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teaching elementary science

Suggestions for classroom teachers

GLENN O. BLOUGH
Specialist in Elementary Science

PAUL E. BLACKWOOD
Assistant Specialist in Elementary Science

FEDERAL SECURITY AGENCY - - - OSCAR R. EWING, *Administrator*
Office of Education - - - - - - JOHN W. STUDEBAKER, *Commissioner*

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FOREWORD

Teaching science in the elementary school is being more and more widely accepted as a responsibility by those who are planning the education of children. When questions and interests of children are taken into account in planning their school activities, then science inevitably becomes a part of the program. It helps children find answers to questions about their environment. But science, properly taught, can do much more. It can build scientific attitudes, sharpen the ability of children to think critically, and help them develop skills in problem solving.

Many teachers see these values. But no matter how enthusiastic elementary teachers are about teaching science, they wish for direct and practical help in order to do their best at this relatively new elementary school emphasis.

Teaching elementary science is intended to give the elementary classroom teacher such help by showing the place of science in the lives of children and in the elementary school program, by describing what the subject is and how children learn it. And, most important, the bulletin suggests practical methods of teaching science.

The publication should be useful in a number of ways. Individual teachers may wish to read it for its numerous suggestions about teaching science. Groups of teachers planning for the improvement of their science programs may find it valuable as a basis for discussion. Elementary science curriculum committees will find in it a point of view which they may wish to consider. Elementary principals will find that it offers many suggestions by which they can help and encourage their teachers to teach science.

The present age of science has introduced new problems and complexities into the lives of everyone, and the schools have many obligations to help children live happily and intelligently. One of these obligations is to teach elementary science, and it is hoped that this bulletin will further the program of good science teaching in the elementary school.

BESS GOODYKOONTZ
Director, Division of Elementary Education.

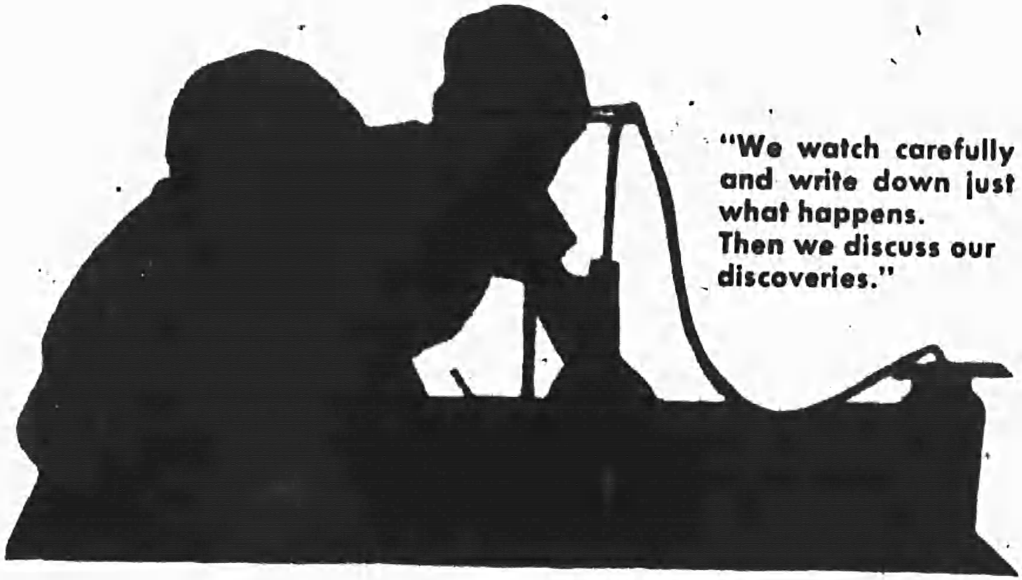
"It's wonderful what you can see when you use a microscope."

Courtesy, University School, Ohio State University

Introduction

THIS is intended to be a how-to-do guide for the elementary classroom teacher whose principal has recently said, "We really must teach more science. You know our children are living in a scientific age." It's for teachers who want to learn some down-to-earth things about how to begin to teach science if they don't know much subject matter, haven't had much experience with doing experiments, and are perhaps a little awed by the prospects of science teaching. Just reading this bulletin won't make anybody a better science teacher. It is hoped that trying out some of the ideas and adapting them to fit specific needs, will. Just reading it won't give anyone enthusiasm for teaching science either, but using some of the suggestions in working with children may help to keep children's natural enthusiasm alive, and may expand it somewhat.

Many teachers have caught enthusiasm for teaching science from enthusiastic children. Good science teaching results when teachers are convinced of the importance of this area of learning, know how children learn, become familiar enough with the subject matter so that they can combine their knowledge of child growth and development with this knowledge to the end that an enjoyable, forthright learning situation results. Many classroom teachers are now doing this; many more should. No suggested outline of subject matter is included since selection and organization of content material differs with various schools and is best done by the individuals with first-hand knowledge of the needs, aptitudes, abilities, and interests of the pupil groups and of the local resources available.



"We watch carefully and write down just what happens. Then we discuss our discoveries."

elementary science

What is it?

SCIENCE in the grade school. What is it? First of all it's *not* a lot of things it was once thought to be. It's not a series of object lessons about a piece of granite, an old wasp's nest, an acorn, or a tulip. It's not hit and miss like that. It's not learning the names of the parts of a grasshopper or of a trillium. It's not learning to identify 20 trees, 20 insects, 20 flowers, or 20 anything else.

What is it, then? It's a study of the problems that are found wherever children live. More formally stated, it is a study of the natural environment. It's not pieces of chemistry and physics and biology and astronomy and geology. Its content comes from these areas, but it's a study of problems that pop into curious children's minds as they live and grow from one day to the next, like: What makes the wind blow? What's in a cloud? What's a stone made of? What does a bell do when it rings? How can a seed grow into a tree? What makes a rainbow? Anyone who has ever visited with grade-school girls and boys knows that most of them are chock-full of questions like this and generally they like to know the answers to them. Well, finding the answers—that's science.

And it doesn't have to be technical. The full explanation is not what the 10-year-old needs. He couldn't understand that. It's a foundation in the simple terms of the how, the when, the where, and the what of the things that happen around him every day. That's his science. He doesn't need the technical terms, the formulas, and the detailed explanations. Those will come later, but when he is 10 he needs to get satisfaction out of his tendency to be curious. He needs to have his curiosity broadened, his interests nurtured, and his enthusiasms encouraged. That's the kind of science which fits him and with which he is equipped to deal.

Where is it?

Science in the grade school—where is it? Everywhere that elementary school children are. In the air they breathe, water they drink, food they eat: "What's oxygen?" "How do minerals get into water?" "What's a vitamin?"

Science is in the things they see on their way to school: "How does electricity make a street car move?" "Why does my dog stick out his tongue when he pants in hot weather?" "What makes the sky blue?"

Science is in their homes: "What makes our doorbell work?" "What makes lemons taste sour?" "How does our furnace heat our house?"

Science is in the schoolhouse: "How can the fire extinguisher put out a fire?" "What made the rust in the drinking fountain?" "Why did we all have to be vaccinated?" Science, then, is all around the girls and boys we teach. It's the study of their environment. They can't help but see it. They'll see more of it with a little help. They'll get more excited about it with a little encouragement. They'll learn more about it with a teacher who sees the possibility of its use, and uses her teaching skill to help children learn about their environment.

What can it do?

Science is all about us. So what? First of all you don't want children to grow up unaware of the things that are going on in front of their open eyes. It is generally true that a well-informed person is an interesting one and some information regarding the environment is one of the pieces of equipment that go to make up an informed individual. That doesn't mean that you expect to pump your pupils full of facts that they can call up at the drop of a hat to fit a blank space in a conversation. What, then? It means that you want *to help them to come to learn generalizations or meanings which they can use in interpreting problems in their environment.*

To illustrate: The members of the lily family have three sepals, three petals usually colored alike, six stamens, one pistil, etc. Benny Palmer, aged 10, can live a full and well-rounded life without committing this to his little memory. But suppose he learns through an examination of many plants and many animals that "Plants and animals are put into groups according to certain characteristics, and that knowing these characteristics helps you know the large group to which the living thing belongs." This generalization can then be helpful in identifying animals and plants he sees, thus making it possible to study their habits, to determine their helpfulness or harmfulness,

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Courtesy, Public Schools Kraggrille, Ind.

"Every day we watch our science things to see what is happening."

and so on. He has become aware of this generalization through careful study and through observation and it was the result of pressing together many small ideas into one large one. One aim in science, then, is to teach generalizations that can be used by pupils in interpreting the problems they come across in their daily living. *The more nearly we can come to studying the problems that really make a difference in the lives of girls and boys the closer we are to having a science program without which we can't keep school.*

You don't want your girls and boys to grow up to be sloppy thinkers. The method by which science generalizations were originally discovered is the kind of thinking we hope girls and boys can grow in ability to do. We may call it a *scientific way of getting the right answer.* Now, there's nothing brand new about this idea. Probably, you've been doing it for years in arithmetic and other subjects: defining the problem, suggesting several hypotheses, gathering evidence, drawing conclusions, checking conclusions. That doesn't mean that every time a problem comes up you get out these steps and make pupils climb them.

