTUAL, MORAL AND PHYSICAL (Akron, Ohio: Werner Co., 1860), p. 120.

Men must, as far as is possible, be taught to become wise by studying the heavens, the earth, oaks, and beeches. . . that is to say, they must learn to know and investigate the things themselves, and not the observations that other people have made about the things.

John Amos Comenius, THE GREAT DIDACTIC OF JOHN AMOS COMENIUS, 1650, edited and translated by M.W. Keatinge. (London: A. & C. Black, Ltd., 1907.)

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The child's world is filled with a great variety of objects and events that stimulate, almost compel, exploration and learning. The learning goes on inside the child. Each young investigator reacts individually to the surrounding environment, adjusting the response to his or her interpretation of that environment. The child's senses and intelligence help in making these interpretations. Emotions, too, play a part as the child gains an awareness of self and of the world.

We can think of a child's world as a series of separate environments to be explored. We know that the world exists as an unsegmented whole, yet this perspective may help us to understand the child's viewpoint. Central to the child is his or her own body, the internal environment bounded by the skin from birth to death. Beyond the body is the familiar environment in which the child lives, continuously encroaching upon the child. The two—the child and the external environment—constantly interact. The degree of interaction depends on the meaning the child derives from the environment and has much to do with the person he or she becomes. Eventually the child explores the environment that extends beyond the immediate surroundings, and begins to see interrelationships among all three environments.

We can help children learn about themselves and the world by providing opportunities for science adventures that encourage exploration. The episodes that follow are descriptions of such adventures; they are meant to encourage you to create similar opportunities for children. The episodes focus on some or all of these objectives: the acquisition of science concepts, the learning of process skills, the recognition of values and attitudes, and the ability to work alone and with others.

Each episode may feature the development of a variety of process skills. For simplicity, however, only those skills that receive the most emphasis are identified at the beginning of each episode. As used here, the terms that are used to identify some skills have special meanings. *Creating* may imply not only self-expression through art, music, poetry, prose and movement, but also the designing of experiments and equipment. *Observing* may require the use of one or more of the senses: seeing, hearing, tasting, smelling and touching. *Discovering* occurs when children find out something new to them, *investigating* requires more probing and *experimenting* involves a structured approach including the control of variables.

The Internal Environment

What's Inside Me?

Gaining Information, Investigating, Creating

"You can trace around my body. Then I'll do yours." These were among the comments heard one day when a group of 6-, 7- and 8-year-olds became involved in finding out about themselves. Their questions led to trips to the public and school libraries for books, pictures and other information. Jamie's father, a doctor, gave the children a medical book. The children discovered that they could lay one of its transparencies on another to reveal the location of the lungs, the heart, stomach and kidneys. The children were amazed at the size and shape of the liver. It became a much talked-about part of the body.

Tracings on white paper took the shape of each child's body. Someone suggested that they glue "arteries" and "veins" to their paper "bodies." Red yarn represented the arteries and blue yarn, the veins. After further use of the source books and a myriad of questions, Jamie's father helped the children find out about the importance of the various organs in the body. Then paper cutouts representing the various organs were glued to the "bodies."

Next the children decided to study the human skeleton. The many sizes and shapes of bones created wonder and amazement. The children wanted to create their own skeletons from paper. Lacking the ability to draw them to scale, the children traced teacher-made patterns of the major bones. The paper bones were cut out and "hinged" into proper location with brass fasteners. By moving their paper skeletons, the children simulated their own movements. The youngsters recorded their observations and findings in booklets entitled "About Me." These became proud possessions and were shared with the children's families.

Relating the Self to an Object

Measuring, Decision-making, Model-making

A group of 10- and 11-year-olds decided to make scale models of objects, each model to the same scale as the owner's body. When finished, the models could be worn as Halloween costumes. Sara wanted to make a model of a can of bath powder; others selected a wheel, a pencil, a book, a tube of toothpaste, a spool of thread.

To begin, the children made models of their objects to actual scale. Careful measurements were made; suitable materials were selected—cardboard, wire, wooden dowels, yarn, masking tape, glue. Ratio and proportion were discussed and made meaningful when each child built two more models—one smaller and one larger in scale. The children identified and classified the different geometric shapes contained in their objects. They discussed how the shapes were arranged to make the whole.

Finally, each child built a model to "body scale." Of course, the scales varied according to the size of the child and the way the child planned to wear the object. Sara's can of bath powder had to be increased in scale sufficiently for its diameter to exceed the distance across her shoulders. "Will the material I choose be strong enough? Will it be too heavy? Will I be able to move within my model?" These problems and others were discussed and decisions made.

The finished models had the same proportions as the original objects—and the same labeling and trademarks! After a school parade, the Halloween costumes were the subjects of some creative writing: "I Am a Wheel." "How It Feels to be a Pencil." "How It Feels Inside the Environment of a Book."

An Awareness of Self

Communicating

Who Am I?

I am a boy, 11 years of age and my name is Jeffrey. My eyes are brown, my hair is red, I am 4 feet 10 inches high, and I weigh 76 pounds. This is my outer description, but I have an inner being also.

My inner being is my thoughts and feelings that I have. There are things I like and things I don't like. I have my good and bad points, each which I learn from.

My feelings help me get along the road of life without needing, a tow truck to pull me around.

You may fit part of this, but you will never be me.

Developing a Sense of Caring

Wondering, Observing, Questioning.

One day Sharon learned that her family was going on vacation. She wanted someone to care for Tammy, her cat, who was soon to have babies. Hurriedly, she ran to her friends Kari, a 3-year-old, and Sean, a 5-year-old. "Will you take care of Tammy while I'm gone?" The children assured her that their mother would help too.

Each day Kari, Sean and their mother visited Tammy. Their mother pointed out that Tammy's belly was getting bigger and bigger. They touched it gently. They observed that Tammy was having more and more difficulty moving about.

One day they called to Tammy, but no Tammy appeared. "Where do you think she is, Mommy? Do you think she is having her babies?" The children asked with great concern. They looked everywhere, but no Tammy.

Later in the day, Sharon and her family arrived home. Sharon immediately ran to Tammy's box and to her surprise discovered that some of the kittens had been born. Excitedly Sharon called Sean and Kari to come see. With wonder and amazement, the children observed Tammy licking her babies clean. With their eyes closed, the squirming kittens instinctively searched for Tammy's nipples. After watching in silence, the children began to ask questions; their mothers gave thoughtful explanations.

Day after day the children observed the kittens' growth and their behavior. More and more questions! Then came a time when Tammy would allow her babies to be held. The gentleness of the children! Caring! Feeling and interacting to the closeness of life in their hands.

Developing Sensory Awareness

Observing, Identifying, Communicating

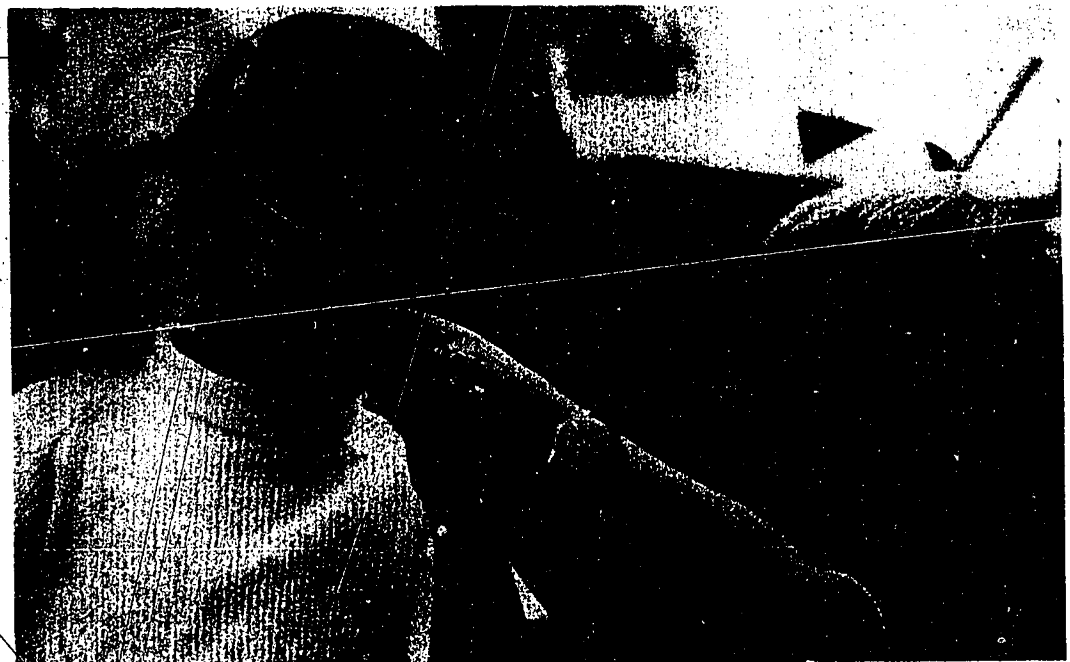
"I smell popcorn!" exclaimed David as he entered the room. And he was right! This was just one of the experiences provided for a group of 4-, 5- and 6-year-olds who were making discoveries with their five senses. The children listened to the kernels pop, observed the white, fluffy corn and tasted it. At a learning center, each person smelled a series of capped bottles to identify their contents.

