The scientific method: Is it still useful?

The existence or nonexistence of a scientific method has been a topic of considerable controversy over the past several years. Many scientists and science educators contend that a structured scientific method does not exist (Halpin and Swab 1990; Collette and Chiappetta 1994). Others might argue that the scientific method is too simplistic in its approach to scientific inquiry (Harwood 2004). And yet, whether valid or not, the scientific method is still presented as an integral part of many science textbooks and as a required component of many state science curricula. A form of the scientific method is also used as the structure of most science fair projects, as a component of student lab reports, and as the basic structure of research reports, theses, and dissertations. Some might argue that the structured approach characteristic of the scientific method is too rigid to use with students. However, while older students may not need such a structured approach to solving scientific problems, middle school and elementary students may benefit from a structured, step-by-step approach (Soroka 1990). Although knowledge generated by the scientific method is not infallible, its stepwise process helps generate new knowledge and theories (Proulx 2004).

While the scientific method is a logical, orderly way to solve a problem or answer a question, it is not a magical formula that is too complicated for nonscientists to comprehend (Keeton and Gould 1986). The scientific method may include a variety of steps, processes, and definitions. It should not be seen as a single series of steps, with no flexibility (McPherson 2001). In one form or another, it has probably been in use for as long as people have wondered about the world around them (Bicak and Bicak 1988). Although the scientific method is not always used in a rigid, stepwise manner, it may be useful for students to understand the structure of the method before they can use it in a less formal way.

A better way to think of the scientific method is as a stepwise, circular approach to solving problems (Proulx 2004). As an outline is a guide for writing a paper, the scientific method is a guide to solving a problem. As mentioned above, this is particularly important for younger students, who may benefit from learning the basic principles of science before they move on to more innovative, creative approaches. Another important factor is the value of the scientific planning process and experience itself. According to Harlen (1985), children learn by planning for themselves, not by following plans developed by others. Students who have used the scientific method in the early grades have learned a logical way to solve problems, and by third and fourth grades can begin designing their own investigations to find answers to their problems/questions while using the scientific method as a model. The scientific method is also an excellent way to develop critical thinking skills in students (McBride and Villanueva 1997). Although the scientific method is not spe-

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FIGURE 1 **Steps of the scientific method**

Problem: A question to be answered

Research: Information gathered about the problem

Hypothesis: A possible explanation or answer

Experiment: A test to check the hypothesis

Observation: Information gathered through the senses and recorded as data

Conclusion: A possible answer to the problem based on evidence from the experiment

cifically mentioned in the *National Science Education Standards*, the skills used in the process are focused on in the "Science as Inquiry" strands (NRC 1996). The rigid approach to using the scientific method that was described earlier is discouraged on p. 144 of the *Standards* (NRC 1996).

There are two basic dilemmas in teaching the scientific method to middle level students: (1) most students have preconceived notions about the scientific method due to previous experiences; and (2) few students understand that the scientific method is somewhat generalizable—it can be applied to problems of a nonscientific nature. There are several ways of dealing with these issues in science classes. To begin with, it is suggested that students be presented with the idea that science is a body of knowledge and a process for gaining knowledge. The body of knowledge includes all of the things of a scientific nature that have been learned in the past. The process for gaining knowledge includes the science process skills (also called inquiry skills) and the scientific method (or other names that we give it such as inquiry cycle, scientific experimentation, and problem solving using science).

In order to address the first dilemma, that of preconceived notions about the scientific method, students can be asked to define the scientific method, list the steps, and give an explanation for each step. This activity allows students to draw on their previous experiences with the scientific method. Students then discuss the definitions and steps they developed and arrive at a class consensus. See Figure 1 for a typical example of steps that students have developed.

An alternative way to look at the scientific method is to identify where the process skills fit into it. The process skills focused on in the "Science as Inquiry" Standard (NRC 1996) are used throughout the scientific method (see Figure 2).

Students often leave out the important step of addressing research. They should understand that background research should be completed before formulating a hypothesis, and that the seeking of information is an essential part of the scientific research process (Fields 1987).

In addressing the second dilemma, students should understand that the scientific method can be used as a tool for answering many different questions (Fields 1987). To emphasize this notion, present students with a nonscientific scenario, for which they must use the scientific method to solve. For example, students might be given the following situation:

You are flying on a small plane across the state to visit your grandparents in the mountains for summer vacation. Only you and the pilot are onboard. Somewhere over the mountains the pilot has a heart attack. The pilot crash-lands the plane into a lush forest at the base of a mountain. You survive the crash. You are alone and have no way of calling for help. What must you do to survive until the rescuers arrive? (adapted from the novel Hatchet *by Gary Paulsen)*

Students may brainstorm responses, such as find food and water or find matches to start a fire. Students then write a problem of their own and attempt to solve it using the scientific method. Problems and their solutions are varied, and may lead to formulation of new problems and situations. Students may choose finding food and water as their problem. They will need to be able to identify plants that are safe to eat (maybe by watching what animals eat). They may need to find a way to capture and kill

FIGURE 2 **Melding the method with process skills**

The scientific method	Science process skills
Problem/Question	Observing, Communicating
Research/Background knowledge	Communicating, Analyzing investigations
Hypothesis	Predicting, Communicating, Identifying variables, Constructing hypotheses, Designing investigations
Experiment	Measuring, Identifying variables, Defining operationally, Communicating, Experimenting
Observation	Observing, Classifying, Communicating, Measuring
Conclusion	Inferring, Communicating, Analyzing experiments

animals for meat, such as using traps made from vines, spears, or slingshots. They will also need to develop a system to collect clean and safe drinking water.

