A Leg (or Three) to Stand On

Using the metaphor of a three-legged stool, an author explores the elements of good science instruction.

By Molly Weinburgh

As I speak with preservice and inservice elementary teachers in my classes at Texas Christian University, I find that many seem to classify science into one of two major groups. They think of science either as a process to be "done" or as "content" to be learned.

In the "doer" group, teachers emphasize the use of science-process skills while engaging children in hands-on activities. As long as the students are having fun and are engaged with real objects, they are convinced that children are learning science.

In the "content" group, teachers emphasize facts and formulas while lecturing or using handouts. As long as the children are able to complete short-answer tests, these teachers are convinced that children are learning science.

I find these groups both interesting and confusing because an either/or, process/content dichotomy seems to miss the boat. To me, science is more than one or the other of these; actually, it's more than just the combination of the two.

The Three Legs of Science

When I think of elementary science instruction, I think of the metaphor of the three-legged stool. I am not the first to use this metaphor to help visualize the components of instruction, but it seems especially appropriate in examining science instruction.

Ask a mathematician to tell you about "balance" and he or she will tell you that having three nonlinear points allows you to create a plane that is one-dimensional (a triangle) and therefore very stable.

Ask a dairyperson why a three-legged stool traditionally was used in the milking process and he or she will tell you that the three-legged stool can balance on uneven surfaces in a way that a four-legged chair cannot. However, a user of a three-legged stool will tell you that if you remove one of the legs, the resulting two-legged stool will teeter unsteadily and come crashing to the floor.

The three "legs" on which science instruction rests are the content of science, process of science, and the nature of science. Each leg performs its own function and need not be competitive with the others. Rather, the legs should work together to produce the balance the mathematician and the dairyperson describe.

Leg One: Content

A major emphasis of science reform efforts is to create a scientifically literate public (AAAS 1993; NRC 1996). For this to happen, children in elementary school must learn information or "scientific content" about the world around them.

This content usually falls into the major areas of life science, Earth/space science, and physical science. It includes such topics as the characteristics of insects (six legs, three body parts, antennae, wings); properties of magnets (attract or repel one another and attract to iron); the definition of a "cycle"; the concept that some things will float in water and some things will not; and the idea that living things require certain things in order to live (food, water, oxygen, place to live).

When content is delivered solely in the form of lectures or readings, it is often not learned at all or is learned in a very superficial way. The teacher then has the interesting—and fun—task of creating experiences to engage children in the processes of science, thereby "discovering" facts such as the examples given above.

Leg Two: Processes

Students of all ages should be engaged in "doing" science (AAAS 1993; NRC 1996). This requires students to learn the process skills and be able to use them when appropriate in helping to answer questions that they have about the world around them.

In order to draw conclusions about natural phenomena, elementary children in the primary grades must be good at the basic skills of observing, recording, communicating, classifying, measuring, inferring, and predicting. Early elementary teachers must actually teach the skills in order for children to be able to use them for scientific exploration.

Upper elementary children build on these skills by learning the integrated skills. The integrated skills include identifying variables, describing relationships, constructing graphs and tables, constructing hypotheses, and designing investigations. These skills allow these older students to take scientific exploration to a deeper level as they manipulate variables and design ways of answering questions. Children should come to middle and high school with these skills, allowing them to explore new phenomena in more sophisticated ways.

Constructivist theory tells us that students must be engaged in experiences that build on their current understanding of phenomena. They must test the new ideas against the old ideas and "make new sense" from the whole process. Using the process skills correctly allows the children to be engaged in the active pursuit of their own knowledge.

However, children can, and often do, draw incorrect conclusions from an experience. For this reason the science teacher must be very careful that the exploration by the children leads to accurate science content.

Leg Three: Nature of Science

"Doing" science and "knowing" science facts comprise "two legs" of good instruction. The third leg involves understanding the nature of science. Teachers must also design lessons so that children become aware of the important elements that make science a unique discipline; that is, they must teach the nature of science (AAAS 1993; NRC 1996). This aspect of good science instruction is often omitted. This phase is orchestrated by the teacher in a very subtle way.