Each child made a "My Touch and Feel Book" in the shape of a large hand. Everyone glued real objects into their books as they were asked to find the soft, fluffy cotton balls; the pieces of "bumpy" cloth; the soft, squishy, squashy pieces of sponge; the pieces of sticky, yucky tape; the feathers that felt "ticklish"; the rough, scratchy pieces of sandpaper. The children had fun trying to describe the textures in words. "Can you think of some things that really hurt when they touch your skin?" "Does your skin feel like your friend's?" "Could you guess it was Jason when you played the blindfold game?"

Everyone took a "listening walk" around the neighborhood. "Let's stop a moment. Close your eyes! What do you hear?" Then onto another place to stop and listen. "Do you all hear the sai e sounds? What does that sound (a siren) tell you?" Back in the classroom, we identified daytime and nighttime sounds: pleasant ones, loud ones that hurt your ears and scary ones. We listened to a record. "How does the music make you feel? Make your body move to show how you feel."

At learning centers, the children had "tasting and smelling parties." They discovered that some foods taste sweet while others taste sour or salty or bitter; some made simple graphs to show their findings. "What happened when lemon juice touched the tiny taste buds on your tongue? Can you taste your favorite food when you have a cold?" The children learned how difficult it is to separate the tastes and smells of foods. Finally they discussed foods they liked now but didn't like when they were younger."

"Oh, I can see the rainbow colors!" exclaimed Susan as she held a prism between her hands. Turning it this way and that, she squealed with delight as she focused on different colored objects in the room. Then the children decided to sort many objects according to their colors. Experimenting with colors was fun! Everyone partly filled empty baby food jars with water, added drops of food coloring, and sorted the jars by color. "How many different colors did we make?" To display their answer, the children began by coloring small squares of blotter paper by



Yech—I know. . . it's a lemon!

dipping one square into each jar. After allowing the squares to dry, the children arranged them in vertical columns, one color to a column, to form a bar graph. Finally the children counted the squares in each column to show how many different colors they had made.

The children discussed how their eyes help them to see. Standing in front of a long mirror, they named all the things that they liked about themselves. At a learning center each child peered into a foot-square mirror. "Look at your eyes, your face, your nose, your mouth, your ears, your hair. Draw yourself. You are special." The children's drawings were mounted on the bulletin board with the caption "A Picture of a Very Special You."

To integrate their learnings, the teacher introduced a "surprise box" containing many common objects. The children took turns selecting an object and then identifying it by using their senses.

Hearing My Heart Beat!

Observing, Discovering, Gaining Information

A group of 6-, 7- and 8-year-olds were fascinated when the school nurse showed them how to use a stethoscope to hear their hearts beat. Thump! Thump! Thump!

The school nurse showed them a model of the heart to help them gain some idea of the size of the heart, how it works, and its relationship to other organs in the body. She described the circulation of the blood away from the heart and back again; she compared the circulation to a family's route away from home along one highway and its return along another.

The children noted that their hearts pumped faster when they jumped up and down or ran around. Everyone took the model of the heart apart to examine its structures. Books and films provided additional information that the children synthesized by drawing pictures and writing descriptions.

Why Smoke Cigarettes?

Investigating, Gaining Information, Recording Data

"You can see the tars from the cigarette here in these transparent lung cavities," explained the officer from the county drug abuse center to a group of amazed 11- and 12-year-olds. They were observing "Smoking Sam, a smoking machine with a personality." After witnessing the dramatic effects of smoking just one cigarette, they asked many questions pertaining to the effects of smoking on health. They became aware that the air in a room could become polluted if several people smoked. "What might happen to non-smokers?" the children queried.

Previously some of the children had interviewed smokers and non-smokers who were willing parents, relatives and neighbors. The children discussed interview techniques and developed questions such as, "Why do people start to smoke? How do you think smoking affects health? How can someone stop smoking? How do non-smokers feel about people who smoke?" The findings were tabulated and reported to the class.

Some children made graphs showing the number of cigarette packs some smokers used in one week and the costs involved. Others collected cigarette advertisements, suggested reasons for their effectiveness, and determined whether the ads appealed to emotions or reason. The children suggested reasons why the Surgeon General's message is printed in cigarette advertisements.

The children gathered information from a wide variety of sources: photographs of lung tissues affected by smoking, pamphlets from health agencies, models of the lungs. The children discussed this information with reference to their own bodies, especially to their respiratory systems. They listed reasons for saying that smoking is a health hazard.

Finally, the children wrote to the student-teacher's father, a smoker. The letters outlined the hazards of smoking and urged him to stop. The father wrote to the children to thank them for the information. During the semester, the children repeatedly asked "Would he stop?" and "Did he stop?"

Looking at Our Teeth

Observing, Discovering, Investigating.

"Open wide! Ooooh, you have gold teeth! Why do you have gold teeth? I have fillings but they're not gold." One 6-year-old questioned another during a dental student's visit to the class.

The student introduced the children to models of teeth and questioned them to learn what they already knew. They discussed the various types and uses of teeth. Working in pairs, each child used a small hand mirror to examine his or her partner's teeth. Each child carefully observed the upper and lower teeth with the mirror. Discoveries! Many discoveries! Then all the mirrors were sterilized—another learning experience—and all partners traded places, the examiner becoming the examined. Differences in diet and dental care became apparent as the children asked questions.

The dental student used the overhead projector to show pictures of teeth and explained how they grow. The children were interested to learn about plaque formation and cavities; they learned new vocabulary words. Good dental hygiene was stressed. There was great excitement when each child received a new toothbrush to take home.

Filmstrips, pictures and stories reinforced the learnings. The models of teeth left by the dental student gave everyone opportunities to study teeth more carefully. The children drew pictures of good foods to eat and proper care of the teeth. The study of teeth led to an interest in other parts of the body and a study of the ear, eye and heart.

Celebrating the Senses

Observing, Identifying, Communicating

Everyone in our neighborhood, children and adults of every age, participated together in these activities:

—Finger painting with chocolate pudding, yogurt and whipped cream.

—Tasting and smelling batches of popcorn each seasoned with a different flavor, such as garlic butter, barbecue sauce and cheese.

—Instructing someone to draw by giving only verbal directions without naming what is to be drawn.

—Identifying sounds: a bouncing ping-pong ball, air gushing out of a bicycle tire.

—Feeling a variety of textures while blindfolded—Jello, bread dough, corn meal, rice, salt and ice water; describing the sensations and attempting to identify the items.

The children and adults alike became absorbed in the projects. Of course, individual experiences differed: what was experienced, how it was perceived and what was learned depended upon the developmental level of each individual. Nevertheless, everyone agreed that a Celebration of the Senses was a beautiful way for the neighbors to join together.

Uhmm! Chocolate pudding tastes as good as it feels.

The External Environment

Charlotte, Our Spider

Observing, Creating, Sharing

A scream from the back of the room brought the teacher and other children running. Kai, 7-years-old and obviously terrified, stood pointing at the easel. The object of her concern was a small, green garden spider. As we watched, it dropped from the edge of the easel and hung suspended on an invisible dragline.

"Oh," whispered the teacher. "Do you think it's Charlotte who has come to visit us?"* Quietly the children observed the spider. Gathering in its line, it rose swiftly, then dropped almost to the floor once more. In a few moments, the spider touched the floor, scurried into a corner, and disappeared from view. One of the girls got on her hands and knees to investigate. Lo and behold! The spider had a beautifully constructed web under the cupboards. The youngsters watched the spider over the next few days and recorded its behavior.

Gently inducing it to climb aboard a pane of glass, the children viewed the spider's structure without injuring it. Of course the spider was returned to its web, over which a sign now proclaimed, "Charlotte Lives Here." The children agreed, "If you know one, spiders aren't so bad."

After being introduced to poetry about spiders and their webs, many children wrote their own poems and stories. The children learned about many kinds of spiders and how they make their homes; they drew pictures to show where different kinds of spiders live. The children shared their findings and discoveries with the kindergarten and first-grade children.

*E.B. White, *Charlotte's Web* (New York: Harper & Row, 1952).

Being Botanists

Observing, Predicting, Experimenting

A large jar filled with soil and some seedlings was sealed with plastic wrap; it permitted a group of 7- and 8-year-olds to observe changes over a period of weeks. "What do you think will happen?" queried the teacher. A 7-year-old predicted, "They'll all die." A slightly wiser but less certain 8-year-old stated, "They won't die, but they won't grow." Other children's predictions were recorded to be checked against future observations.

When moisture appeared inside the sealed jar, the children read extensively to discover why. Their readings led them to experiment with those factors essential to plant growth —water, soil, air, sunlight. The children grew control and experimental plants to test the effect of the various factors. Some experimental plants were even given "polluted" water. The children recorded their observations and displayed them on a graph. They compared their experimental and control plants. Through discussion, the children gained an awareness of the impact of pollution on plants and the importance of plants to man's survival.

Making Bread and Butter

Observing, Discovering

A group of 3-, 4- and 5-year-olds were studying foods that are important to good health. They tasted several raw foods and then observed the change in taste and texture when the same foods were cooked.

One day they watched as bits of butter "appeared before their very eyes" in empty baby-food jars partly filled with whipping cream. Around the room, pairs of children were saying, "Now you shake it five times. It's your turn now." And finally an excited, "I can see butter!" Others gathered around to see. And sure enough, tiny bits of butter were visible. The teacher suggested that shaking the jar more would make the tiny bits come together to make larger pieces. Soon all the children discovered pieces of butter in their jars. Encouraged by the teacher and the aides, some children tasted the buttermilk. The butter was refrigerated until the following day when the children made bread.