Students enjoy solving problems using the scientific method. In the example presented above, they sometimes become so involved in trying to solve the problem that they have to be reminded that they are dealing with a contrived situation. Once students gain confidence in using the scientific method, they can apply it more successfully to scientific problems and to problems in their own lives, along with using it in a less structured, more realistic fashion. Although the development of planning skills is very important, the plans must actually be carried out for students to understand the full process of planning for an experiment (Harlen 1985). The activity below is an example of a less formal approach to using the scientific method.

In conclusion, the scientific method can be a useful tool for introducing students to the problem-solving nature of science. Although older students may not need such a structured approach, middle school and elementary students may find the scientific method very useful as a model to problem solving. Assessment of understanding of these concepts should not simply include a listing of the steps of the scientific method and their definitions. Students should be presented with scenarios that they can find answers to by using the scientific method as a logical way of solving a problem.

References

Bicak, L. and C. Bicak. 1988. Scientific method: Historical and contemporary perspectives. *American Biology Teacher* 50 (6): 348–353.

Collette, A. and E. Chiappetta. 1994. *Science instruction in the middle and secondary schools*. 3rd ed. Columbus, Oh.: Merrill.

Fields, S. 1987. Introducing science research to elementary school children. *Science and Children* 25 (1): 18–20.

Halpin, M. and J. Swab. 1990. It's the real thing—the scientific method. *Science and Children* 27 (7): 30–31.

Harlen, W. 1985. *Helping children plan investigations*. In *Primary science: Taking the plunge*, ed. W. Harlen, 59–74. London: Heinemann Educational Books.

Harwood,W. 2004. An activity for scientific inquiry. *The Science Teacher*. 71(1): 44–46.

Keeton, W. and J. Gould. 1986. *Biological science*. 4th ed. New York: Norton.

McBride, J. and R. Villanueva. 1997. Salt crystals: Exploring the scientific method. *Science Scope* 20 (4): 20–23.

McPherson, G. 2001. Teaching and learning the scientific method. *American Biology Teacher* 63 (4): 242–245.

National Research Council (NRC). 1996. *National science education standards*. Washington, D.C.: National Academy Press.

Paulsen, G. 1987. *Hatchet*. New York: Bradbury Press.

Proulx, G. 2004. Integrating the scientific method and critical thinking in classroom debates on environmental issues. *American Biology Teacher* 66 (1): 26–33.

Soroka, L. 1990. The scientific method at face value. *The Science Teacher* 57 (8): 45–48.

The scientific method: A problem-solving tool

In this activity, you are going to try to solve a scientific problem of your own choosing based on a given experimental setup. You may find, as the saying goes, that one problem leads to another. It is often difficult to find clear answers in science, even to questions that seem simple.

You will need the following materials for your experiment:

Pie tin or tray	Modeling clay	Candle
Safety glasses	Flask or beaker	Food coloring
Matches	Water	

Do not do the experiment yet, just read the directions:

1. Place a candle in an upright position in the middle of your pie tin or tray using some modeling clay for support.
2. Pour water into the tray until it reaches a depth of about 1 cm. Put three drops of food coloring in the water (for better viewing).
3. Light the candle.
4. Quickly turn the flask or beaker upside down and place it over the candle and into the water.
5. Observe carefully and record your observations.

Before actually doing the experiment, you need to try to predict what the result might be. Possible questions in this case might be "What will happen to the water after the flask is placed over the candle?" or "What will happen to the flame after the flask is placed over the candle?" You already know something about the properties of water, air, and combustion. Choose a question and write your hypothesis. Your hypothesis will be your prediction about what will happen. Once you have developed your hypothesis, you can actually perform the experiment. **Safety note:** During this activity, tie back long gair, clear work area of flammable material, wear safety glasses, and properly extinguish and dispose of matches.

CAUTION

During and after the experiment, record as many observations as you can. Don't forget to use as many senses as possible, and to make both qualitative and quantitative observations. Drawing and labeling a diagram of the activity may assist in making observations and showing what happens. After you finish the experiment, you may be able to draw a conclusion (your answer to the question based on the evidence you gathered), but more than likely, you will just have new questions. Record your new questions for future investigations. If you have time, you may want to start over again with a completely different problem.