"When someone says science teaches such and such, [they are] using the word incorrectly. Science doesn't teach it; experience teaches it....It is very important that if you are going to teach people to make observations, you should show that something wonderful can come from them..."

Richard Feynman, addressing the National Science Teachers Association, April, 1966

Inquiry, Discovery, and Fun

Science is an enormous enterprise. Teaching even a part of it must be a process in thoughtful decisionmaking. Before 1955, the typical science education curriculum used a direct instruction format. It "emphasized knowledge of scientific facts, laws, theories, and applications" and used some laboratory activities to verify concepts previously covered in class. Since then, however, science has been taught with more *discovery-oriented instruction,* emphasizing "the nature, structure, and processes of science."[1]

The discovery-oriented approach integrates laboratory activities into classroom discussion and places greater importance on hands-on, as well as minds-on, activity. While time consuming, students learn how to solve problems in science, gain experience in scientific reasoning, and learn important science content. They experience, firsthand, the delight that new discoveries can bring.

Teachers are faced with the dual challenge of getting students interested in science and keeping them interested, while at the same time meeting achievement standards and expectations. In deciding how to teach science, teachers must ask themselves: What is important for students in my class to know, now? What can and should wait until later? What can they understand? What can be personally investigated by students rather than through media resources? What science materials and processes must students use in their investigations?

Science as inquiry

Scientific inquiry, the quintessential scientific activity, reflects the nature of science or perhaps more accurately, how scientists play the games of science. There are different ways of approaching problems and styles of inquiry in biology, chemistry, earth and space sciences, and physics. In addition, theoretical structures in the different disciplines influence what is observed and how it is observed.

The following is an analytic scheme that determines the inquiry level of activities,[2] each of which has its use in teaching and learning science.

1. *Confirmation*. The student follows a known, specific procedure to verify a concept or principle, or to learn a technique. The student knows what to expect.
2. *Structured inquiry*. The student does not know what results to expect beforehand. Procedures are outlined and the activities and materials provided are structured so that the student can discover relationships and make generalizations from the data collected.
3. *Guided inquiry*. The student is given the problem to investigate but develops the procedures and methods and discovers the concepts or principles.
4. *Open inquiry*. The student develops the problem and the procedure for solving it, interprets the data, and reaches evidence-based conclusions. Open inquiry requires students to use science concepts or principles.

Issues

- Research has shown that learning is enhanced when activities provide students with opportunities to use previously learned concepts and techniques in the process of discovering new ones.[3]
- In elementary science programs, it has been shown that disadvantaged students benefit the most from the use of inquiry in terms of science process, science content, attitude, creativity, and language development. Advantaged students benefit to a somewhat lesser extent except on content knowledge. Students in programs that stress content can be expected to outperform students in activity-based programs that stress process.[4] The reverse is true on process tests. All things being equal, you get what you teach for.
- A major complaint of American teachers regarding inquiry and meaningful tasks in the classroom, is that they do not have as much time to use these techniques as they would like. However, the Third International Math and Science Study (TIMSS) revealed that American eighth graders spend more school hours each year studying science than students in Japan, who routinely perform better in the subject. American eighth graders study science an average of 139 hours each school year. In Japan, students study science for 91 hours each year.[5]
- American science teachers, including Ohio's, typically are expected to teach far more science topics each year than Japanese teachers. American, and Ohio's, students also repeat more content from grade to grade.[6]
- There are several more reasons inquiry is not being given appropriate emphasis in the classroom. They include teacher preparation, classroom management and materials problems, a felt responsibility to prepare students for the next level of schooling and/or testing, confusion over the meaning of inquiry, allegiance to teaching facts, and a belief that inquiry instruction is successful only for above-average ability students.7 Many teachers also claim inquiry is too slow, the risk is too high, it is too difficult for most students, the approach lacks sufficient structure. They cite reading difficulties as a concern, as well as discomfort with the process and its expense.
- In Ohio, 33 percent of third- and fourth-grade teachers report having students conduct their own science experiments most or all of the time, while for seventh- and eighth-grade science teachers the number jumps to 40 percent.[8] In Japan, 77 percent of students report they conduct science experiments "often" or "almost always."[9]

Scientific inquiry, a dialogue between the natural world and the inquirer, must take into account the differences among students. Students differ in what they know and what they can do. They are less persistent than scientists, but equally as eager to explore their world when their interest is piqued.[10] Scientific inquiries are forms of argument and the emphasis should be on interpretation and the generation of new questions and discovery. Students are learning to participate in the scientific community as apprentices.

The learning environment should be reflective of the culture of science. It should foster involvement in doing science; ideas that are subject to what scientists refer to as "peer review" or critical and thoughtful evaluation by the class; and an emphasis on reasoning based on evidence. Most important, the focus of science education should be to introduce students not to definitions, formulas, and elements for memorization, but to the joy of watching, wondering, trying, and discovering.

Adapted from *Minnesota K-12 Science Framework,* SciMath[MN], 1998.

Endnotes

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10. See the sidebar about Bedford Road Collegiate Institute, in W. Gibbs and D. Fox, "The False Crisis in Science Education," *Scientific American, 281*(4), p. 91, 1999.

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This work was produced in whole or in part with funds from the U.S. Department of Education under Eisenhower grant number R168R50003. The content does not necessarily reflect the position or policy of the Department of Education, nor does mention or visual representation of trade names, commercial products, or organizations imply endorsement by the federal government.