The children identified the ingredients for making bread, then briefly observed their colors and other properties. After they measured the ingredients and mixed them together, the children observed that none of the ingredients could now be identified.

Small groups were responsible for kneading the dough; they observed its size. Someone marked the dough's height with a spot on the outside of the bowl before putting it in a warm place. Sometime later, the children were amazed to discover what had happened: "The dough is almost at the top of the bowl. It's bigger." The dough was shaped into loaves and baked. After much anticipation, the children were able to touch, smell and taste the freshly baked bread. What feelings of self-achievement!

Light, Colors, and Rainbows

Discovering, Experimenting, Communicating

While working with water colors, Dean, a 9-year-old with an ever-curious mind, wondered where colors came from. The other children were curious too! The next day the teacher used a flashlight and a prism in the darkened room to flash the colors of the rainbow on the wall. Repeating this procedure, the children discovered that the colors of the rainbow were mixed together in the light from the flashlight. The prism separated the light into its many colors.

The children experimented with the prism, turning it in many directions to see what would happen to the rainbows. "Would the colors always be in the same order? Could

Hey—my turn to mix the flour!

they always make rainbows in every part of the room?"

The boys and girls searched the school library for books about light and color. As they used the references, the children found experiments that they could duplicate in the classroom. "Can you 'catch' a rainbow in your hand?" The children did! They placed a mirror at an angle against the inside of a deep pan of water, then set the pan in the bright sunlight. One child brought an inexpensive polaroid lens for doing more sophisticated experiments. Another child brought a black light. More and more experiments! More and more discoveries!

The culmination of the study was a light-show produced by the children and presented at a school assembly. To accompany the light-show, the children read poetry and prose that they had selected for the occasion.

Will This Seed Grow?

Classifying, Graphing, Investigating

"An avocado is a huge seed," announced Karen to her friend Lisa. Groups of 7- and 8-year-olds were sorting and classifying their seeds by size, color and shape. Some children made simple graphs to display their observations. For example, the children who classified seeds by size placed big seeds on one strip of paper and small ones on another; then the children counted the number of seeds in each column. The graphs were discussed and compared.

A discussion of seeds and their growth stimulated many questions. "How long will it take my seed to grow?" "Will this seed grow?" The children decided to try to answer some of their own questions. Each child planted seeds of one kind and kept a record of observations. Both the kind of seed and the type of record—a graph, picture or story—was the child's choice. When some of the seeds did not germinate, the children discussed the probable causes. One child explained to another, "You forgot to tell them you loved them!"

Exploring a Marsh

Observing, Creating

Two sisters, 5 and 7 years old, were exploring their new neighborhood with their aunt. They came upon a marsh and, to their delight, saw lots of little green hopping frogs. Watching for a long time, they observed one frog catch a bug on its long, sticky tongue and heard another call out *rivit, rivit*.

The three investigators talked about what frogs eat, how they move, where they like to live, and how they hatch from eggs into tadpoles and then grow into frogs. As the three explored the marsh, they captured a fast-moving frog, inspected it at close range and freed it. Upon returning home, the children's encyclopedia was used to learn more. The trio completed their science venture by writing the following poem.

Cribet

There once was a frog named Cribet.
All it would say is "rivit."
It saw a big fly. . .
Said, "Can't let it go by!"
Out came its sticky tongue
And the fly was no more among.
Cribet liked to jump, jump, jump.
It was moving so fast. . . kerplunk.
It was in the hands of a little child.
And afraid it would never again see the wild.
The child was curious but kind, you see.
And after watching Cribet, set it free.

Learning about Cooking

Observing, Measuring, Discovering

"Squishy, sticky, rough, smooth, yummy, white, slippery" were among the descriptive words used by 6- and 7-year-olds as they tasted, touched, looked at the ingredients they would use in making peanut butter cookies. This activity was one of a series in which the children observed changes caused by mixing, heating, freezing and melting ingredients.

"Make the sugar come to this line." "Now you have one cup." "How much peanut butter do we need?" "Which spoon is marked one-half?" "One-half looks like this." The children observed the effect of mixing the ingredients. "Now you can't see the sugar." "Or the flour!" "I can smell the peanut butter." With hands scrubbed clean, each child rolled a piece of dough into a small ball. "How does it feel?" "What do you smell?" Each ball was placed carefully on a greased pan and pressed flat with a fork. A toy clock was set to show when the cookies would be baked. Some children watched as the hands of the real clock moved slowly. At last, it was time to taste the cookies and discuss the effects of heating and cooling them.

On another occasion, the children made ice cream. Individuals measured the dry and liquid ingredients, then mixed them. Everyone learned how to use an ice cream freezer to change the liquid mixture into a solid one. After putting ice and salt in the freezer, individuals took turns turning the handle of the freezer. When the dasher was finally removed, everyone tasted the ice cream, sensed its coldness and described the change that had taken place. "Ice made the liquid freeze." "It's different now." "It's cold and solid."

Still another change—melting—was observed by the children when they made cheese sandwiches. Everyone saw that heat made the cheese "bubble" and melt on the bread. "Be careful!" "It's hot!" "Don't burn your tongue!" After eating the sandwiches, individuals discussed other examples of melting that they had observed. Everyone observed what happens when you hold an ice cube in your hands or in your mouth.

Learning about Snails

Gaining Information, Experimenting, Observing

"Who has seen one of these lately?" Holding up a tiny garden-variety snail and a magazine article on snails, the teacher stimulated and challenged a group of 10- and 11-year-olds to begin a study of snails. Searching the article many times, the children gathered suggestions for designing their own investigations.

The children brought snails to class from the school yard and their home gardens. Each owner identified his or her snail by marking its shell with colored nail polish. The snails were kept in aquaria, each containing a layer of fallen leaves about three centimeters in depth, potting soil, a few twigs and a shallow container filled with water to a depth of about four millimeters. The children placed a clamshell or a piece of bone in each aquarium to provide the calcium used by the snails as building material for their shells. Each snail's weight, coloring and distinctive markings were recorded.

The young investigators made discoveries about snail structure and movement. Using a sheet of clean glass or clear plastic, some children observed how the snail is pushed along by its foot on a mucous path that it leaves behind. When the sheet was held vertically, the snail moved upward; when the sheet was slowly rotated back and forth, the snail turned and continued moving upward. The magazine article explained the observations: snails can sense changes in their position relative to the direction of gravity. By listening carefully, the children could hear a snail eating hard materials such as crisp lettuce and carrots. They learned that the radula is a toothed, filelike muscle inside a snail's mouth, functioning much like teeth and a tongue. To feel a snail's radula, the children allowed snails to "eat" thin films of honey or jam from their finger tips. Other children tested the movement of snails away from a light source and over a distance measured in centimeters. The children also tested the snails' reaction to light. These investigations provided the children with opportunities for graphing and comparing data. Snail races were even organized!

The children became totally involved in the study; they lost their initial feelings of revulsion and became "fond" of their snails. The study led to an appreciation of and interest in other living things.

Balancing Towers

Constructing, Discovering, Creating

"How high can you make a tower from blocks?" The towers rose, collapsed amid the groans of the 4- and 5-year-olds and soared again, each time with sturdier bases. Some 7- and 8-year olds used drinking straws and straight pins to build their towers. "How wide can you make your tower?" "How did you balance it?" Within a short time, the children were able to apply the knowledge gained from both successes and failures.

See! I can make my tower taller.

Eventually, four children worked together to build a tower by pooling their experience.

The children were proud of their structures and shared them with their families. Snapshots were taken. Some individuals continued the activity for days. One child made a tower out of toothpicks fastened together with bits of orange peel. Another made a colorful mobile from spray-painted toothpicks.

From Natural Site to Learning Center
Observing, Experimenting, Comparing

"We can put frogs near the pond. They need to live near water and where there's plenty of insects for them to catch." A desert site adjacent to the school was being developed into a learning center by adults and a group of 10-, 11- and 12-year-olds. The community was involved in the project; many children, parents and other interested adults gave of their time over weekends to help in developing different aspects of the Master Plan. The site was to become a place where children of various ages could interact with the environment in a constructive manner and develop positive attitudes regarding the environment.

The children's activities varied. Some took soil samples to determine the water-holding capacity of soils at different places. These places were marked on a map of the site. Examining the soil for its contents, other children found that it contained parts of dead organisms, bits of leaves, and bits of rock. The temperature of the soil—in shady spots and open places—was recorded on various days.

Some children used soil samples to experiment with plant growth. "Will plants other than cactuses grow in the soil? What kinds of soils do wild-flower seeds and California poppy seeds need? Should fertilizers be added to the soils? What food chains can we discover? Which plants require shady places? Open places?"

As they developed the site, the children and adults asked questions, made predictions, and tested hypotheses; they consulted books and resource specialists. Data from experiments and observations were recorded in charts and displayed in graphs. When food chains were represented pictorially, the children learned about the plants and animals that inhabited various areas at the site. Through their direct involvement, the children understood one ecosystem: a pond and it's community of plants and animals.

Garage Science
Observing, Gaining Information

"Daddy, what are you doing?" asked a curious 6-year-old, watching her father working under the hood of the family's car. "I'm checking this battery on a voltmeter to see if it needs to be recharged. Let me show you." Joined by an 8-year-old sister, the father used simple language to explain.

