Inquiry-Based Science

Strategies and techniques for encouraging inquiry in the classroom

UPON ENTERING A SCIENCE CLASSROOM, one should be able to observe an exciting learning environment in which students are wondering why and finding out. Students should be asking questions, resolving discrepancies, figuring out patterns, representing ideas, discussing information, and solving problems. This vision of science teaching is associated with the term *inquiry*.

Inquiry became prominent in science education in the late 1950s and early 1960s. The Biological Sciences Curriculum Study stressed the importance of inquiry in scientific investigations (BSCS, 1970) during the post-*Sputnik* era. More recently, the nation's science reform committees have released recommendations that stress the inclusion of inquiry into school science programs. *Science for All Americans* (AAAS, 1990) emphasizes that the teaching of science should be consistent with the nature of scientific inquiry. The *National Science Education Standards* (NRC, 1996) emphasize that inquiry is central to learning science. George DeBoer (1991, p. 206) conveys the significance of this idea in his assertion: "If a single word had to be chosen to describe the goal of science education during the 30-year period that began in the late 1950s, it would have to be inquiry."

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The purpose of this article is to define two approaches to inquiry-based science teaching and to describe many ways to conduct this type of science instruction.

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TWO APPROACHES TO INQUIRY

There are at least two ways to view inquiry—general inquiry and scientific inquiry. General inquiry refers to finding out about anything and everything. It does not specify the context or place limits on the approach. This open approach to finding out can be aligned with the teaching-science-by-inquiry approach that evolved from the post-*Sputnik* era of science curriculum programs in which students' attitudes, reasoning skills, habits of mind, and so on were stressed. General inquiry has also been referred to as "teaching science through inquiry" and "learning by discovery," and it was given a great deal of impetus by Jerome Bruner (1961).

In contrast to teaching science *by* inquiry (general inquiry) is the notion of teaching science *as* inquiry (scientific inquiry). Teaching science as inquiry stresses active student learning and the importance of understanding a scientific topic. Here the content becomes a critical aspect of the inquiry. During the time of the science reform movement of the 1950s and 1960s, James Rutherford called attention to the consensus on teaching science that was held among the profession—that science should be taught as a process rather than as content. He said that science is often taught as a body of content or as a set of techniques thought to resemble scientific inquiry. He considered neither approach appropriate because "the conclusions of science are closely linked with the inquiry which produced them and that is why we must take into account the close organic connections between process and content in science" (Rutherford, 1964, p. 80).

STRATEGIES AND TECHNIQUES

How can science teachers benefit from what has been written about inquiry in school science? Fortunately,

FIGURE 1.

Basic and integrated science process skills.

Process skill	Definition
Basic skill	
Observing	Noting the properties of objects and situations using the five senses
Classifying	Relating objects and events according to their properties or attributes
Space time relations	Visualizing and manipulating objects and events, dealing with shapes, time, distance, and speed
Using numbers	Using quantitative relationships, e.g., scientific notation, error, significant numbers, precision, ratios, and proportions
Measuring	Expressing the amount of an object or substance in quantitative terms, such as meters, liters, grams, and newtons
Inferring	Giving an explanation for a particular object or event
Predicting	Forecasting a future occurrence based on past observation or the extension of data
Integrated skill	
Defining	Following directions about what to do or observing and then developing statements that present operationally concrete descriptions of an object or event by telling one what to do or observe
Formulating models	Constructing images, objects, or mathematical formulas to explain ideas
Controlling variables	Manipulating and controlling properties that relate to situations or events for the purpose of determining causation
Interpreting data	Arriving at explanations, inferences, or hypotheses from data that have been graphed or placed in a table, frequently involving the mean, mode, median, range, frequency distribution, *t*-test, and chi-square test
Hypothesizing	Stating a tentative generalization of observations or inferences that may be used to explain a relatively larger number of events but that is subject to immediate or eventual testing by one or more experiments
Experimenting	Testing a hypothesis through the manipulation and control of independent variables and noting the effects on a dependent variable; interpreting and presenting results in the form of a report that others can follow to replicate the experiment

Taken from the American Association for the Advancement of Science: *Science: A Process Approach Commentary for Teachers.* Washington, D.C., 1965.

many strategies and techniques have been used successfully by science teachers and discussed in the literature, such as the following:

- Asking questions,
- Science process skills,
- Discrepant events,
- Inductive activities,
- Deductive activities,
- Gathering information, and
- Problem solving.

These methods can all be used during the study of a topic to help students understand fundamental science concepts within many relevant contexts that relate to students' lives (Collette and Chiappetta, 1994).

QUESTIONS

Questions can stimulate thought and action. They are at the heart of the inquiry process. There is nothing like a good question to get students thinking critically about the world in which they live.

