Science Is Doing

By Robert D. Boram

Recently I was talking to a veteran fifth-grade teacher. The subject moved to science. The teacher, who has spent more than 25 years "in the trenches," told me how much she enjoyed teaching the vocabulary and facts of science, but added that she felt very uncomfortable with the "hands-on" aspects of the subject. Needless to say, there is no activity-oriented science learning in her classroom. This seems to be the rule rather than the exception in many elementary classrooms.

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What's wrong with teaching science as "facts"? If you read only the new developments in science at the rate of a page per minute, after one year you would be about seven years behind. Computer science books are usually out of date by the time they are published. Much of what we know about human physiology is being revised and updated. Teaching "just the facts" of science is truly impossible.

Part of the problem may be that we misunderstand what science really is. Albert Einstein stated that "the object of all science is to coordinate our experiences and bring them into a logical system."[1] In other words, science is the attempt to make sense of our experiences and observations. Neils Bohr, a Noble laureate, stated that "the task of science is to both extend the range of our experience and reduce it to order."[2]

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Accordingly, science teaching should include making observations; taking measurements; and collecting, organizing, and interpreting additional data. Such activities, under the guidance of the teacher, can lead students to the facts, principles, laws, and generalizations that scientists have established.[3]

The veteran teacher mentioned at the beginning of the article had never really taught science. She had taught vocabulary and "facts," but her students had been deprived of the opportunity to actually *do* science. For, in fact, "science is the quest for knowledge, not the knowledge itself."[4] Henri Poincare, French scientist and mathematician, stated that "science is built up with facts as a house is with stones, but a collection of facts is no more a science than a heap of stones is a house."[5] Students need experience and observation to provide a framework for the science class.

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A Quest for Knowledge

The teacher must set up an opportunity for the students to undertake science as a quest for knowledge. This means providing the students with materials and directions so they can collect data that will allow them to discover various concepts in science.

Some teachers will feel anxious about doing hands-on science activities: "What if the students ask me questions I can't answer?" "What if they don't get the right answer?" This anxiety can be lessened by viewing science less as a search for "right" answers and more as a thrill-of-the-chase adventure. Students should focus on the data generated from the specific investigation.

The teacher is not required to explain phenomena. In fact, it would be better to have the students try to explain what they observe and experience. The teacher can be quite comfortable and effective by helping the students to make objective observations, keep records, and communicate to others what they have done and discovered. Helping students observe facts, even if these contradict preconceived notions, can be the focal point for further investigation, questioning, and experimental design.[6]

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The Teacher's Role

The teacher's role is both vital and subtle. First, *preparation*. The teacher must prepare and organize materials, as well as data sheets and directions, for student investigations. Safety considerations and cautions must also be addressed.

Second, *guidance*. Once the students begin the investigation, the teacher should serve as a facilitator for data collection. At no point during this stage should the teacher tell the students what results are "correct." All data are valid and "correct." Some data may not be easily explained using standard analysis and interpretation, but they are data that the students have collected, and that makes them important. Throughout the investigation the teacher should ask the students questions about their data to help them focus on the concept at hand.

Third, *leading a discussion*. Once the data have been collected, data tables completed, graphs drawn, and drawings made, it is the teacher's turn to direct a discussion of the results. This discussion should utilize the students' data.

For example, in one experiment, the students add a couple of drops of blue food coloring to two glasses filled with 250 ml of water. One glass holds hot water, the other cold water. The student data indicates that the blue color diffused throughout the warm water faster than the cold water. You might start the discussion by asking, "Why did this glass of water turn completely blue first?" Typically students will say, "Because the water is warm."

Taking it from there you ask, "What is it about warm water that causes it to turn blue more quickly?" There may be a variety of answers to this question. Accept all answers and write them on the chalkboard.

Ask students to group similar answers together and then discuss and analyze each set of answers. If the students suspect that the food coloring caused the difference, then repeat the experiment, using exactly the same amount of food coloring in each jar. If students think that the water is different in ways other than temperature, Pictures removed

point out that it came from the same source or repeat the experiment, using the same cold water source and heating a portion of the water. Ultimately the discussion can focus on the energy in the two cups of water, leading to the conclusion that the food coloring traveled faster in the warm water because the warm water had more energy.