The girls were introduced to several concepts: Electric current is caused by chemical action inside a battery; the combination of water and sulfuric acid starts the flow of electricity between positive and negative plates inside. The father drew a diagram showing the inside of the battery, pointed out its parts, and explained them. The father warned that sulfuric acid is very strong and could be dangerous. . . could even burn a hole in clothing!

The girls learned that a battery consists of one or more units called *cells* and that, by connecting several cells, the electric current can be made stronger. "Electricity is measured in volts. See the needle moving on the voltmeter? That indicates how strong the current is. . . how useful the battery is." Thus, the question, "Daddy, what are you doing?" resulted in a lesson on electricity in a family's garage.

Big Wheels, Little Wheels
Observing, Classifying, Graphing

"This wagon is hard to pull!" "See, the wheels won't turn much." Mike, Susan and John were using small wagons having "wheels" of different shapes. Some wheels were squares, others were triangles, while others were round. These 7- and 8-year-olds discovered that the roundness of the wheels on the small wagon made it easy to pull along the floor or up the ramp. The triangular and square "wheels" just went "bumpety, bump, bump."

Previously, the children had classified a collection of objects as *wheels* or *non-wheels*. Now they displayed the total number of objects in each category by making a graph. They discovered that round, flat objects, such as metal washers, wooden disks, and wheels from broken toys, would roll and usually fall over; but spherical objects, such as balls and beads, would continue to roll.

One day the children and their teacher stood on a busy corner near the school and watched wheels moving past them along the street—wheels on trucks, cars, a street cleaner, a bicycle and a motor scooter. They discovered that wheels turn on axles. At a gasoline service station, everyone gathered around a car mounted on a hoist and watched as the attendant spun a wheel around and around on the axle. Later they pointed out wheels moving around axles on bicycles, on roller skates, and on skate boards. The children discovered that many familiar objects are wheels; they were surprised to find out that doorknobs are wheels and axles.

"What if there were no wheels in the world?" The children's imaginations and speculations helped them become aware of the importance of wheels to everyone.

Hatching Baby Chicks
Verifying, Measuring, Interpreting

"Look there! It's a baby chick!" "I can see another one coming out of the shell! It can't stand up! See, it's all wet." These were among the exclamations made by a group of excited 4-, 5- and 6-year-olds as they observed six baby chicks, wet and weak, peck their way out of their shells. Each chick's egg tooth looked just like the one they had seen in their reference book.

"How many days did it take our chicks to hatch?" "Yes, it was 21 days." The children recalled that each day they had added another yellow, paper egg to the calendar. The children consulted an illustrated chart to find out how the embryo looked from the day the eggs were placed in the incubator to the day they hatched.

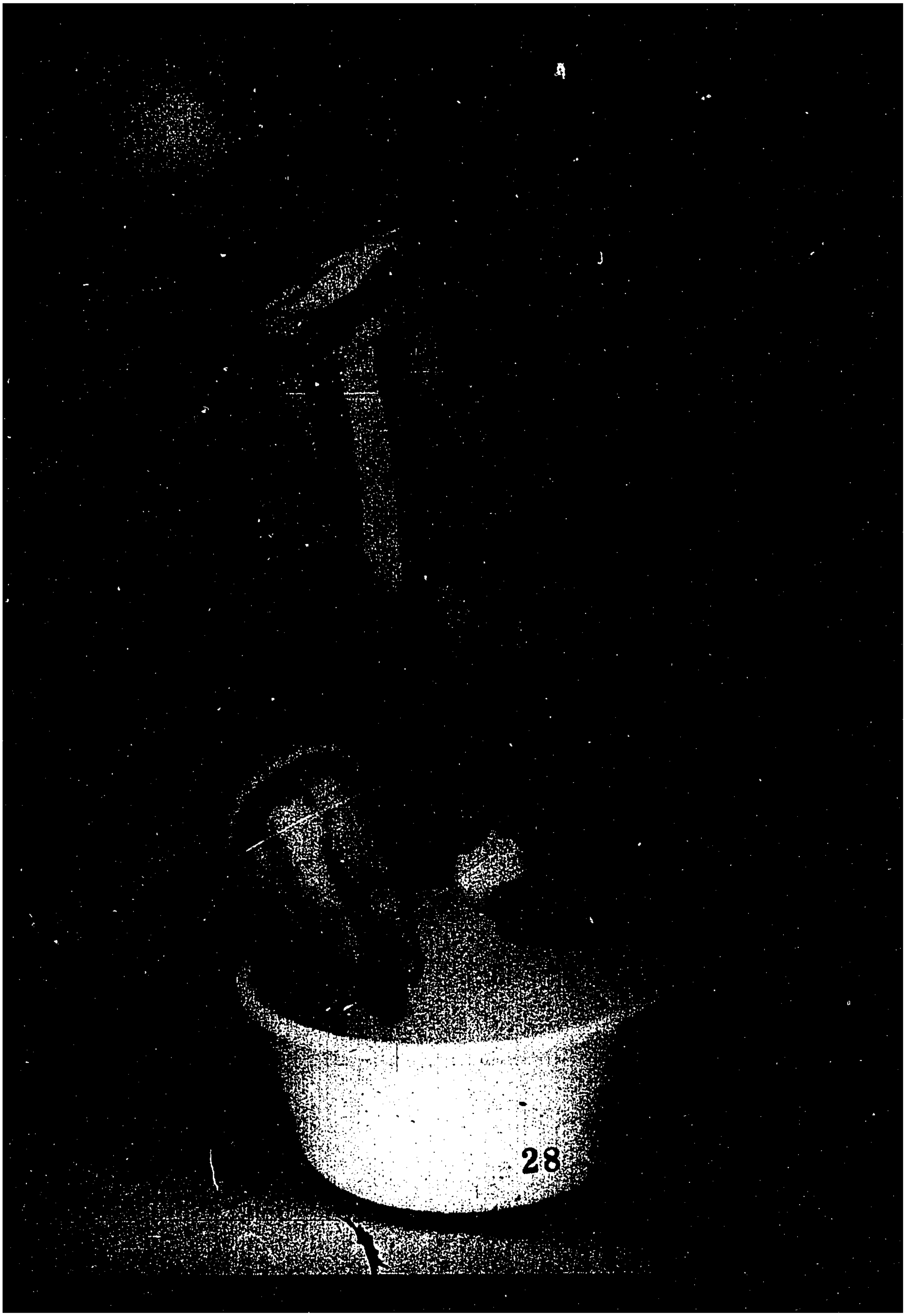
The chicks, each coded with a spot of food coloring, were weighed at two-day intervals by using a balance scale. The young investigators found out how many rods would balance each chick; they recorded their findings. A simple graph helped the children to observe the growth of each chick.

How Much Do Our Chicks Weigh (in rods)?

Chick	Day 1	Day 3	Day 5
"Red" chick	5	7	9
"Green" chick	5	8	10
"Blue" chick	6	7	9

Observations led to more questions, explanations and pictures. Through body movements the children pretended to be developing chicks, crouching as though inside the egg, using the egg tooth to peck out of the shell, emerging wet and weak, gaining strength and finally becoming a fluffy baby chick—walking, pecking and running.

Do you think this egg will become a chick?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Learning about Erosion

Model-making, Demonstrating, Communicating

Red flames of fire moved along the ridge. A plane zoomed down to drop a "water bomb" on the fire. The sirens of a fire engine could be heard coming along the highway. A group of 9- and 10-year-olds anxiously watched the brush fire move down the other side of the hill and away from their community. Excitement! Anxiety! Fear! Relief!

During the following days, everyone shared news items and pictures of the fire. The discussion ranged through many topics: safety precautions regarding the use of matches and campfires, the "no smoking" signs posted at many natural sites, and the dryness of the vegetation due to little rain. The children discussed some consequences of fires—the destruction of valuable watershed areas, mudslides, erosion of soil, destruction of animals and their homes.

Discussions, questions and predictions led everyone to study erosion and ecology. The boys and girls explored the devastated area and the adjacent area that escaped the effects of the fire. Afterwards, the children consulted many sources of information, including environmental agencies.

The students organized committees to investigate various problems. One group demonstrated what would happen to a denuded hill if a heavy rain fell. Some of the children built a hill of soil about one meter high in a large aluminum foil pan; others marked bands one-centimeter wide along the length of Popsicle sticks; still others used crayons to color the bands in this order: red, green, orange, blue, yellow, purple. With the red ends out, the children pushed the sticks into the hill at various places and at right angles to its surface. The sticks were inserted until the line between the orange and blue bands was at the surface of the hill. Then someone punched tiny holes in the bottom of a can, poured water into the can and made it "rain" on the hill.

The children used the colored bands to

Is that fire damage ahead?

demonstrate where erosion took place, where the soil washed away and where it built up. They observed canyons, landslides and streams forming. Then a few individuals showed what happens to rain when vegetation is growing on a hill.

The children developed some understanding of how fires can change an environment, and pose immediate and long-term dangers to a community. Some individuals made posters illustrating their findings and feelings. Since the camping season was not too far away, the children carried on a schoolwide campaign to alert everyone to fire-prevention methods.