Actually, this scientific way to solve problems can work out in your way of helping pupils attack a problem even though it's not labeled with these formal steps. For example: Children want to know what makes a compass needle point north and south. You make sure that they say the problem as carefully as it needs to be said, so that it asks exactly what children want to know. Then pupils tell what they think makes the needle behave that way. Some explanations seem to make sense; some don't. "How can we find out whose idea is right?" you ask. And pupils say, "Read our science books." "Ask Mr. Jackson, the physics teacher." "Do an experiment."

Then, the pupils carry out their suggestions, discover an explanation, check it as carefully as they can by known authority, and they have solved the problem and can now make use of their knowledge. Simple, of course, and it's only the beginning of their introduction to a way of solving problems that, if properly used, is more than likely to produce reliable results. Pupils can make great strides in ability to solve problems in this manner—if they have intelligent guidance. Contact with this way of problem solving cannot come too early in a child's school experience. It takes a long time to become an accurate solver-of-problems. Daily newspapers are full of incidents indicating that many adults do not solve problems with any degree of accuracy.

You want girls and boys to *develop certain scientific ways of thinking as they work.* For example: Things don't just happen; they happen because of natural causes, so don't be superstitious. Be open-minded toward opinions of others. Hold your conclusions tentative until you are sure. Look to reliable sources for evidence. Be willing to change your mind if you discover that you were wrong. Don't jump to conclusions. Be curious about things and don't be satisfied with a vague explanation. These are a few of the safeguards of scientific thinking that a carefully directed study of science can help pupils attain. Again, the earlier the contact with this kind of thinking, the better. (See illustration of method on p. 24.)

Then, too, you want *to broaden the interests of the girls and boys.* They seem to be naturally curious about many of the things about them, but there's half a world of things they know nothing about so they can't be curious about the things in it. A study of the stars may open up a new field of interest in the sixth grade and for a certain few it may turn out to be a lasting interest. A study of how plants grow may stir up an interest in plant culture that would otherwise have remained buried. Studies of children's interests seem to show that children are interested in all aspects of their environment, not just in animal and plant life as was once supposed. Some pupils, however, appear to have more or less narrow interests and need help in seeing other possibilities. Pages could be written to illustrate. Many life-long interests that have turned out to be basic, were born early in a child's school experience. Many scientists say that their interest in science began when they were still very young. These interests were encouraged and developed. With better science teaching in the elementary school more such results might come about.

You also want to have your pupils grow *in appreciation of the things around them* and here's a touchy subject we have still much to learn about—how young children, or anyone else for that matter, come to appreciate things. Little sermons about the beauties of nature won't do it for most children. The teacher's sentimental gushes about the beautiful butterflies, bees, and flowers won't either. While we are all learning new ways of helping pupils to grow in their appreciation, let's try to teach them to *see*, to look closely, to examine carefully, and to discover by themselves what wonders there are in the world about them. In the common green leaf a manufacturing process goes on that man himself has not duplicated. He has learned that the raw materials used in the process are water and carbon dioxide, that the green coloring matter in the leaf is indispensable to the process, and that it cannot happen without the help of light. He can analyze the resulting process to the last molecule, but he, himself, cannot duplicate the process nor is he able to understand it completely. Furthermore, without this process life itself could not exist. As a child learns these truths, is helped to realize their significance, his appreciation grows. Perhaps through such understanding and through working with an enthusiastic, intelligent, appreciative teacher these appreciations may gradually become a part of the pupil. At any rate, appreciation is an aim to be kept in mind by every science teacher. Successful ways of accomplishing this aim still remain undiscovered by many teachers.

These, then, are a few of the things that the study of science can do for the children in our schools. That is, they can if the teachers of science are *fully aware* that these are the purposes, and are fully intent on seeing that science is taught in such a way that these aims are accomplished. Aims that remain planted in publications like this, in the opening page of a course of study or in a teacher's manual without being used, do not help children. But, on the other hand, aims that are in the teacher's mind and in the minds of children as well, will help them. Such aims color the selection of content, the method of teaching it, the activities selected, the method of evaluation and everything else that is done in the classroom. Here, then, is a point for all science teachers to remember—*decide what it is you hope to accomplish by teaching science, keep it in mind, keep checking to see that you are staying on the track, and keep evaluating to find out how closely you are coming to your goal.* And, above all, let these purposes be those of the pupils as nearly as possible and let pupils help with the plans for accomplishing these objectives.

Elementary science and nature study

There has been and still is, in many places, controversy over whether a program in science in the elementary school should be called elementary science or whether the term nature study should still be used. Some schools have so-called nature-study programs that are excellent. They are actually teaching science in the broadest sense and have the most modern objectives in mind. For some reason or other, they have continued to use nature study as a name for their program. In other places, the program is called elementary science, but the philosophy under which it operates is antiquated and holds to the original narrower view of nature study. From this it appears that the name is not so important as is the content and method of the procedure actually used in the program. The science programs that use the best from the nature-study idea and build to it the best that we have learned in recent years about broader science experiences with children are those that are most outstanding today. While the difference does not lie entirely in the name, programs in elementary science are likely to be broader in scope and conform more nearly to modern needs than those called nature study.

To illustrate this point: The nature-study idea stresses the study of an object such as a rock or tree rather than a broad problem concerning rock formation or forestry. It is likely to lay stress on identification of rocks and trees rather than using this as a means to an end. It is not likely to be concerned with the study of the problems of real concern in the lives of children or the whole field of science, but deals rather with the study of plants and animals. Experience with children, as is indicated elsewhere in this bulletin, shows that they are interested in all phases of their environment. From this brief sketch of nature-study ideas it appears that the original idea of nature study has been supplanted by a program more suited to the needs of today's boys and girls. The world in which these boys and girls live today has changed greatly during the past several years; so, too, must their program of studies.

From the nature-study idea, however, we realize the importance of first-hand experience with observing life around us, not just reading and hearing *about* it. A nature trail that points out kinds of plants and animals, homes of animals, spots that show interrelationships among living things, relationships between living things and their environments, and special adaptations of these living things is useful learning equipment. A nature trail, then, although it has its origin in the nature study idea has, if properly used, much to contribute to an up-to-date science program. Schools that are near a wood lot, near a park, or in the country are especially fortunate if they avail themselves of the opportunity to establish such a nature trail, or in some other organized way make use of this resource. Again it is objectives and the point of view that are essential to consider if such experiences are to fit in with a modern elementary science program.

Camping experience is another source of first-hand information and appreciation which a modern elementary science program might well include. The experience of building a campfire, preparing sleeping quarters, getting pure drinking water, procuring and preparing food, and many other necessary activities are packed full of science. Again, how much science and what kind of science is learned depends on the point of view of the individual in charge.

In deciding whether or not your point of view is in line with pupils' needs, measure it in relation to the objectives discussed earlier in this section. These, along with the purposes for the total elementary program, are the guides that point the way. Don't think that you have a modern science program if you spend half of science time covering walnuts with tinfoil and hanging them on a Christmas tree, pressing leaves, coloring robin pictures, or cutting paper snowflakes. Such activities do not achieve the objectives of a science program that fits the needs of children.

Science and the elementary school program

An elementary science program that tries to exist without consideration of its relationship to the general elementary school program is bound to be ineffective. To accomplish the aims you have just read is not enough and anyway they are closely linked to the broader aims of the elementary school. A science program's right to exist as an area of subject matter must be challenged on the basis of its contributions in accomplishing the general objectives of elementary education.

The general purposes of the elementary school have been variously stated. Perhaps the most important is to help children gain the ideals, understandings, and skills essential to becoming good citizens. This involves giving them the basic skills of reading, writing, and arithmetic, as fundamental tools for gaining information. In addition, it means giving them an opportunity to identify and understand social procedures and problems. It means giving them opportunities to participate both in suggesting solutions and carrying out their suggestions. It means developing social sensitivity of children to the needs of individuals and groups. The elementary school should help children recognize and practice a number of human relationship skills—cooperation, selection of leaders, group planning. Also the elementary school should provide conditions conducive to physical and mental health and give the children information and skills for developing these traits. It should help children develop wholesome interests for their leisure time. These are general aims of a good elementary school program and no science program can be effective without keeping them in mind.

The objectives for teaching elementary science must be geared into these broader concepts of the elementary school's purpose. How we teach science, what content the children need, what activities are most useful to them, how we help children plan and evaluate, all must be shaped in accordance with these objectives.