Leading a discussion may take more time than having the students fill out a worksheet or answer questions at the end of a science chapter, but discussing the data will require the students to use higher-order thinking skills.

How It Works

A few classroom examples illustrate how this science process works. Several students wanted to compare plants grown in the dark with some grown in the light. We decided to plant four bean seeds in each of two flower pots, water them, and then place one on the window sill and the other in a dark cabinet. We observed the plants twice a week and recorded their height, the color of the leaves, and other relevant information.

Several students predicted that the bean seeds planted in the dark would not grow. They were surprised to find that after a couple of weeks these plants were taller than the ones on the window sill. Some students wanted to know why the plants in the dark were growing "better" than the ones in the light. At this point the teacher may be tempted to tell the students what is happening. However, it is usually best to have them continue making observations and collecting data.

Before long the plants in the dark were almost twice as tall as those in the light. Then the plants in the dark died. Students continued to observe the plants in the light until they produced a seed pod. The growth of both sets of plants was plotted against time on the same graph.

In the discussion that followed the students developed some theories about the growth of plants in light and dark. These included the following: that light may actually stunt the growth of the plants; that the plants grown in the dark grew until they used up their energy, and that the cotyledons (two halves of the bean seed) provide energy for the seed to get started. Several theories led to further experiments. To determine the role of the cotyledons in plant growth we sprouted the embryo in three different ways: separated from the cotyledons, attached to one cotyledon, and attached to both cotyledons.

Another challenging investigation for elementary students is making a flashlight bulb glow using one "D" cell battery, a flashlight bulb, and a wire with the insulation removed from both ends. The students, with very little help, soon discover that the bottom and side of the bulb must be connected to opposite ends of the battery in order to make the bulb glow. Once the students understand the concept of an electrical circuit, they can be challenged to put two flashlight bulbs or two batteries in the circuit.

With a few magnets and a collection of objects from around the room, students can discover that magnets attract only other magnets or objects made of iron. If the students think that metal is attracted to magnets, have them try attaching the magnets to a pop can, a penny, aluminum foil, or other metal objects that are not made of iron.

Working with two magnets, the students can discover that magnets have two poles and that like poles repel and opposite poles attract. By wrapping a wire around a large nail or an iron rod and attaching the ends of the wire to a battery, the students can discover the properties of an electromagnet, which are the same as an ordinary magnet.

Students can explore the life cycle of insects by using mealworms. (These are available at many bait shops.) Have the students set up a home for the mealworms in a container filled with oatmeal or some other type of meal and a moisture source such as a sliver of potato or apple. Ask students to draw pictures of the animals and collect data from their observations. They should check on the mealworms often and watch closely any changes that take place. The entire life cycle may take six to ten weeks.

Integrating Science Into the Curriculum

Science activities need not be a separate part of the curriculum. They can be integrated into other subjects. Because each discovery activity provides experiences about which the student can write, science can be incorporated into writing class. Science activities can also become a springboard for a whole language reading lesson.

Classroom science activities require that both the students and the teacher become engaged in investigating and learning about the world around them. By doing science the students must use a number of skills: recall, imagination, classification, generalization, comparison, evaluation, analysis, synthesis, deduction, and inference.[7] These skills are essential to creative and critical thinking. But another important feature of doing science, as opposed to learning facts, is that students enjoy the process—and when learning is fun, teaching is easier!

Dr. Robert D. Boram holds a Ph.D. in science education and an M.S. in physics with emphasis in education. He is currently Assistant Professor of Science in the Department of Physical Sciences at Morehead State University in Morehead, Kentucky. Dr. Boram has worked at a museum as a science educator and director of summer apprentice programs, and as a physics curriculum instructor for the National Science Foundation's Honors Workshop for Secondary Teachers. He has taught science classes for elementary teachers, as well as in-service programs on activity-centered science teaching and critical thinking. Dr. Boram has teaching experience in the areas of science, astronomy, math, and other subjects at the university, academy, and junior high levels.

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