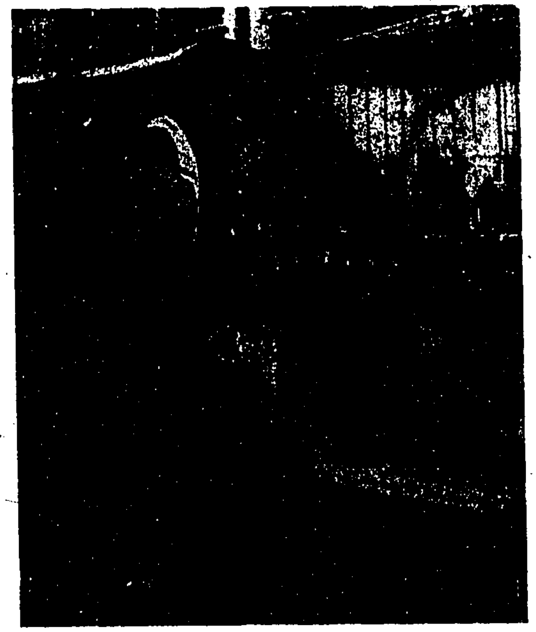
Visiting Farm Animals

Questioning, Observing, Communicating

"Does chocolate milk come from brown cows?" "Where does butter grow?" "How big are cows?" "Do pigs really stink?" Drawing on the children's questions and natural interest in farm animals and their products, the teacher had prepared the 3- and 4-year-olds for a visit to a nearby agricultural college. Since young children learn through direct experience, a field trip to a farm or agricultural college is a valuable opportunity. The children learn from what they touch, taste, smell and see.

"It stinks!" "Look at the baby pigs eating! Doesn't that hurt the mother pig?" "They are so wiggly." "The milk just squirts out." "Is this where eggs from the store come from?" The children drank milk from the cows, churned butter from the cream and ate eggs from the chickens.

Everyone had the opportunity to ask questions and correct misconceptions. "Is the piglet soft?" "Does it bite?" "How fast will it grow?" "When was it born?" "Did you see the piglets drinking from their mothers?" The children's observations led them to new questions that extended their knowledge of the world and its inhabitants.



But where are the eggs?

The Expanded Environment

Learning about Weather

Observing, Recording Data, Predicting, Mapping

Red, yellow, blue balloons filled with helium gas floated upward over the playground and the school. The boys and girls releasing the balloons observed them rise higher and higher over the houses and tree tops. The balloons all moved in much the same direction, then finally disappeared from view into the atmosphere. The group of 10- and 11-year-olds were studying air currents, part of a unit on weather. A stamped postcard dangled from the length of string attached to each balloon. One side of the card described the balloon's purpose and requested that the finder record the date and place when found; the other side gave the name and the school address of the sender.

After releasing the balloons, the children recorded their directions; they discussed their other observations, recorded them and predicted where the balloons might be found. The predictions were plotted on a map of the state. As each postcard was returned, the date and place were recorded on the map and the air currents plotted. The children discovered that the wind carried some of the balloons many miles from the school and in directions opposite from those predicted. Further reading and investigating led the children to hypothesize that some balloons were lifted into the troposphere and carried by air currents moving in different directions.

The children constructed barometers, wind vanes, rain gauges and humidity indicators. Using these instruments, everyone collected and recorded data about weather conditions in the community. After attempting some weather forecasting, they compared their predictions with those of professional forecasters, gaining an appreciation for their work. The boys and girls learned that weather is the result of the interaction of many environmental factors, such as air pressure, temperature and the amount of moisture in the air.

The Cause of Shadows

Observing, Measuring, Recording

"I could step on Kermit's head this morning but now it's not there," stated Susan, a puzzled 7-year-old. The children were playing a game that involved stepping on each other's shadows. The children volunteered their ideas in response to Susan's observations. Realizing that this could be a means to making the concept of time more meaningful, the teacher asked a small group to measure their shadows, hour by hour, and record the results. One child volunteered to measure the shadow cast by a yardstick; another used a meterstick.

Soon the boys and girls were investigating the sun's apparent positions throughout the day due to the earth's rotation. Some 8-year-olds who had studied the four time zones of the United States and Earth's movement in space were asked to serve as resource people. Using a globe of Earth and a flashlight, they demonstrated Earth's rotation in space—the cause of day and night. They helped the 7-year-olds simulate Earth's rotation.

With the help of a 12-year-old, some interested children continued to measure their shadows for one month and then charted their data. The children became aware of the way shadows are formed and learned that the sun's apparent position in the sky could help them tell the time of day.

Everyone had fun playing at different times of the day. Now the children could explain why their shadows were long sometimes and very short at others. The boys and girls also had fun making shadow pictures. A piece of white construction paper was taped to the wall and a light was focused on the paper. While some children made shadow shapes with their hands, others traced around the shapes. The children understood that their hands, too, could stop the light to make shadows.

Space Exploration

Investigating, Measuring, Creating

A group of 8-, 9- and 10-year-olds became fascinated with outer space. They were intrigued by rockets and space travel; they wondered whether life exists on other planets and whether we might be able to live on other planets. Everyone shared maps, globes, charts, rocket models, books and other materials related to the solar system. Individuals investigated such variables as gravity, temperature and atmosphere present on the known planets.

Applying what they had learned, the children designed a "space walk" on the playground. The distances of the planets from the sun were represented, using a reasonable scale. On the playground the

How many meters to Mercury?

children placed standards with flags labeled the "Sun," "Mercury," and so on for each of the other known planets. The children then walked through their solar system and acquired some feeling about the distances between the planets.

Later, each child chose a planet and used his or her knowledge of the planet's atmosphere, temperature and gravity to design a creature that could live on that planet. A variety of materials was used in highly creative ways. Each creature was displayed with an explanation stating how it could live on its planet.

Designing a City

Problem-Solving, Mapping, Model-making

"Having a fire station nearby is good." "A place near my house has lots of trash everywhere." "A freeway is good if you have a car and want to go somewhere fast, but is also bad because it produces noise and pollution." These were among the evaluations made by 10-, 11- and 12-year-olds as they constructed a model city reflecting the needs of their community ten years into the future. The year-long project integrated all curriculum areas.

The children explored and photographed their neighborhoods. Individuals surveyed the topography of the community—hills, canyons, a river. Some children used a variety of resources to compile information about these and other natural features.

The bulletin board displayed maps of their community drawn to scale, drawings representing structures in the new city, plans for individual parcels of land and graphs of population changes. Individuals conferred with architects and regional planners. The children's plan for the city began to take form. A large floor-model made to scale was carved from squares of styrofoam. Various materials were used to create factories, transportation systems, land-use patterns.

"Is there adequate housing for the population? What kinds of transportation will be used? How will waste materials be treated? Where will schools be located? Industries? Recreation areas?" After much discussion, the children interviewed their parents and other adults. An overwhelming number of those surveyed preferred single-family homes. The children, however, pointed out that cluster housing is a better use of land. Reviewing their data, the children discovered that the adults opposed any law requiring trees on residential property. Again the children disagreed. They included that provision in the community's ordinances.

Having developed their model and plan, the children and their teachers assessed the strengths and weakness of their design for the future. The project's high point occurred when the children presented their plan and model to the community's regional planning commission.

Space Stations and Algae

Investigating, Gaining Information, Communicating

"Algae as food?" This was the topic selected for study by a committee of 10- and 11-year-olds. They became interested after seeing a film that discussed the possibility that algae would be grown in space stations to supply food for people living in that enclosed ecological system.

Each committee member assumed a task. Some members searched for information in the school and public libraries. Others secured samples of algae from a nearby pond, from the aquaria of several friends, and from the pet store. Everyone observed different algae under the microscope, made drawings of their observations and noted likenesses and differences.

From their readings, the boys and girls learned many interesting facts: Today, as in the past, algae are a source of high-protein

Draw the river to the east of the hill.

food in people's diets; algae remove some carbon dioxide from the air and replace it with oxygen. Thus algae would be ideal for growing in a space station and a good source of food for people living on Earth. One committee member found a recipe for making cookies from algae.

Chlorella Cinnamon Pinwheels

4 tablespoons Chlorella powder
2 cups flour
½ teaspoon salt
3 teaspoons baking powder
4 tablespoons shortening
¾ cup milk
melted butter
sugar
cinnamon

Combine first six ingredients. Spread dough with melted butter; dust dough with sugar and cinnamon. Roll like a jelly roll, cut into half-inch slices, and bake at 350 degrees until brown.

After a meeting with the teacher, the committee agreed to make the cookies. "Where to get powdered algae?" One of the mothers found it in an organic food store in the community. The committee decided to distribute the cookies as a surprise when giving their report.

The report was presented and the cookies were distributed. "Did you make them?" "It doesn't taste too bad." "They look sort of funny." "I like it." The children agreed that the cookies weren't favorites, but realized that maybe, just maybe, they would have to learn to like foods made from algae.

Solar Energy

Gaining Information, Constructing, Communicating

A group of 8- and 9-year-olds began to think about ways they could save electrical energy at home and at school. Their ideas were recorded on chart paper. One child mentioned that a television program suggested that sunlight could be used to heat homes and to make electricity. How could this be done? Ideas were suggested. The term *solar energy* was used and inquiries made as to its meaning.

Searching for more information at home, school and public libraries, the children found a variety of books and current magazine articles (some simplified by parents) about the energy shortage and the uses of solar energy. Soon the classroom had a viewing area where a small group could look at filmstrips; a listening center where others could listen to tapes (made by the teacher) to accompany some pictures; a center for browsing, reading resource materials, and interpreting pictures.