For example, how shall we teach science so that it will help children to be better citizens? If the teacher herself selects all of the content, organizes it, decides how it is to be learned, and makes all other decisions, how are children to grow in ability to organize, to plan, and work together? If we agree that being able to plan and work together is one of the attributes of a good citizen, certainly we must make plenty of provisions for children to plan and work together. In this connection there is a distinct difference between exercising leadership as a teacher and dictating from behind the desk. The teacher, as a leader, may make initial steps to create interest, open possible avenues of procedure, and then be a helper. Because of her experience she is, or is supposed to be, able to exercise some guidance but orchids to the teacher who has learned to be silent at the proper time. Children learn to be responsible citizens through *being* just that in science projects as in other school activities. The subject-matter area exists in large part for the purpose of developing this potentiality. So in teaching science, let's give many real opportunities for children to plan together, make decisions, make mistakes, decide how to rectify them, recognize their successes, set up new procedures, and evaluate the results.

Another example: How shall we teach science so that it will contribute toward growth in learning to use tools for gaining information? Certainly not by *telling* the children the answers to every question they may ask, or by telling them always to *read* the answer. How do we gain information on science? By experimenting, by observing, by asking people who know, by reading, by looking at motion pictures, and in other ways. Again, how do pupils learn when to use these ways and when to depend on their results? They learn through practice in deciding, then through trying out their proposed plans, then evaluating the effectiveness of their efforts. Gradually, through practice, pupils grow in their ability to use the tools available for gaining knowledge—but this is true only if we help them. Every area of subject matter has here a definite contribution to make if we give it a chance.

Space permits only brief discussion of the relationship of science to the elementary school program, but it should be obvious from these examples that this area of experience, along with the other areas, exists only for the purpose of realizing to the fullest possible degree the objectives of elementary school.

"We watch our baby chicks eat and grow. We feed them every day."

the science teacher

IF WE wait until all elementary teachers feel comfortably equipped to handle science we shall never get started. The most successful teachers of science in the elementary school have said to themselves, "I believe in the importance of including some science in my work. I don't believe my program is complete without it. I don't know much science, but I know how children learn. I don't mind being asked questions that I can't answer because I know how to help children find answers." And they have started on that basis.

These teachers have many problems. They need to build background in science, to learn how to teach it, to find the necessary apparatus and other materials. But they have two essential pieces of equipment: They realize the importance of including science and they know how children learn. The following suggestions have been found useful by many such teachers:

1. Approach the teaching of science with confidence not with the awe usually reserved for the first sight of a two-trunked elephant. It's not as unusual as you think. It's not so much different from teaching social studies, language arts, or arithmetic, in which most teachers feel at ease. It's not harder to teach; in fact, in some ways it is easier because it deals with concrete things and reaches the real interests of many children.

2. Don't expect to know the answers to all of the science questions children ask you. If you plan to wait until you do, you'll never begin teaching science. Teachers *tell* children too much anyway. If you know children, and know how to help them learn, half of your teaching battle is won. Don't be afraid to *learn with* children. Let them set up plans for finding the answers to their problems and then you act as a guide and learn with them. Of

course you need to know *some* subject matter, but you don't need to be a science specialist. The next few advice items will help you build up some science background.

3. After a unit or area of science study has been decided on, read some of the basic science textbooks that are on the learning level of the pupils you teach. Read these lower-grade books and then get some good general science or biology textbooks (the kind used in junior high schools or tenth grade) and read them. Here you will find most of the science subject-matter background essential for teaching young children.

4. Do some of the experiments and other activities that are suggested in these books so you'll have the *feel* of the material. These simple science experiments are not half as complex as you may think they are.

5. Do some of the "things to do" that the books suggest—trips to take, observations to make, experiments to do, collections to make. Seeing is both believing and inspiring and it is much easier to get your pupils interested in and excited about the town's filtration plant if you have yourself seen how wonderful it is.

6. Talk with a junior high-school or a high-school science teacher near your school and enlist his help. Secondary science teachers often can give you teaching ideas, suggest experiments, and help provide materials and books. Science is their special field and they are usually full of helpful ideas.

Remember that it's the unfamiliar that's likely to make you timid, so give yourself as much first-hand experience as you can with the science material. Following the four preceding suggestions is almost sure to make you confident enough to tackle a new science unit.

7. Don't feel too handicapped because you lack materials. Children can bring from home almost everything you actually need. What they can't produce, you can get at the dime or hardware store, borrow from the high-school science department, find in the schoolyard, get from the school janitor, or let the children make. Expensive complicated apparatus is worse than useless in the elementary science class. It is likely to be confusing and to draw attention to itself rather than to the problem at hand.

8. Let pupils experiment. It's one way children learn and they like it. Use some of the more apt pupils in your class to help gather materials and set up the experiments. (See pp. 13–16 for help in doing experiments.)

9. Start your science by teaching a unit with which you feel most at home. This may be contrary to the belief of some persons that pupils should initiate all problems for study. Probably the importance of that is open to question anyway. If some of your college science training, a personal hobby, or an intense interest of yours has given you background in some special field, using that knowledge or interest to determine your choice of unit may be

your springboard into science teaching. Later it will be easier for you to follow children's leads. They can always enter into the planning even if the original idea came from you as the teacher.

10. Make all use possible of the teachers' manuals that accompany your textbook in science. Teachers' manuals are usually packed with teaching ideas that have been tested and found good. They are often helpful even if you are not following the text which they have been prepared to accompany.

11. Keep track of your science material, your notes on teaching, your plans, etc., so you can use them at a future time and so that other teachers may borrow them. The second time over a unit is easier, especially if you have access to the material you used before.

12. Talk to other grade teachers about what things they have found successful, and be ready to share your experience with them. Such an exchange is often a great help.

how children learn science

CHILDREN learn science in a variety of ways just as they learn anything else. They learn it more readily when they are interested in it, when they can see that it makes some difference to them, when it's graphic, involves some manipulation on their part, is not too hard but hard enough to make them think, and when it gives them some satisfaction in having found out something they wanted to know. A big order? Sure. But it's not peculiar to science. It's true for arithmetic, language arts, or any other area of learning. The activities selected by and for children, then, should take these things into account. Keeping them in mind, let us then examine some of the ways in which children learn science.

Experimenting

Experimenting is one of the important ways to learn science principles and generalizations. When performing experiments with children it is important to remember that: Experiments should be kept simple; the commonest material is often sufficient and almost always desirable; pupils are capable of originating their own experiments and can often bring the necessary material from home and are, under the circumstances, usually most enthusiastic about performing them.

Certain guideposts for experimenting are essential to consider if pupils are to realize in the fullest measure the potentialities to be derived from this way of learning. Here are some of them.

1. Experiments should be conducted so that they will cause pupils to think. An experiment in which the teacher *tells* the pupils everything obviously gives no food to nurture growing minds.

2. By all means, children should be conscious of the purpose for performing an experiment. It is often desirable to write the purpose on the board in a simple direct form. This comes about easily when the experiment is done to solve a problem which the pupils themselves have raised. Certainly

the problems should be children's problems insofar as possible and should not be done by using a textbook in the manner in which a cook uses a recipe book. For example: The children arrive in school on a slippery winter morning. The janitor has scattered salt on the school steps to clear the ice. The children want to know what happens to the ice and why that happens. They decide to set up an experiment to discover the reason. Chances are they will not be easily satisfied with superficial performance. They get the point of why they are experimenting and are therefore more likely to press the performance to an ultimately satisfying conclusion. Other experiments may arise from the textbook, but the plan of action should as far as possible be worked out by the pupils using the book as reference.

3. Careful planning is essential to successful experimenting. Appropriate materials must be assembled (by the children, if possible), a plan of procedure must be set up, the plan must then be accurately followed to insure that the results can be depended upon. Less "jumping the gun" and more "hey, wait a minute, let's take another look at this," should be the motto in grade-school science experiments.

4. Insofar as possible, children themselves should perform the experiments. They may work as individuals or as groups depending on the type of experiments and the amount of material available. Experiments involving use of fire or other possible dangers, or experiments of a complicated nature, if used at all, should be performed by the teacher.

5. Many times, children themselves can originate experiments to answer their questions. These are often the most satisfactory from every point of view. Contrary to the belief of some teachers, experiments need not always be complicated, nor need they have been previously described in a science book—sometimes they are; sometimes they're not.

6. Experiments should be performed carefully, and exactly according to the directions, either those from books or those originated by the class.

7. Pupils should learn the value of using a control when they perform an experiment so that their results will be more dependable. For example: Suppose children are attempting to discover whether or not leaves of plants give off water. They set up the usual experiment of covering a plant with a glass jar and shutting off the soil from contact with the air in the jar. The next morning droplets of water are found on the inside surface of the jar. The children immediately decide that they have discovered the answer to the problem. But how can they be sure that the water did not come out of the air in the jar? They can't. But suppose they assemble another set of apparatus exactly like the first—a plant pot, a glass jar, soil, etc., but without a plant. The jars are placed side by side and observed. This time if water appears on the inside surface of the jar with the plant in it and does not appear on the other jar's surface, the water must have come from the

plant leaves. Such a procedure of controlled experimentation is essential if experiments are to assume their full meaning as activities for children. In this connection it is essential that the experiment be tried more than once before conclusions are drawn. (See also item 9.)

8. Simple apparatus is more appropriate for use in experiments in the elementary school than complicated material. Intricate pieces of apparatus borrowed from high-school laboratories, as has been previously pointed out, often detract from the real point of the experiment.