Children need to understand that science is a human endeavor and that people of all ages, races, sexes, and nationalities engage in this enterprise. They also need to know that science is based on evidence—not faith or logic. Teachers can use language such as, "How do you know that? Give me some evidence" as the children answer questions, thereby helping children begin to realize that only by having evidence can credence be given to their answers.

In addition, being able to repeat an experience is necessary. Teachers can ask young children if someone else got similar results or if the child could do the same thing again and get similar results. Upper elementary students can be given the chance to realize that science "content" is tentative and can change as new information is found. Teachers should plan experiences that allow children to recognize that when more information is added, the interpretation may change.

Blending It All Together

We all know that every lesson does not lend itself to having equal parts of content, processes of science, and nature of science. That would result in a sequence of science experiences that would become repetitious and boring.

Science experiences for elementary students should blend the three "legs" in such a way that students learn how to do science, learn specific information about the world around them, and learn what makes the pursuit of knowledge "science." A science teacher's job is, then, to establish an environment in which all three aspects are learned over time.

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Teaching Standards

Standard A: Teachers of science plan an inquiry-based science program for their students.

Standard B: Teachers of science guide and facilitate learning.

Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning.

Many of the prospective teachers I teach have wished to observe a model lesson including all three aspects of science instruction. I have taught the following first-grade lesson several times as a demonstration with the preservice teachers and inservice teachers observing.

In this lesson, the content objectives are to teach students the following ideas:

- Fruits bear seeds.
- There are a characteristic number of seeds in certain fruits.
- The seeds from a particular fruit look alike.

First, I divided students into small groups, with each group of children getting two or three fruits, making sure that there were examples of each type of fruit—those with one seed and those with many seeds, for example—for each group. Group one had an avocado (or any fruit with only one seed, e.g., plum, peach), a green bean, and an apple; group two had a green bean, okra, and an apple; group three had an avocado, okra, and apple; and group four had a green bean, an avocado, and okra.

In order to learn the desired *content* about the relationship between fruit and seeds, the students engaged in investigations using the *processes* of science. Students observed each type of fruit, communicated with each other about their observations, recorded what they noticed, and hypothesized what might be inside.

Students often expressed that the okra was rough or prickly, green, and bigger on one end than the other and that the green bean was long and skinny, bumpy, and green. After talking about these external characteristics, they usually drew a picture with sentence-writing help from the teachers. Many of the students hypothesized that seeds would be inside but had no idea of how many seeds to expect.

I then asked for suggestions on how to find out if their hypotheses were correct and allowed the students to generate the idea of opening the fruit. They opened each fruit, using the processes of science as they made additional observations and collected data.

After the children collected data about their fruits, I helped students process the information in a way that resulted in correct content and an understanding of the nature of science. For example, group one was asked to share one fact about their avocado. Then groups three and four were asked if they had the same data. Group three then gave another fact about avocados with me again asking group one and four if they agreed. This process helped the students see that all of the groups found that avocados have one large, brown, slightly pointed seed and that all avocados have a seed.

Next, I asked group two what they now predicted about another avocado. They then opened the fruit to see if their prediction was correct. Lastly, I asked the students to make a general statement that was the same for all avocados.

This technique was repeated with all the fruits so that the students observed that green beans usually have between four and seven small, round green seeds; apples have 15 teardrop-shaped, brown seeds; and okra have "lots" of small flat, white seeds. This technique helped the students begin to pick up on several ideas about the *nature* of science: data from one group had to be very similar to data from another, general statements had to be backed with evidence, and a hypothesis could be made after collecting data and seeing a pattern.

A Balancing Act

As teachers, our job is to provide an environment in which our students have three legs to stand on. This involves creating opportunities to learn science content, science process, and the nature of science in the appropriate proportion. With just a little thought, most lessons can balance all three legs of good science instruction. My hope is that elementary teachers will reflect on lessons that they have taught in the past or are planning for the future and include the components that are missing. Lessons with all three legs will be much stronger than those with one or two legs missing. ■

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References

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