After sharing information and ideas, each child "invented" a "solar machine" that would use the energy of the sun—maybe even heat homes. A variety of materials were used to construct their inventions. For each device, the "inventor" wrote a brief description of how it would work. The inventions were displayed and the information shared with children from another class. A highlight of the study was the "solar oven" made by a boy in a nearby junior high school. He demonstrated the oven so that the children could see how it worked. There was much excitement when everyone ate hot dogs cooked by solar energy!

Designing Kites

Constructing, Observing, Investigating

Colorful kites fluttered successfully in the air or trailed woefully on the ground. To culminate a study of Japan and to celebrate the Japanese holiday Boys' Day, the children had constructed the traditional fish-shaped kites from tissue paper. The 9-year-olds had tried a variety of fish-shapes and sizes. Everyone soon learned that certain shapes became airborn more easily. Those children whose kites would not fly called upon their more successful peers for the necessary modifications.

The young investigators discovered that certain forces act on a kite. To fly, the force pushing upward on a kite must be greater than the downward pull of gravity. They also learned that the forward thrust on a kite must be greater than the backward force, or drag, due to the kite's tail or shape. If the drag is greater than the thrust, the kite takes a nose dive. Many children changed the shapes of their kites to take advantage of the forces acting on the kites.

During a week of calm days that grounded all the kites, the children studied local wind conditions and visited a meteorologist at the weather station. When the wind conditions improved, the children again flew their kites which, having been redesigned, were easily lifted by the air currents.

What Causes Fading?

Predicting, Experimenting, Creating

A conversation between two 7-year-old girls about their blue-jean slacks, one pair more faded than the other, led to the prediction that sunlight causes fading.

For two weeks the girls conducted an experiment to test the prediction. First they obtained two pieces of printed fabric, identical in size. The girls stapled squares of black paper onto one piece of the fabric; each day they placed it in direct sunlight and removed one square. Every day they washed the other piece of fabric in soap and water, and hung it in the room to dry. The washed and unwashed pieces were compared daily. After two weeks, the girls had visual proof that sunlight could cause fading. The soap and water caused some fading but not as much as the sunlight.

The girls applied what they learned about sunlight to create lovely designs on colored construction paper. These papers were then used as covers for the children's written stories and illustrations of their experiment.

Making Salt Water Suitable for Drinking

Gaining Information, Experimenting, Interpreting

"Can we remove salt from sea water to make it good to drink?" Two 12-year-old boys wanted to investigate this problem in connection with a study of the ocean and its resources. The children searched for information at the school and public libraries. From magazine articles and newspaper items, the boys learned that ocean water might be needed for drinking purposes in the future; they found out about a desalination plant in a nearby community.

After designing an experiment to test their hypothesis, the children collected and set up their equipment: an intricate assemblage of flasks connected by rubber and glass tubing. The distillation system was successful after days of experimentation, failures and changes in design. The boys became totally involved; they even tasted the ocean water to test that it was free of salt.

The two investigators discussed their experiments with their classmates, shared their findings, and answered questions. "Would it be practical to use your system for removing salt from ocean water?" This was asked in different ways by the class. The answer seemed to be conclusive: distillation is an unsatisfactory way to supply water in great quantity. Other ways would need to be found! "You should help find these ways when you are older." The boys were rewarded by the encouragement of their classmates.

Studying Stars and Planets

Interpreting, Observing, Creating

"What does *sign of the zodiac* mean?" queried the 11-, 12- and 13-year-olds. For her birthday, Jennifer had received a pendant with the sign of Pisces on it. When everyone else found out their signs, the class began a study of astrology and astronomy.

The children learned about the beliefs of the early people who developed the ideas of the zodiac. As the children read their horoscopes and those of their friends, they began to question and analyze them. "How could the statements be true about everyone born between those dates?" The children had many ideas. Some decided to interview people about statements in their horoscopes "to see whether they fit." Others began to search in science books for information about the stars and planets. Information gained from the interviews and readings were shared. The children concluded that the horoscopes and stories about the effect of stars and planets on people's lives were unscientific. Some children thought that the stories were fun to read but unacceptable as science.

Further activities involved the children in making see-through star maps, using plastic sheets and colored dots for stars. The maps showed some of the constellations visible to the children in the night sky. At night with the aid of a flashlight and star maps, the children searched the sky for various stars and constellations. The children learned that the constellations seemed to move from hour to hour and week to week because of the earth's rotation. On one evening the principal, children, teacher and parents viewed some of the stars and the planet Venus through a telescope brought to the school grounds by a high school student. This experience encouraged more questions and further investigations.

The children applied their learnings to a variety of creative experiences. They wrote their own legends from the star patterns that they imagined they saw in the sky. Using astrological and astronomical designs, the children made pendants and other objects from clay, then fired them in the school kiln. They wrote plays complete with sound effects, that featured interplanetary and interstellar space travel.

What Animal is That?

Observing, Investigating, Comparing

"That shell moved! What is it?" "Will it bite me?" "Does it pinch?" "The colors are beautiful!" A group of 11- and 12-year-olds were full of comments and questions as they observed a land crab for the first time. Their curiosity soon led to a search for information. They compared the land crab with the water crab, identifying similarities and differences in appearance, structure, habitat and life cycle.

The children's research uncovered many interesting facts. If a land crab does not have a shell it will burrow; if it has a shell it will shed it and grow a larger one. Crabs are scavengers and will eat almost anything living or dead. In the Pacific Islands, some crabs can get through the shell of a coconut to eat the meat.

Exploring an Environment

Observing, Gaining Information

My Trip to Carlsbad Caverns

by Kendall, age 12

JUNE 22—My family and I flew from Los Angeles to Albuquerque, then over the Chihuahuan Desert to Carlsbad. We had lots of turbulence caused by hot air rising off the desert and meeting the cooler upper air.

JUNE 23—Today we drove to Carlsbad National Park. At the caverns we took the 3-mile trip in at the natural entrance and 850 feet to the bottom on a switch-back trail. We walked through lots of rooms and chambers and learned how they formed. They were made about 200 million years ago when all the area was a shallow sea. The water seeped into cracks in the Capitan Reef (most of it is still buried), dissolving the limestone. The water level dropped slowly and air took its place. Lime water dripped down forming *stalactites. Where there was no water on the floor, stalagmites built up. The formations took many beautiful shapes like drapery, cave pearls, soda straws and helictites.*

JUNE 24—We went back to the caverns today where the temperature is about 56 degrees all the time. We stayed until evening to see about 4500 bats spiral out at one time from the natural entrance. The bats are the Mexican Free-tail which migrate to the caverns each summer. The bat colony can eat a half ton of insects each night. The bat droppings, or guano, used to be mined for the citrus orchards of California. We learned that the natural entrance was known to the prehistoric Indians 4,000 years ago. The Indians left paintings on the cave walls.

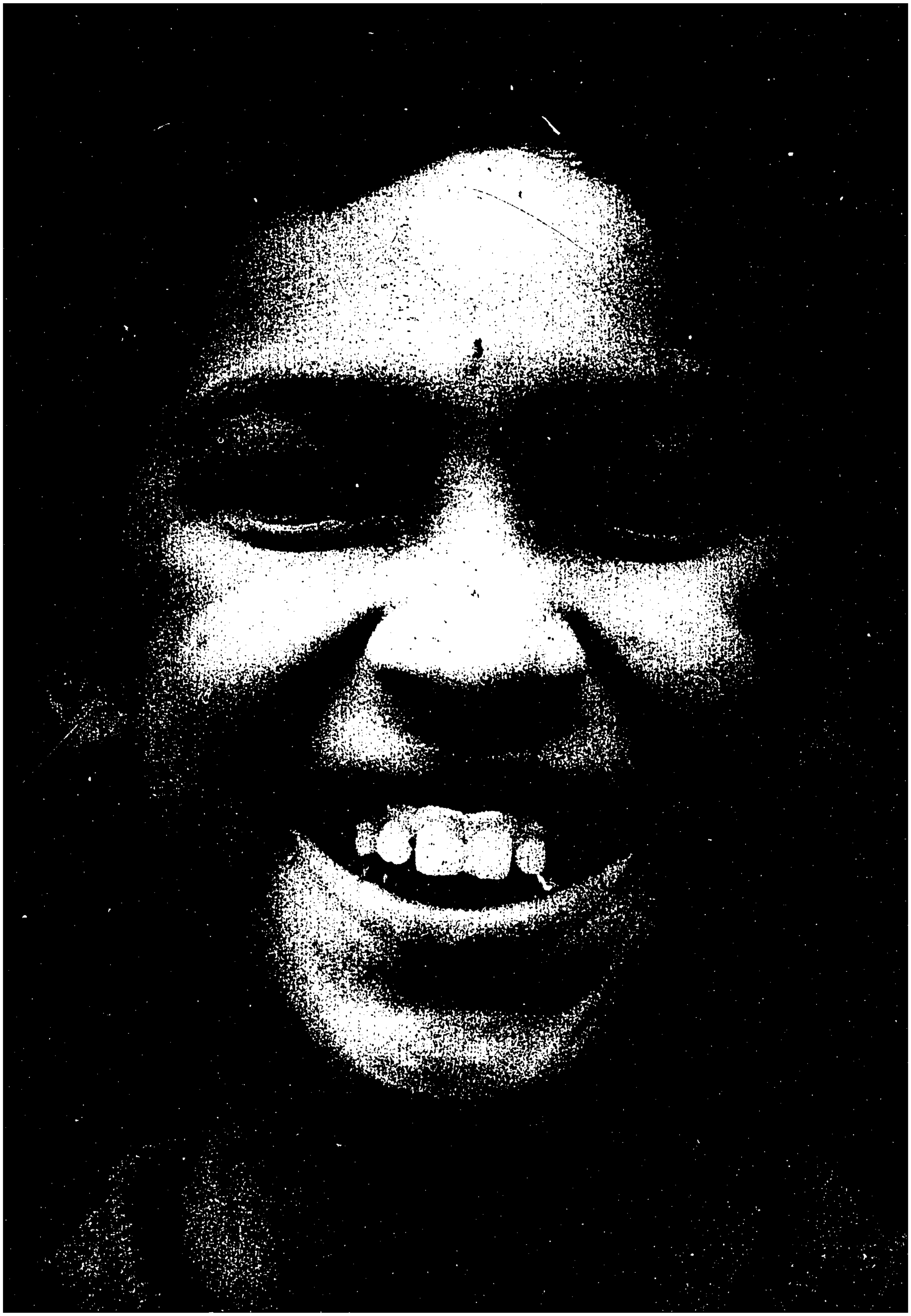
JUNE 25—We left Carlsbad today, flying over the Chihuahuan Desert again and got a good look at the Pecos River which runs through Carlsbad and northeast of the Guadaloupe Mountains, the exposed section of the reef where the caverns are located. The trip was fun and we want to go again.