9. Pupils should exercise great caution in drawing conclusions from an experiment. They cannot prove anything from having performed an experiment once. They must hold their finding tentative until more evidence—either from additional experiments performed themselves or from authentic books—has been found. Results should be accurately and completely stated and in some cases recorded in a carefully written paragraph. Pupils should most certainly not generalize on insufficient experimental evidence.

10. As many applications to everyday life situations and problems as possible should be made from an experiment. This is a difficult step, but it is one of the most important reasons for studying science in the first place. When an experiment has been performed, only the first step in its usefulness

Courtesy, Seattle, Wash., Public Schools

"It's the acid in the lemon acting on the metal that generates the electricity. Watch the compass needle and you'll see."

has been taken. For example, after pupils have experimented with rusting iron they may want to see how things may be kept from rusting. An experiment is set up involving a wet, unpainted nail and a similar nail covered with a layer of paint. The experimenters note that the unpainted nail rusts and that the other one does not. Now in a real life situation how is this principle applied? In school? At home? On the way to school and elsewhere? The experiment was done to make the idea real. The applications must be made to see how important this idea is and how useful. Problems arising from real life situations that result in experimenting to find the answer are probably the most successful of all classroom activities.

Helping children to learn through doing their own experiments is, then, not a difficult job. Pupils should realize that they are experimenting not to discover information for the first time as is the case with real scientists, but for the purpose of *understanding* scientific ideas more clearly.

Reading

Reading ranks high in the list of ways in which children learn science. Unfortunately some courses in science deteriorate into reading periods to the exclusion of all other activities. That is bad. Reading is one of the ways to learn science and as such deserves thoughtful planning if it is to be an effective tool. Accurate material on the reading level of the various class members must be available and there must be guidance to help pupils read it. The following considerations in using reading material are important:

1. The science class is a logical spot for children to learn to differentiate between fact and fancy in their reading. That is, they should come to know that some books are written for pure enjoyment; others are sources for gaining knowledge. They should learn to challenge the authenticity of the materials they read. They should learn that the date of copyright and the authorship are important in judging the authenticity of material. They should learn to exercise care in drawing such conclusions about material, i. e., that checking one fact in a reference with an authentic source does not necessarily indicate that the book is accurate. Finding an error on a printed page may be an enlightening experience for a pupil, for through this he may learn the valuable lesson that just because something appears in print does not necessarily mean that it is accurate.

2. Reading should be done with a definite purpose in mind, i. e., to check a pupil's own conclusion, to find information, to find out how to perform an experiment, to answer a question or to solve a problem, or for some other definite purpose.

3. A variety of sources of reading material on a given topic is generally desirable because through several sources, more information is obtained and varying points of view may become apparent.

4. It is often necessary and desirable for science pupils to do individual reading as a type of simple "research." Under such circumstances careful note taking is essential so that an accurate report may be given to the class. This is an important aspect of reading in science.

5. Selection of appropriate reading material is prerequisite to success in reading activity. This is largely the responsibility of the teacher, but the help of the children is also desirable. Material which is too difficult, or which is too easy, or which is inappropriate because it does not answer the children's questions is discouraging when offered to children. Slow-learning pupils or pupils with reading difficulties need special attention in selection of their reading materials.

Reading is a learning tool of which all science teachers should be aware. Developing skill in reading and learning in science can go hand in hand. But reading is only one of the ways to learn science. To overemphasize its use is to ignore some of the essential purposes for teaching science.

To learn science, to enjoy it, and to make it functional in the lives of girls and boys it must leave the pages of a book and get into their daily experience in a graphic way. The textbook will serve as an excellent guide. Problems will be raised by the pupils and teacher together. Ways to solve the problem will be decided on by the group. Then, reading may be, and almost always is, one of the ways which is extremely useful. Pupils cannot experiment nor observe nor find out through an interview everything they need to know. The textbook will supply much of the needed information but that doesn't mean that "we will open our book to page 18 and read to 24 and then talk about what we have read."

Observing

Observing is another essential activity in all science teaching and pupils should grow in their ability to observe more accurately and thoroughly. Through the use of their senses children can come to experience many things. Feeling the texture of material or the heat from an electric wire attached to a dry cell, seeing cloud formations, seeing the changes in lengths of shadows, listening to birds, and many other similar activities are an important part of their science work. They make the learning more vivid. The following list of verbs give a key to the many opportunities for observing: Touch, lift, smell, weigh, taste, measure, watch, find, and others.

Children observe to determine the characteristics of things, to see the changes in growing things, to learn the habits of animals, and to see the results of experiments, *but* they must learn to do so with ever-growing accuracy and to report their observations carefully enough to be reliable.

This ability to observe accurately and to report the observations correctly is a part of all of the activities in science. Experimenting is a total loss without it; field trips and visual aids cannot be effective without it. Much is to be learned from our daily surroundings if we can train ourselves to be more careful in our observations. Pupils who have experience with this method of learning early in their school experience have a running start on those who do not.

Taking field trips

Making excursions to solve problems and to give information and appreciation, are important activities in elementary science. (For further discussion of use of community resources see pp. 27–30.) Trips to the park, the zoo, the telephone exchange, the sawmill, the airport, the water purification plant, and to other similar places within reach of the school are commonly made by teachers and pupils. These can result in a headache for the teacher, a field day for the children, and bad public relations for the school because of the "monkeyshines" of poorly directed children unless the trip is well planned and motivated.

Children should make excursions with definite purposes in mind. They should go to answer questions that are best settled by first-hand observation of the kind trips furnish. By all means, pupils should be aware of the purpose for the trip and the person who is to act as guide should know in advance what the children want to see and learn, and the teacher should make a before-hand trip to see the place for herself and to talk with the guide. She should then be alert to assist the guide in keeping the group together, making sure that there is plenty of opportunity to see and to ask questions.

Excursions should be made an integral part of a study under consideration and not just something to do. Field trips can be of inestimable value to a science program, or they can be, and sometimes are, useless boondoggling. It is probably safe to say that more time should be spent getting ready for an excursion, and in gathering deductions from it, than on the actual excursion itself.

Using visual aids

Another way in which pupils learn science is to see it pictured either in motion or otherwise. Much has been said about the desirability of using visual aids in connection with grade school science teaching. Without the use of some of the aids now available, a science course is incomplete, but much depends on how the aids are used. Let it be said that motion pictures and slide films are but one of the many useful helps. There are others equally important.

If motion pictures or slide films are used, here are a few essentials to be considered:

1. The selection of a film is important just as is the selection of a book. Films designed for use at higher levels are generally useless for elementary

pupils. A film which is too difficult is likely to be confusing to young pupils. Films should be selected which deal directly with the problem under consideration and that are prepared specifically for the levels in which they are being used.

2. Films should be previewed by the teacher and a committee of pupils to determine fitness for showing and to make proper preparation for use. Previewing a film helps to determine the purpose for which the film may be wisely used and when it is to be shown—at the beginning, middle or end of a unit of study—or at more than one of these places as the case may be.

3. The class should be prepared before seeing the film. Pupils should know what to look for in the film and know why they are seeing it.

4. It is often desirable to have a class see a good film more than once—especially if it presents basic concepts to be remembered.

5. The follow-up discussion of a film is essential. During such discussion, questions are asked, ideas clarified, and further explanations are made.

6. Effort should be made to help pupils realize that the films are not shown as entertainment but for the purpose of learning.

As has been pointed out, motion pictures and slide films are but one of the types of visual aids useful in elementary school science. The use of pictures from magazines and other similar sources is often overlooked. In many schools, teachers, pupils, and parents have, in cooperation, assembled an excellent teaching collection of pictures. Pictures that show how animals grow, how they are adapted for their environment, where they live, and what they eat, are examples of such picture collections. Pictures that show how we use electricity, machines, lenses, various kinds of power, are other examples. The important thing to remember is that these collections should be made to show certain important ideas and not be just a collection of pretty pictures. A file of such pictures may be kept so that they are readily accessible.

Models are often useful in making ideas clear and they should be used chiefly for that purpose. There are many instances of model making in elementary science classes which are almost entirely a waste of time. For example, making a wax model of the parts of a flower at the elementary school level is hardly to be considered legitimate since a detailed knowledge of flower structure is not essential to any learnings at this level. On the other hand, rather difficult concepts about the solar system can be more easily understood by use of a model of the solar system. It will give an idea of the relative sizes and of distances between its members, and help pupils to gain better conceptions of other ideas of size and space concepts with which elementary pupils can begin to deal. The purpose for model making should, then, be carefully considered just as the construction of any other instructional aid. Building model weather instruments, making balancing toys, making an electric questioner are other construction activities that contribute toward understandings of concern to elementary pupils.

There are, then, as we have seen, several types of activities through which pupils learn science. The selection of an activity depends on what is to be accomplished. Let it be activity for promoting understanding, interest, and appreciation and not just activity for the purpose of having something going on. An activity should make a science principle or idea more graphic, more interesting. Certainly, it must give pupils a chance to be active in the sense of participating with their minds as well as their hands.

illustrating a method of teaching

NOW let's get down to cases. We have discussed purposes of science teaching, given general suggestions to the teacher, explored some of the ways by which children learn science. Let's see how some of these ideas fit into a classroom situation.

Every schoolroom situation is different from every other. We are all aware of that. Teachers' interests, backgrounds, abilities vary just as do those of the pupils. Localities differ in what they can contribute and in the problems they present. It is therefore difficult to be specific. It must be remembered that the presentation here is but one of the many ways of teaching. It is included merely for the ideas that can be adapted for use by individual teachers.

For the purpose of illustration, let us select a unit of about third- or fourth-grade level built around the concepts involved in evaporation and condensation of water as it affects daily living.

Some of the preparation will be made by the teacher before she begins working with the pupils; some will be done later by the teacher and pupils as they plan together.

A first step

What's to be done first? Let's look again at the general purposes for teaching science already established on pages 3–6. It is within this general framework of purpose that we shall work. These purposes must be kept in mind. So also must the general aims of elementary education. They guide us. The more specific aims for the particular area of subject matter may be stated as follows:

1. To provide experiences as a means of forming science principles and generalizations about condensation and evaporation of water.

2. To help pupils apply these principles and generalizations to interpret things that happen around them.

3. To give practice in the use of scientific attitudes and skills in problem solving.

4. To broaden their interests in the everyday phenomena of their environment.

5. To give opportunity for growth in social adjustment.

How shall we select the subject-matter content useful in attaining these objectives? Remembering that it is science principles we are interested in rather than the accumulation of isolated, unimportant facts, let us think through what this subject matter might include. This selection serves as a general guide for the teacher to see the possible scope of the unit. The list may be made by the teacher as she reads to gain the necessary subject-matter background or she may find a basic list in teachers' guides to textbooks. In the case of evaporation and condensation the following examples of the subject-matter concepts might be used as an outline:

When water evaporates it changes to water vapor.
Water evaporates into the air from many places.
When water vapor changes back into water, we say it condenses.
Water usually condenses on cold things.
Water vapor may condense to make dew.
Dew evaporates.
Frost may come out of air that is freezing cold.
Frost melts and evaporates when warmed.
Rain comes from clouds.
Some clouds are made of many, many tiny drops of water; some are made of tiny pieces of ice.
Some of the rain evaporates; some of it goes into the ground.
There are many different kinds of clouds.
Snow is made when the air is freezing cold.
Snowflakes are made of snow crystals.
Snow melts and evaporates when warmed.
Wind helps water evaporate.

Exploring the possibilities in advance

Before plunging into the unit with pupils it may be wise for the inexperienced teacher to discover the available facilities in the following ways: By reading books, courses of study, and similar sources; through exploring the school facilities for materials for use in experimenting, visual aids, and other aids to learning; through investigating possibilities for field trips; and by other possible means. A review of the suggestions for the beginning teacher (see pp. 10–12) will be helpful here.

Up to this point the teacher has been building her own background. This preparation does not mean that she plans the whole scope and sequence of the unit by herself. She is getting ready so that she can act as a more intelligent guide as she begins to work with pupils.

Beginning to teach

Having become sufficiently familiar with the possibilities the teacher is now ready to begin working and planning with the pupils. *An open-minded teacher is a prerequisite to successful planning with children.* Unless the teacher *actually wants* suggestions to come from the pupils and is prepared to work with pupils in evaluating their suggestions and then proceeding with them, she is acting under false pretenses when she asks for them. Pupils, when they are convinced of the sincerity of the teacher, are full of suggestions—good ones, too. But they seldom become convinced when the teacher asks for their ideas and then ignores them and substitutes her own. It is surprising how much we, as teachers, are actually guilty of such misrepresentation as this!

Since, for purposes of illustration, a unit for consideration has already been selected, the teacher needs to think of ideas for launching it—for making it interesting, real, concrete, vital, and enjoyable. Where can we begin? Well, the water level in the schoolroom aquarium keeps getting lower and every week or so the water needs to be replenished. Pupils have been curious about this. Water colors in the paint boxes dry up where they are being used and more water must be added. Why? Wet play clothes are hung near heat to help them dry. It rains, the sun comes out, the grass gets dry, and pupils can then go out to play. These are everyday happenings involving evaporation and condensation.

Suppose we use the aquarium as a starting point. Pupils notice that the water keeps disappearing. The question arises: "Where do you suppose the water goes?" Pupils offer their ideas: "The aquarium leaks" or "The water goes into the air," or "The fish drink it." "Have you seen other places where water disappears like this?" the teacher asks. Pupils suggest places. "Where do you think this water is going?" she asks. Pupils suggest places. "Sometimes water disappears quickly; sometimes slowly. Why do you suppose this happens?" Pupils give their ideas. Through such a preliminary discussion as this pupils raise problems and interest is aroused. A readiness for the study is coming about. The questions that arise are listed for answering. Some of them may be: "What happens to the water when it disappears?" "Why can't we see it then?" "Why does it disappear?" "Could we keep it from disappearing?" "Can we get it back again?" "How can we make it disappear faster?"

"Now, how do you suppose we can find the answers?" the teacher asks. Suggestions from the pupils are important here. We want them to learn ways to answer their own questions and then to proceed to use these ways so that they will arrive at reliable conclusions. The pupils suggest: Reading, experimenting, asking questions, watching things, and other ways.

"How shall we begin?" The questions may be arranged in some order that seems logical for answering. A library committee working with the teacher may search for books that will assist in finding the answers. These sources will suggest various experiments and activities. Suggestions have been made (pp. 13–18) for use of reading material, for experimenting, and observing.

In performing experiments, as in all other activities it is essential to keep them geared to the purposes for teaching the unit. For example, we want to help pupils grow in the use of a scientific attitude. We say, "Don't let pupils jump to conclusions, and be sure to use a control in performing experiments whenever possible." In this unit, one of the problems may be: "Why do clothes on the line dry faster on a windy day?" To solve this problem, pupils may perform the experiment of making a wet spot on the blackboard and fanning it with a piece of cardboard. The spot, of course, will soon disappear.

Pupils will decide immediately that the wind made by fanning caused the water to evaporate faster. *But they shouldn't decide that.* As a small, alert boy once said, under such circumstances, "I can't remember how big it was to begin with." So the question arises, "How can we fix our experiment so we can be sure that wind is helping the water evaporate faster?" "Put two spots on the blackboard, fan one and *don't* fan the other," someone suggests. Now you are getting on the track. So two spots are made near each other and fanned. Someone says, "Some of the fanning is getting on

[illegible]

"Now we see what really happens."

both spots." "What shall we do?" someone asks. "Put the spots farther apart," another pupil suggests. This is done, but one of the spots is small, the other large. "There's still something wrong with the experiment," someone says. "What is it?" "The spots must be just alike or we can't decide that the wind is helping." The experiment is tried again. This time with two spots as nearly alike as possible and sufficiently far apart. This time the pupils are willing to decide that this experiment helps them to see that wind helps water to evaporate. But they must be sure to have more experiences before they decide for sure.

"Now have you ever seen other places where wind helps evaporation?" (The teacher has in mind people blowing on ink to make it dry when they can't find a blotter; hair driers; and the like.)

Through this method of keeping careful check on how children draw conclusions they gradually come to be more accurate in their observations and reportings, a situation highly to be desired according to our objectives.

Space does not permit detailed accounts of other individual lessons. This example has been included to show one possible way of proceeding. It is hoped that continued reference to the suggestions on pages 13–20 will help the teacher in directing the activities of the unit as it proceeds.

It is essential that the teacher keep referring to the generalizations originally assembled in order that the experiences will be leading in the direction of understanding them. The pupils will not at first connect the ideas of water disappearing with the concept of what causes rain, snow, and other weather forms. This idea will come to them as their study progresses. Since the teacher has previously assembled these core ideas she can help to direct the activities to include these more expanded aspects of the problem.

If there is sufficient interest in the study, the pupils may want to plan a culminating activity. This may be done in many different ways. Again it is important for pupils to plan for themselves. They may wish to show the results of their work to another grade, to their parents, or at a general assembly. They may then plan a series of easy experiments, perform and explain them; plan and draw a series of large pictures that show the important ideas they have learned; or write stories that illustrate the generalizations they have discovered.

Science and other learning areas

The study of science cannot progress without including many of the other areas in the curriculum. Nor should it. For example, reading is an essential tool to use as pupils search for solutions to their problems.

Writing is often a natural part of a science activity. In fact, a written record of progress on a unit or of plans for further study is almost always desirable. The record may be in the form of a set of directions for performing an original experiment which the pupils have decided to do. It may be a series of observations which the children have made. It may be a brief, accurate paragraph telling what the experiment shows, or a list of questions yet to be answered. Whatever the written record is, it should be made only if it contributes to better learning from the science experience. Writing as an essential part of record keeping has meaning to children and is not merely an exercise in developing writing skills.