SUGGESTED GUIDELINES
Exploring with Children

As you participate in science adventures with the children, ask yourself if you are—

- ☐ guiding the children's development of process skills, attitudes and concepts—from the life and physical sciences.
- ☐ providing opportunities for children to work independently and with others.
- ☐ allowing children to try ideas, pose questions and make mistakes without being ridiculed.
- ☐ extending activities when the spontaneous behavior of the children suggests this.
- ☐ making available many and varied materials, since children learn through direct experience with them.
- ☐ using human and natural resources in the community.
- ☐ fostering children's creative expressions—art, melodies and songs, constructions, poems and stories, body movement.
- ☐ looking for opportunities to individualize learning, integrate the curriculum, use team teaching, set up learning centers and use multi-age groupings.

What observations can you make?



Evaluating Children's Growth

Part 3

Me

As long as I live
I shall always be
Myself—and no other,
Just me.

Like a tree.

Like a willow or elder,
An aspen, a thorn,
Or a cypress forlorn.

Like a flower,
For its hour
A primrose, a pink,
Or a violet—
Sunned by the sun
And with dewdrops wet.

Always just me.

A sense of self lies deep within a child. To develop this awareness, children require an environment in which they can become self-directing and self-disciplined, time to discover their own identity, encouragement from others, and evaluation regarding growth and behavioral change. Evaluation is a particularly strong motivating force for self-development. In school, it is a continuous, cooperative process by the teacher, the peer group and the child. Essential to this assessment is a recognition of the child's uniqueness.

Evaluation is an integral part of the teaching-learning process because it reveals readiness for instruction and progress toward objectives. The teacher needs to find out what children have learned and how they have learned this. The assessment is based on the teacher's objectives for the children and information about the children's achievement of these objectives.

To assess a child's achievement, the teacher may use many sources of information: diaries, reports, anecdotal records, children's records of their work, written tests, examples of creative expressions. These sources are evidences of an individual's learnings.

What sources of information can be used to evaluate students' achievement resulting from science experiences? Many examples are presented here to answer this question. The examples are keyed by page number to many of the episodes featured in Part 2. The information used for evaluation reflects the children's process skills, understanding and application of scientific concepts, and ability to work alone and with others. A set of guidelines for evaluating each of these areas is also provided with Part 3. Of course, other areas of evaluation might include an assessment of children's communication skills—listening, speaking, reading and writing—and ability to express attitudes regarding their interaction with the environment.

Process Skills

Developing Sensory Awareness (p. 12)

The "My Touch and Feel Books" were valuable tools for assessing the children's ability to identify specific objects by touching them. When asked to identify a soft, fluffy object, a child had to select the appropriate item from a collection of items and glue it onto one page of the book. This procedure continued for the remaining objects.

Learning about Weather (p. 25)

After the ascent of the balloons, the children recorded their observations: the directions that the balloons floated in the atmosphere. Each child predicted where his or her balloon would be found. Then all predictions were plotted on a map. As the postcards were returned, the new data were plotted on the map and compared with the predictions. New hypotheses were made and investigated. Since the children could not adequately test their hypotheses, they used books and other sources to find some plausible explanations. The extent to which the children applied this knowledge was a way to assess their achievement.

The Cause of Shadows (p. 26)

As they measured their shadows, the children collected and recorded data that contributed to their development of a more meaningful concept of time. Two individuals were resourceful and used a yardstick and a meterstick as measuring tools. The accuracy of the children's records aided their interpretation of the data. Later, when the children played shadow tag, they could apply what they had learned about the cause of shadows.

Making Salt Water Suitable for Drinking (p. 31)

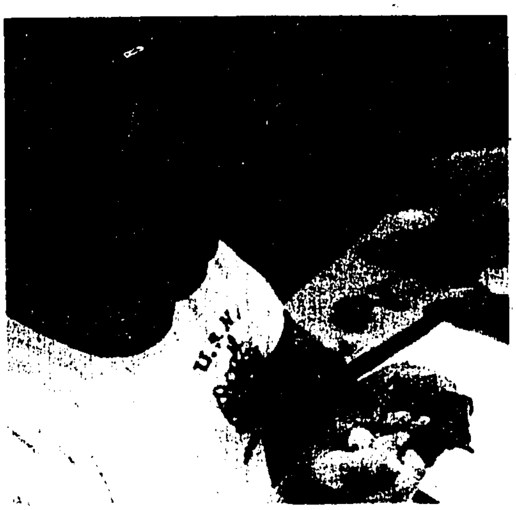
The children selected a problem of social concern involving science and technology.

In addition to their application of newly acquired concepts, their use of well developed process skills was apparent throughout the investigation. The boys collected information, selected a hypothesis and tested it by designing an experiment. They assembled appropriate apparatus, but had to change the way it was assembled and to modify their precedures. The boys repeated the experiment several times to find out whether the results were the same each time.

SUGGESTED GUIDELINES
Evaluating Process Skills

As you assess a child's skills in using scientific processes, observe whether the child is—

- ☐ proposing and designing investigations and controlled experiments.
- ☐ modifying and substituting procedures to check for consistent results.
- ☐ making predictions and later selecting data to check them.
- ☐ handling materials effectively.
- ☐ suggesting and using substitute materials for unavailable ones.
- ☐ making and recording observations carefully.
- ☐ interpreting data.



I'll test the hardness of the rock by scratching it.

Concept Formation

What's Inside Me? (p. 10)

The children showed an understanding of learned concepts when they selected yarn to represent veins and arteries, and then glued it to the paper "bodies." When they later placed cutouts—lungs, heart and stomach—on the "bodies," the children were applying acquired knowledge.

Relating the Self to an Object (p. 11)

The child applied the concept of scale to a new situation: choosing an object and then making a model of it so large that he or she could fit inside it. In addition, the child demonstrated process skills, such as modifying procedures and making new sets of measurements.

Exploring a Marsh (p. 18)

The concepts that the sisters acquired as they explored the marsh are reflected in their creative expression—the poem, "Cribet." What they learned through their senses at the marsh and during their search for information upon their return was communicated in the poem. Cooperation and mutual respect were, of course, other outcomes.

Hatching Baby Chicks (p. 22)

Through body movements, each child interpreted the sequential development of a baby chick. In doing this, the children applied biological concepts to an imaginative event.

Space Exploration (p. 26)

The children used their imaginations to create their creatures; they used their knowledge of the planets to explain why the creatures could live on given planets. These explanations provided a way to assess writing skills.

Solar Energy (p. 30)

The "solar machine" devised by each child was evidence of the "inventor's" application of learned ideas. The written descriptions of the machines particularly illustrated the child's ability to communicate new concepts.

Exploring an Environment (p. 32)

Kendall's diary reveals that he applied scientific concepts to explain and interpret what he observed during his trip. In addition, the diary provided a way to assess Kendall's writing skills.

SUGGESTED GUIDELINES
Evaluating Concept Formation

As you assess a child's understanding and application of an acquired concept, observe whether the child—

- ☐ draws a picture or diagram to illustrate the concept and/or its application.
- ☐ creates an object that illustrates the concept and/or its application.
- ☐ applies concepts during creative activities such as body movement, creative writing, arts and crafts.
- ☐ applies concepts to imaginative events.
- ☐ applies concepts to new situations.

Those are oysters? My mother makes oyster stew.

Interaction

Making Bread and Butter (p. 16)

Many opportunities arose for the children to become aware of the importance of working together. Self-evaluation with guidance from the teacher occurred as problem situations arose.

From Natural Site to Learning Center (p. 21)

Children and adults discussed the best solutions to problems encountered as the site developed. Adults respected children's ideas; children listened to adults. Working together, a small group of children and an adult drew diagrams and sketches to communicate ideas; they gained respect for each other. When a problem arose during the adults' weekend work session, the children would look for information and draw sketches to help find possible solutions during the school week. These were presented in conference with the adults during the following weekend session. Other outcomes included, of course, the development of environmental concepts.