There are times when it is essential to use art skills in connection with the science unit. Sketches of experiments are often necessary to illustrate ideas. If large pictures are made to show findings, the principles learned in art should certainly be used. Again, only in cases where art learnings and skills are necessary to the satisfactory completion of the activity should they be included.

Skills in arithmetic may also be needed. If pupils wish to measure the amount of evaporation, to decide what proportion of the total amount of water has evaporated, they need arithmetic. If they wish to melt a quart of ice and find out how much water is formed, they again need arithmetical knowledge. There are many such places where arithmetical computations are needed.

The foregoing examples show how the science unit needs the other subject-matter areas to make it complete. Wherever the subject-matter areas are mutually helpful we should by all means combine them. As our programs are at present arranged in most schools we are continuing to cling to subject-matter compartments. Such an arrangement, however, does not preclude use of subjects for mutual benefit. Perhaps the best teaching takes place when the pupils and teacher become so interested in working together that whatever seems to need doing to solve a problem is done without regard for whether it is arithmetic, spelling, reading, or something else. When it gets to be soon without anybody realizing it—is perhaps the ultimate for which we strive. This comes about when we are skillful enough to build our school programs around the genuine concerns of girls and boys and to direct their learning that the goals for elementary education are realized for as large a percentage of our pupils as possible.

Evaluation

Evaluation is an important aspect of the science program and much still remains to be done in this field. Tests on the recall of subject matter are common, but at present, little of significance has been accomplished in measuring growth in ability to use scientific method of problem solving, in use of scientific attitude, in appreciation of and interest in the natural environment.

Observing reactions of individual pupils as they offer suggestions, as they participate in class experiments and similar activities, and react in problem situations, is perhaps the best method of evaluating growth in some of the more intangible elements which we hope to accomplish through science teaching. Growth in interest by individuals may be noted as they comment more freely in science classes, bring things to school, and use some of their free time for science activities. Growth in problem-solving ability evidences itself in science classes as well as in arithmetic classes and other places where this technique is essential. Certainly the grade, if one is necessary, should be based not alone on examinations designed to test retention of subject matter, but insofar as possible on attainment of the other aims set up for the unit.

It is essential that pupils, together with the teacher, evaluate their accomplishments before going on with another interest. Such questions as these might be discussed: What things did we do best? How could we have improved our way of working? What did we do to be sure that our experiments told us true things?

science resources at your door

IT'S the hardest thing in the world to make these fossils live," says the teacher, and she's not just trying to be funny. It is hard to make an animal 50 feet high and 80 feet long seem real to children who are used to seeing animals the size of horses and jack rabbits. Then some child says, "They have one of these dinosaurs we've been talking about down at the museum in the county building. I saw it while I was waiting for dad one day last summer." "Let's all go and see it."

Believing and understanding a thing are much easier when we actually see it than when we just read about it, see a picture of it, or hear someone describe it. Countless resources for helping to make ideas real to children are near to every science classroom. These resources need to be used much more than they are now. They consist of everything from Jack's Aunt Minnie who has lived in Guatemala, to the fire extinguisher that hangs on the wall in the school corridor. No science program can be really successful without extensive and intelligent use of these resources. They are in the school, at home, in the community, everywhere. The following description of typical resources viewed in the subject context where they may be most useful, illustrate successful practices.

In the school

Pupils are learning how heat travels and how heating systems function. The book diagrams are helpful. Experiments are important. Reading is necessary, too, but heat is traveling into the air of the schoolroom from somewhere, either from a furnace in another building, from one in the basement of the building where the pupils are studying, or from a stove in the classroom itself. Why not investigate? The school engineer will help. Taking a trip to the furnace room, looking into the furnace, tracing the pipes to the room, discovering how the air currents travel in the room, and similar activities bring a realness to the project that would otherwise be impossible.

Pupils are studying electricity and how it travels. They learn about fuses, conductors, insulators, switches, and meters. If the school uses electricity all of these things are easily observed. Again the school engineer knows where the fuse box is, can change a fuse, knows where the meter is, how the switches operate, and many other things. Actually seeing these things helps to get the elementary science of electricity out of the book and into the realm of the child's understanding.

Pupils are studying chemical changes. They observe the chemical change of rusting, of burning (furnace); note the various products of chemical change (window glass, paper, etc.) in the schoolroom; examine the fire extinguisher to see how it operates by the use of a chemical change and observe to see how undesirable chemical changes are controlled and desirable ones encouraged. Examples are everywhere.

Following is a list of other similar school resources: Thermostats, electric bells, pulleys and other simple machines, school drinking fountains, slate blackboards, light fixtures, pianos and other musical instruments, plants, pressure cookers in the school cafeteria, school radios, telephones, aquariums. The list of materials is nearly endless.

Around the school

The class is studying the effects of erosion on land forms. A heavy rain falls. A trip to the edge of the schoolyard reveals a temporary stream brown as coffee carrying away the topsoil of the playground. A drinking glass full of the water held to the light reveals the cause of the color. Letting the glass stand for an hour finds the soil collected at the bottom of the glass. The sidewalk next to the yard is covered with soil washed from the playground. Here is a real example of erosion.

The class is studying animals and how they live together. In the ground just outside the window, ants are busy taking care of their eggs, guarding the queen, feeding her, getting food, and doing the many other things the pupils have read about. Seeing ants under a magnifying glass, watching them carry, seeing them making a tunnel, and feeding them are all activities that make what the books says real.

Many other things wait to be discovered in the schoolyard: Trees and other plants going through the annual cycle of growth and dormancy; birds, insects, and other animals; swings and see-saws that illustrate scientific principles; plants with special adaptations; flowers, rocks, seed pods, dew, and other forms of precipitation; fungus growths; nodules on clover roots; and examples of different kinds of soils. Exploration of these things helps to bring science ideas to life and creates appreciation of them.

At home

Science in the home takes on new meaning when pupils become acquainted with it in relation to their school study.

For example, the children are studying machines, and how they help to do work. Modern homes contain many of the things commonly used to illustrate the principles of doing work. In the kitchen are egg beaters, can

Courtesy, Putnam Elementary School, University of Ohio

"See that woodpecker? It's looking for something to eat. Its home is in that dead tree limb and it was there last year, too."

openers, knives, corkscrews, and many other tools. In the shop there are hammers, saws, and chisels. In the garage there are jackscrews and levers. There is a washing machine, a lawn mower; perhaps there is a pump, farm machinery, a windmill, pulleys for loading hay, inclined planes for loading stock, balances for weighing, pulleys for hanging out clothes or storing hay. All of them do work in a useful and real way.

Children are learning how we use plants in our daily living. They keep an account of the different kinds of plants that are growing in their home gardens or farms. They examine the kitchen cupboard for examples of spices, etc. They are learning how plants are adapted to the environment, so they dig up dandelions to examine the long-root system; bring various kinds of leaves to school for examination; and bring plants to school that show special adaptations which illustrate ideas under consideration.

Other science resources of the home include heating and lighting systems, home appliances, pets, farm animals, method of insect control, fuels, and the like.

In the community

Every community is rich in resources that are indispensable to good science teaching. They include not only places to visit, but persons to consult. Some schools have a committee of teachers whose job it is to assemble and keep up to date a card file of all such resources, including information about them, steps to take in making arrangements for their use, how to obtain advance information, persons to see, and similar data.

These cards might contain information concerning: An amateur astronomer who will show his telescope to science classes, a man who keeps bees, a gardener, a home-lighting expert, a world traveler, a chemist, a member of the fire department, an amateur ornithologist, an aviator, a doctor, and other individuals who have valuable first-hand information and experience to contribute to pupils studying various phases of science.

The use of an individual as a resource person carries with it certain responsibilities for both pupils and teachers. From the social point of view, extending an invitation, planning for good audience participation situations, introducing the visitor to the group, and conducting questioning periods must all be planned for by the teacher and pupils. Careful planning is essential, too, if pupils are to receive maximum benefits from these resource persons. A list of questions may be prepared in advance to help give proper focus to the meeting. There is no reason to assume that Mr. Zilch who built his own telescope and knows more about Mars than anybody in town can talk helpfully with a fifth grade. In all probability he has not seen, since his own school days, so many girls and boys in one room and has little idea of their interests and capacities. The list of questions and a talk with the teacher in advance of this school appearance will be very helpful to most resource persons.

The cards also contain a list of places to visit and essential data about them, such as location, persons in charge, comments on usefulness, and other details. Such places might include: The water purification plant, airport, industrial plants, weather bureaus, parks, radio stations, city departments, greenhouses, bird sanctuaries, markets, and stone quarries. Again, the value of such visits will be greatly enhanced by careful pupil-teacher planning in answering such questions as: What arrangements must be made before taking the trip? What safety rules and rules of courtesy need to be observed in taking the trip? How can we organize to make best use of our time? What things do we want to find out? How can we best organize this information? What use shall we make of the findings after the trip?

In the use of any community resource—person, place, or thing—there are certain considerations to be kept in mind. School public relations are involved whenever pupils leave the school building. Sensible, sincere planning needs to be done by pupils and teacher to insure appropriate conduct and good learning. Taking a trip provides an excellent opportunity for pupil-teacher planning in a real situation. Everyone concerned should be thoroughly aware of the purpose for the trip. If possible, free time should be provided in which pupils may reexamine, according to their special interests, materials which they have seen as a group. There should be plenty of opportunity for questions.

Increasing the amount and effective use of available resources is bound to increase the value of any science program in the elementary school.

materials and apparatus

THE PROBLEM of obtaining apparatus and other materials for use in demonstrations and experiments in science in the elementary school is not nearly so difficult to solve as many teachers believe. It is not necessary to spend a large amount of money for expensive apparatus. Most science experiments in the grade school are simple and rightly so. The materials, too, should be kept simple. Home-made equipment often serves the purpose as well as, or better than, more elaborate, purchased equipment.

The problem of storing materials and making room for performing experiments has been solved in a variety of ways. Several schools have constructed portable supply cupboards and demonstration tables. (See illustration, p. 35.) This one is 38 inches in height, the top is 30 by 54 inches. The drawers and compartments are of different shapes and sizes to accommodate various types of materials. It is easily moved on the 3-inch rubber casters. Such a table can be built in the school shop and has been found extremely helpful in teaching science.

Most commercial supply companies do not find it profitable to fill small orders for science equipment from individual teachers. For this reason, they suggest that orders for all the schools in the system be pooled, if possible. Some teachers will find it advantageous to consult with general science, biology, chemistry, and physics teachers in ordering supplies. It is not necessary to order a large amount of expensive equipment for teaching elementary school science. Local 10-cent stores, drug stores, and hardware stores, can often supply some of the materials. Some can be borrowed for brief use from nearby high schools. Children can bring some from home; chemistry sets supply some of the hard-to-get items.

The following list of materials is considered to be about the minimum number of items necessary to teach usual grade-school science. How much of each item will be necessary depends, of course, on how large the school is, how much individual experimenting is done, and whether or not this equipment is to be routed from one school to another. Some school systems prepare kits of material useful for teaching specific units (electricity, sound, and the like) which are available upon request from a central place and are returned after use to be reissued. The following list is for the purpose of assisting teachers in assembling the essential equipment for establishing a science program:

NOTE: The following materials are for use in the subject units as indicated. The list is relatively complete and the unit can be taught without having every item in the list.

Obtainable from scientific supply houses

I. Electricity and Magnetism

Piece of lodestone.
Pair of bar magnets.
Large horseshoe magnet.
U-magnet.
Knitting needles.
Shaker of iron filings.
Magnetic needle.
Magnetic compass.
Glass friction rod.
Hard rubber friction rod.
Electric lamps and sockets (small).
Fur for rubbing friction rods.
Colored pith balls for static electricity.
Demonstration electric motor.
Telephone receiver.
Telephone transmitter.
Dry cells.
Insulated copper wire.
Electric push buttons.
Electric bell.

II. Air and Weather

Glass barometer tube with well and medicine dropper for filling with mercury.
Mercury (3 pounds needed).
Tin cup.

III. Sound and Light

Tuning fork.
Concave and convex mirror.
Prism.
Reading glass, 2-inch diameter.
Color rotator to show the results of mixing colors.

IV. Fire and Heat

Boy Scout fire drill set.
Ball and ring apparatus to show that metals expand when heated.
Compound bar to show that some metals expand more than others when heated.
Apparatus to show that heat travels faster in some metals than others.
Apparatus to show that some substances conduct heat better than others.

General Supplies and Apparatus

Iron ring stand, large size.
Clamp for ring stand.
Iron ring with clamp for fastening on ring stand.
Wire gauze with asbestos center for placing over rings or tripod.
Iron tripod.
Forceps for handling heated objects and chemicals.
Tongs for lifting hot objects.
Iron spoon for heat and chemical work.
Alcohol burner or Bunsen burner (Bunsen burners are usable only with gas).
Rubber tubing for Bunsen burner, one-fourth-inch inside diameter (needed only if you have gas), 4 feet.
Rubber stoppers, solid, 1- and 2-hole, assorted sizes, 2–6.
Corks, bag of assorted sizes, 12–26.
Corks, bag of assorted sizes, 0–11.

Test tubes, 6 by three-fourth-inch (pyrex).
Test-tube holders.
Test-tube brush.
Test-tube holder; holds 12 tubes.
Glass tubing, 6-millimeter outside diameter.
Rubber tubing to fit glass tubing, three-sixteenths-inch inside diameter.
Pyrex flask, 1-pint size.
Battery jar, small-sized.
Battery jar, large-sized.
Glass funnel, 100-millimeter top diameter.
Glass graduate, 100-cubic-centimeter capacity.
Thermometer, double scale (both centigrade and Fahrenheit).
Pyrex beakers (nest).
Powdered iron.
Petri dishes (for growth of bacteria).
Litmus paper.
Powdered sulphur.

Obtainable from local sources

The following list of materials is composed of items available from local sources (home, 10-cent store, drug store, etc.). Some items, such as the kitchen tools, musical instruments, etc., will, of course, be used for only a short period of time and returned; others will become a part of the permanent equipment of the science room.

I. Living Things

An aquarium (stocked with fish, snails, water plants, etc.).
A terrarium (stocked with growing plants, etc., a suitable place to keep a small turtle, a frog, or salamander, or small snake).
Larvae of different kinds.
Cocoons and chrysalids.
Seeds (bean, corn, etc.).
Growing plants (geranium, ivy, begonia, bulbs, cactus, etc.).
An ant observation house.

II. Glassware

Fruit jars.
Milk bottles.
Glass tumblers.
Lamp chimneys.
Cups and saucers.
Pieces of window glass which may be cut into small-sized pieces.
Flower pots (various sizes).
Small mirrors.

III. Miscellaneous

Safety matches.
Scissors.
Teaspoons and tablespoons.
Rubber bands.
Tin cup.
Ball of string.
Scraps of different kinds of metal (zinc, aluminum, copper, etc.).
Worn-out dry cell.
Paring knife and table knife.
Colored chalk.
Blotters.
Balls.
Wire—steel and copper.
Flashlight.
Scraps of different kinds of cloth (silk, wool, cotton, etc.).
Burned-out light fuses of various kinds.

Electric appliances out of repair, i. e., extension cord, hot pad, etc. (for examination).
Mechanical toys illustrating machine principles.
Pans of various shapes and sizes.
Hot plate.
Needles.
Tack puller.
Tongs.
Egg beater.
Rubber balloons.
Cellophane (clear and colored).
Pet cages.
Burned-out light bulbs.
Worn-out electric motors.
Candles of various lengths.
Sand, clay, loam, humus.
Globe and map of the world.
Medicine dropper.
Yardstick.
Chalk boxes.
Nutcracker.
Wedges.
Thermometer (broken to be examined).
Musical instruments of various kinds.
Gummed labels.

IV. Construction Materials

Nails, tacks, screws.
Paints and varnishes.
Hammer, pliers, file, screw driver.
Glue and paste.

V. Chemicals

Soda.	Marble chips.	Vinegar.	Ammonia.
Starch.	Lime for lime water.	Table salt.	Iodine.
Sugar.	Red ink.	Paraffin.	Dyes.

VI. Collections

Seeds and fruits.
Leaves.
Shells and other sea life.
Birds' nests (made in autumn).
Local rocks, minerals, fossils.
Science pictures of various kinds.
Insects.

Courtesy, Sunnydale School, King County, Wash.

Sixth-graders helped to make this cabinet. It's handy to use; has plenty of storage space; and is on casters so it can be easily moved from room to room.

selected bibliography

Books and pamphlets

The following books and pamphlets are some sources of information which will be useful to teachers and others interested in the teaching of science in the elementary school:

BLOUGH, GLENN O. Elementary science series. Washington, U. S. Government Printing Office, 1947. 11 p. 10 cents. (U. S. Office of Education.)

Reprint of four articles from SCHOOL LIFE presenting a philosophy for science teaching, the objectives, activities used in teaching science, and a discussion of current trends.

CRAIG, GERALD S. Science for the elementary-school teacher. New York, Ginn & Co., 1946. 551 p.

Contains discussion of method as well as complete development of subject matter for teachers' background and a suggested sequence of meanings in science for the elementary school.

——— Science in childhood education. New York, Bureau of Publications, Teachers College, Columbia University, 1944. 86 p.

Practical suggestions for teaching science, including discussion of objectives, philosophy, and use of community resources.

CROXTON, W. C. Science in the elementary school, including an activity program. New York, McGraw Hill, 1937. 454 p.

Presents discussion of methods of teaching, aims, teacher's preparation, evaluation of results. Part two contains details of an activity program.

CURTIS, FRANCIS D. A digest of investigations in the teaching of science in the elementary and secondary schools. Philadelphia, Blakiston, 1926. 341 p.

Includes the research investigations published prior to 1925, i. e., learning studies and curricular studies.

——— A second digest of investigations in the teaching of science. Philadelphia, Blakiston, 1931. 424 p.