Designing a City (p. 28)

The children developed skill in working together and were involved in a variety of self-evaluation procedures. With some guidance from the teacher, they developed a checklist to indicate whether behaviors, such as solving problems through discussion, respecting others' ideas and cooperating, were shown "sometimes," "often," or "many times." The checklist and "anecdotal records" of their own behaviors often became the basis for conferences with the teacher at the child's request. The children often initiated group discussions that assessed study skills and interpersonal behavior. In addition, the children demonstrated the use of inquiry skills and the ability to apply acquired concepts to model-making.

Designing Kites (p. 30)

The children learned from each other: those whose kites would not fly utilized the suggestions of those who did. Some children sought help from classmates; others redesigned their kites after being challenged by their peers. Cooperation and mutual respect were outcomes that the children identified when they evaluated their experiences during a group discussion.

SUGGESTED GUIDELINES
Evaluating Interaction

As you assess a child's ability to work independently and with others, observe whether the child—

- ☐ works independently to carry out procedures for solving a problem.
- ☐ works well with others on a group project.
- ☐ suggests ways to work with others.
- ☐ is willing to settle problems through discussion.
- ☐ respects the ideas of others in a group.

What happens if I stir the bubbles?

Selected References

Althouse, Rosemary, & Cecil Main. *Science Experiments for Young Children.* New York: Teachers College Press, Columbia University, 1975. A set of paperbacks, each introducing children to a different area of exploration: growing, seeds, pets, air, water, food, color, magnets, wheels. Suggested concepts, materials, procedures and possible behavioral outcomes are listed for each activity. Some activities are appropriate for preschool children.

Blough, Glenn O., & Marjorie H. Campbell. *Making & Using Classroom Science Materials in the Elementary School.* New York: Holt, Rinehart & Winston, 1954. Detailed descriptions explain how to construct and use a variety of teaching materials, such as simple weather instruments and simple machines.

Blough, Glenn O., & Julius Schwartz. *Elementary School Science and How To Teach It,* 5th ed. New York: Holt, Rinehart & Winston, 1974. Highlights the objectives, concepts and principles essential to the teaching of science. Describes methods for guiding inquiry, especially those that involve learners in the discovery process. Content areas include the earth and the universe, living things, and matter and energy. The authors suggest ways to introduce children to the nature and use of the metric system.

Carin, Arthur, & Robert Sund. *Teaching Science Through Discovery,* 3rd ed. Columbus, Ohio: Charles E. Merrill, 1975. Applies Piaget's theories to science teaching and describes the impact of federally funded science programs. Defines goals and objectives of science education, giving a rationale for learning through discovery. Describes activities in the physical, biological and earth sciences, each activity focusing on processes of inquiry such as observing, inferring and classifying.

Craig, Gerald S. *Science for the Elementary School Teacher,* 5th ed. Waltham, MA: Ginn-Blaisdell, 1966. A source of scientific information and activity ideas. Science teaching is discussed with regard to child development and the child's relationship to science. Science content includes the earth and the universe, the life of the earth, and the energy of the universe. A section on evaluating behavior is especially useful to teachers.

Hill, Katherine. *Exploring the Natural World With Young Children.* New York: Harcourt Brace Jovanovich, 1976. Description of opportunities that adults can provide for children to foster their firsthand exploration of the world around them. Includes suggestions for developing children's process skills, such as observing and classifying, and for evaluating learning. A particularly excellent source of ideas for preschool children.

Piltz, Albert, & Robert Sund. *Creative Teaching of Science in the Elementary School.* Boston: Allyn & Bacon, 1968. Concise, lucid anecdotal descriptions of science activities that foster children's creative abilities and promote problem-solving both in and out of school. Piaget's stages of cognitive development and their implications for science teaching are discussed. Techniques to guide teachers in selecting curriculum materials are suggested.

Polland, Barbara. *The Sensible Book, A Celebration of Your Five Senses.* Milbrae, Calif.: Celestial Arts, 1974. Questions, statements, and photographs skillfully guide children and adults in sensory explorations. The suggested experiences serve to increase the communication between adult and child as they relate their experiences, clarify their thoughts and challenge each other's ideas. Beautiful photographs capture children's activities as they see, touch, smell, listen and taste.

Rowe, Mary Budd. *Teaching Science as Continuous Inquiry.* New York: McGraw-Hill, 1973. Provides a conceptual framework for thinking about biological and physical phenomena. Introduces techniques for fostering inquiry, such as pacing of rewards, organizing teams and questioning students. Emphasizes evaluation through diagnosis and decision-making skills.

Schmidt, Victor E., & Verne Rockcastle. *Teaching Science With Everyday Things.* New York: McGraw-Hill, 1968. Emphasizes investigation through direct experience with familiar objects. Each of the chapters includes a point of view, objectives for making science teaching effective and pleasant, and suggested activities in many science areas. Provides sample questions that might be asked of children to encourage the development of their process skills.

Selberg, Edith; Louise Neal; & Matthew F. Vessel. *Discovering Science in the Elementary School.* Reading, Mass.: Addison Wesley, 1970. Discusses ways to help children learn scientific

concepts and develop process skills. Reviews the contribution of research to the selection of appropriate concepts. A detailed chart indicates scientific content and process skills appropriate to children aged 5-8 and 9-12. The authors suggest a variety of activities, pointing out process skills that might be developed and evaluative techniques that might be used. The role of the teacher is described as guide and facilitator of learning.

Sund, Robert. *Piaget for Educators*. Columbus, Ohio: Charles E. Merrill, 1976. Detailed discussion of Piaget's theories of cognitive development and their implications for science teaching. Many examples give meaning to each developmental stage described.

Selected ACEI Publications

Bibliography of Books for Children. Annotated list; titles arranged by age level and subject; major awards noted. Invaluable reference to science literature, science fiction. 1974. 112 pp. $2.75. ISBN 0-87173-008-1.

Bits & Pieces—Imaginative Uses for Children's Learning. Recycling of finds, left-overs, giveaways and throwaways for creative learning in class and at home. Includes ideas for science curricula. 1967. 72 pp. $2.00. ISBN 0-87173-014-6.

Children and Drugs. Offers guidelines to teachers for working with drug-using children and their parents. Suggestions for drug education that could be incorporated in science curricula. Award winner. 1972. 64 pp. $2.00 ISBN 0-87173-015-4.

Children's Views of Themselves. By Ira J. Gordon. Lively and sympathetic look at children through new eyes and deepened perception of their feelings and ego-building needs; how adults can develop sensitivity. 1972. 40 pp. $2.00. ISBN 0-87173-019-7.

Cooking and Eating with Children—A Way to Learn. Stresses the need to provide children with healthful foods and the importance of eating in a pleasant climate. Recipe section; guide on child input. Suggestions for learning about science, including nutrition. 1974. 48 pp. $2.50. ISBN 0-87173-006-5.

Creating with Materials for Work and Play. Portfolio of twelve leaflets. Learning through the use of varied media and materials. Practical ideas for art, dance, science, drama and more. 1969. $2.00. ISBN 0-87173-053-7.

Good and Inexpensive Books for Children. Selections chosen for quality and price. Classified by fiction, biography, hobbies, science, etc. Includes author and title indexes; list of publishers. 1972. 64 pp. $2.00. ISBN 0-87173-022-7.

Guide to Children's Magazines, Newspapers, Reference Books. Annotated list designed to acquaint parents and teachers with excellent literature. Quality scientific periodicals and references included. 1974. 12 pp. 50¢ each, 10 copies $4.00. ISBN 0-87173-007-3.

Involvement Bulletin Boards. The place of bulletin boards in learning experiences; ideas for science curricula. Brightly illustrated. 1970. 64 pp. $2.25. ISBN 0-87173-024-3.

Learning Centers—Children on Their Own. Combines theory and practice. Describes models of individualized teaching. Discusses roles, organization, evaluation, helpful hardware and open space. 1970. 84 pp. $2.50. ISBN 0-87173-026-X.

Play: Children's Business. Defends importance of learning through play; play for the convalescent child. Includes toy/play materials guide, suggested films. 1974. 56 pp. $2.95. ISBN 0-87173-005-7.

Selecting Educational Equipment and Materials for School and Home. Aid to selection, procurement and use of quality materials to meet growing/learning needs of children. Thoroughly treats science items. Manufacturer/distributor list. 1976. 108 pp. $3.50. ISBN 0-87173-010-3.

Teaching About Spaceship Earth—A Role-Playing Experience for the Middle Grades. Practical ideas for teaching science and a valuable tool for peace education. November issue of *Intercom* by Center for War/Peace Studies. 1972. 68 pp. $1.50.

Teaching for Social Values in Social Studies. Looks at value clarification and information as essential elements of social studies, environmental instruction. Many thought-provoking exercises. 1974. 72 pp. $2.75. ISBN 0-87173-009-X.

Testing and Evaluation: New Views. Confronts questions of why traditional evaluation procedures are inadequate, what tests do and don't do. Outlines a new frame of reference for meaningful evaluation. 1975. 64 pp. $2.50. ISBN 0-87173-000-6.

Transitional Years—Middle School Portfolio. Specific ideas for working with inbetweeners (ages 10-14). Classroom organization, curricula, evaluation covered in fourteen leaflets. Leaflet VIII entitled "Science: Middle School Years." 1968. $1.25. ISBN 0-87173-061-8.

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