Includes chiefly the research investigations published from 1925 through 1930.

——— A third digest of investigations in the teaching of science. Philadelphia, Blakiston, 1939. 419 p.

Includes chiefly the research investigations published from 1931 through 1937.

HEISS, E. D., OBURN, E. S., HOFFMAN, C. W. Modern methods and materials for teaching science. New York, Macmillan, 1940. 351 p.

Contains a section on principles of science teaching, one on materials and devices for teaching science, and one on sources of materials for teaching science.

NATIONAL SOCIETY FOR THE STUDY OF EDUCATION. Thirty-first Yearbook. Part I. A program for teaching science. Bloomington, Ill., Public School Publishing Co., 1932. 370 p.

Contains a treatment of trends in science teaching and indicates recommendation for further work. Treats present practices, criticism of practices, contributions of science teaching.

——— Forty-Sixth Yearbook, Part I. Science education in American schools, Chicago, University of Chicago Press, 1947. 296 p.

Large section devoted to science in the elementary school, including organization of the curriculum, materials and methods, judging the results, use of resource materials, and improvement of instruction.

NOLL, VICTOR H. The teaching of science in elementary and secondary schools. New York, Longmans, Green, 1939. 238 p,

Contains material on general methods, curriculum, and testing.

PRESTON, RALPH C. Science an approach in the elementary school, Philadelphia public schools. 1945. 39 p.

PROGRESSIVE EDUCATION ASSOCIATION. COMMISSION ON SECONDARY SCHOOL CURRICULUMS. Science in general education. New York, Appleton-Century, 1937. 591 p.

Contains suggestions for science teachers in secondary schools and in the lower divisions of colleges.

Science instruction in elementary and high school grades. Publication of the Laboratory Schools, the University of Chicago, Chicago, Ill. 1939. 232 p.

Contains a curriculum in science with a report of the underlying philosophy.

SLAVSON, S. R., *and* SPEER, R. K. Science in the new education. New York, Prentice Hall, 1934. 396 p.

Places special emphasis on elementary school science, including trends, children's interests, objectives, current practices, and methods.

STEVENS, BERTHA. Child and the universe. New York, John Day Co., 1931.

Presents an overview of the child in relation to his environmental influences.

This is science. Bulletin of the Association for Childhood Education, Washington, D. C., 1945. 43 p.

Contains practical material useful to teachers of elementary science.

Time for science. Yearbook, National Science Teachers Association, Washington, National Education Association, 1946. 51 p.

Discusses need for more time for preparation for teaching science as well as for its presentation in the classroom.

UNDERHILL, ORRA E. The origins and development of elementary-school science. Chicago, Scott-Foresman, 1941. 347 p.

Discusses first teaching of science in elementary school, object teaching, development of curricula, teaching of nature study, and recent trends.

WOODRING, M. N., OAKES, M. E., *and* BROWN, H. E. Enriching teaching of science in the high school. New York, Bureau of Publications, Teachers College, Columbia University, 1941. 402 p.

Lists free and inexpensive material useful in teaching science at both elementary and high-school levels.

Research studies

Following are some of the research studies available and useful as guides in determining practices in the teaching of elementary science:

CRAIG, GERALD S. Certain techniques used in developing a course of study in science for the Horace Mann Elementary School. New York, Bureau of Publications, Teachers College, Columbia University, 1927. (Contribution to Education No. 276.)

Describes the method and presents the results of a study to determine content in science for elementary grades.

HILL, KATHERINE ELIZABETH. Children's contributions in science discussions. New York, Bureau of Publications, Teachers College, Columbia University, 1947. 97 p. (Contribution to Education, No. 931.)

A consideration of children's verbal responses in relation to certain objectives for science instruction.

LATON, ANITA D., *and* PILLEY, JOHN S. Suggestions for teaching scientific method. New York, Bureau of Educational Research in Science, Teachers College, Columbia University, 1940.

Presents helpful material on procedures for bringing about scientific problem solving in the classroom.

PITLUGA, GEORGE E. Science excursions into the community. New York, Teachers College, Columbia University, 1943. 154 p.

Describes techniques for planning and conducting excursions, and gives specific examples of excursions in areas of health and safety, home life, controlling natural environment for human needs, and communicating and transporting.

WEST, JOE YOUNG. A technique for appraising certain observable behavior of children in science in elementary schools. New York, Teachers College, Columbia University, 1937. (Contribution to Education, No. 728.)

Describes methods of appraisal, indicates which appear most appropriate; shows teaching practices and how appraisal techniques are applicable to them.

WILLIAMS, ALICE M. Children's choices in science books. New York, Bureau of Publications, Teachers College, Columbia University, 1940. 163 p.

States children's reactions to science books in libraries and to 35 science books through controlled experimentation and observation.

State courses of study in elementary science

The following State bulletins and courses of study in science are not included with the general elementary curriculum, but are published under separate cover:

CALIFORNIA STATE DEPARTMENT OF EDUCATION, SACRAMENTO. Science in the elementary school. 1945. 416 p.

KANSAS STATE SUPERINTENDENT OF PUBLIC INSTRUCTION. Teachers' guide to the Kansas elementary school program of studies. Science. The Department, Topeka, 1940. 129 p.

LOUISIANA STATE DEPARTMENT OF EDUCATION. Revised course of study in science for the elementary schools. Baton Rouge, the Department, 1941. 178 p. (Bulletin No. 465.)

NEW YORK. UNIVERSITY OF THE STATE OF NEW YORK. Elementary school science. A syllabus for elementary schools. Albany, N. Y. The University of the State of New York Press, 1942. 182 p.

NORTH CAROLINA STATE SUPERINTENDENT OF PUBLIC INSTRUCTION. Science for the elementary School. Raleigh, 1941. 115 p. (Publication No. 227.)

OHIO STATE DEPARTMENT OF EDUCATION. Science education for the elementary schools of Ohio. Columbus, the Department, 1946. 192 p. (Curriculum Bulletin No. 3.)

OREGON STATE SUPERINTENDENT OF PUBLIC INSTRUCTION. Tentative guide to science for Oregon schools. Part 1. Elementary and junior high school grades. Salem, 1941. 101 p.

SOUTH CAROLINA STATE DEPARTMENT OF EDUCATION. Suggestions for the teaching of science in the twelve-year school program. Columbia, The Department, 1946. 115 p.

TENNESSEE STATE DEPARTMENT OF EDUCATION. A science program for elementary schools, grades one, two, and three and a science program for elementary schools for grades four, five, and six. Nashville, The Department, 1944. 63 p. and 66 p.

UTAH STATE DEPARTMENT OF PUBLIC INSTRUCTION. Science supplement to a Teaching guide for the elementary schools of Utah. Salt Lake City, The Department, 1946. 99 p.

Science experiment books for children

ARBY, CHARLES K. Science experiences for elementary schools, New York, Bureau of Publications, Teachers College, Columbia University, 1942. 98 p.

BARR, MARIAN E. Without fire: A book of experiments. New York, Rinehart, 1946. 48 p.

BAKER, R. RAY. So that's the reason. Chicago, Reilly and Lee, 1939. 125 p.

BRANLEY, FRANKLIN M. *and* BEELER, NELSON F. Science experiments. New York, Crowell, 1947. 115 p.

FREEMAN, IRA M. Invitation to experiment. New York, Dutton, 1940. 238 p.

FREEMAN, MAE *and* FREEMAN, IRA. Fun with chemistry. New York, Random House, 1944. 58 p.

——— ——— Fun with science. New York, Random House, 1943. 60 p.

GARRISON, CHARLOTTE G. Science experiences for little children. New York, Charles Scribner's Sons, 1939. 111 p.

GORDON, BERTHA F. Prove it yourself. Dansville, N. Y. F. A. Owen Publishing Company, 1928. 255 p.

HORNING, JOHN L. *and* MCGINNIS, GEORGE C. An open door to chemistry. New York, D. Appleton-Century, 1946. 86 p.

KEELOR, K. L. Working with electricity. New York, The Macmillan Co., 1938. 111 p.

LORD, EUGENE H. Experimenting at home with the wonders of science. New York, D. Appleton-Century, 1940. 243 p.

LYNDE, CARLETON J. Science experiments with home equipment. Scranton, Pa., International Textbook Company, 1937. 226 p.

——— Science experiments with inexpensive equipment. Scranton, Pa., International Textbook Company, 1939. 226 p.

——— Science experiments with 10-cent store equipment. Scranton, Pa., International Textbook Company, 1939. 226 p.

MCKAY, HERBERT. Easy experiments in elementary science. New York, Oxford University Press, 1932. 144 p.

MORGAN, A. P. The boy electrician. New York, Lothrop, 1948. 407 p.

——— Things a boy can do with chemistry. New York, Appleton-Century, 1940. 288 p.

SCHNEIDER, HERMAN *and* SCHNEIDER, NINA. Let's find out. New York, William R. Scott, 1946. 39 p.

YATES, RAYMOND F. Science with simple things. New York, Appleton-Century, 1940. 245 p.

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