Skilled science teachers are good at asking questions that cause students to generate their own questions. When students formulate questions of personal interest, they are more likely to engage in activities they find meaningful. Consider the following questions that a physical science teacher helped her students formulate to guide their investigations and realize the importance of chemistry in the production of athletic equipment and apparel:

- Do some basketball shoes help you to jump higher than other shoes do?
- Can you hit a baseball farther with an aluminum bat or a wood bat?
- Why do some swimsuits dry faster than others?
- Why do acrylic athletic socks cost more than all-cotton socks?
- Which is a better type of athletic T-shirt and why: all-cotton or cotton/polyester blend?
- Do certain brands of golf balls have more bounce than others?

SCIENCE PROCESS SKILLS

Science processes are also used to guide student learning. These skills focus on thinking patterns that scientists use to construct knowledge, represent ideas, and communicate information. Science process skills help students pose questions, state problems, make observations, classify data, construct inferences, form hypotheses, communicate findings, and conduct experiments. The acquisition and frequent use of these skills can better equip students to solve problems, learn on their own, and appreciate science. Figure 1 presents a list of many of the most commonly used science process skills in science programs.

DISCREPANT EVENTS

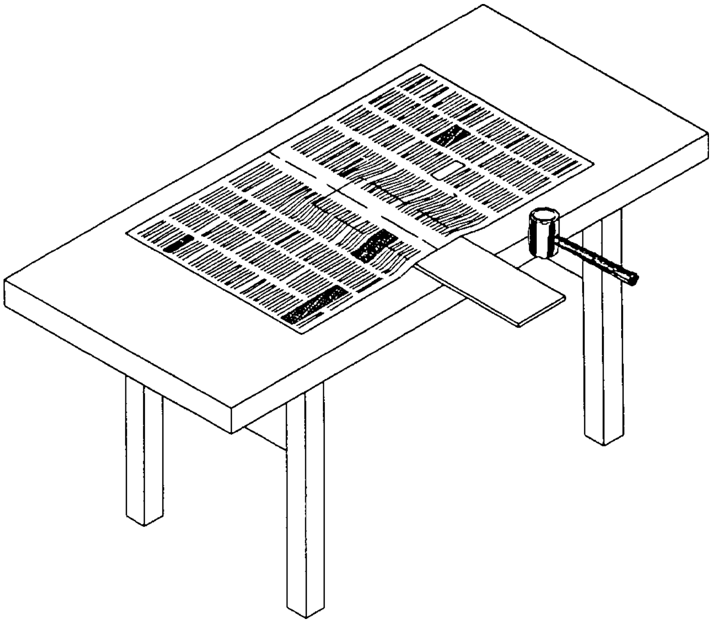
Whenever teachers get the attention of their students, they hold the potential to initiate learning. Introducing discrepancies can be a powerful way to begin the thinking and learning process. A discrepant event puzzles students, causing them to wonder why the event occurred as it did. Puzzlement can stimulate students to engage in reasoning and the desire to find out (Piaget, 1971). Discrepant events can be used to promote inquiry. Some of the most provocative discrepant-event demonstrations pertain to the laws of motion, center of gravity, Bernoulli's principle, density, and vacuum, to mention a few.

One of my favorite discrepant-event demonstrations is to place a roofing shingle (or a thin wooden board) under two sheets of newspaper (two sheets work best) as shown in Figure 2. The teacher shows students the roofing shingle and slips it under two sheets of newspaper. One end of the shingle should extend to the middle of the newspaper; the other end over the table as shown in the diagram. Students are asked to observe carefully as the teacher moves his or her hands across the newspaper from the center to the sides, flattening the paper and pressing it to the table. Students then are asked to predict what will happen when the teacher strikes the end of the shingle extending beyond the table with a hammer or rubber mallet. (The teacher should wear safety goggles and keep people out of the area behind the table because pieces of broken shingle may fly in that direction.)

Most students predict that the paper will fly off the table when the hammer strikes the shingle. They are surprised when the shingle breaks into pieces from the hard blow of the hammer and the paper remains on the table. Through a series of questions and answers, the teacher can help students realize that a partial vacuum is created when the blow from the hammer attempts to raise the shingle off the table, resulting in less air pressure under the newspaper than on its upper surface. This demonstration can lead to the study of air pressure and weather as well as other topics.

FIGURE 2.

Setup for discrepant event-demonstration.



INDUCTIVE ACTIVITIES

The inductive approach provides students with learning situations in which they can discover a concept or principle. With this approach, the learner first encounters the attributes and instances of an idea, then names and discusses the idea. This empirical-inductive approach gives students a concrete experience whereby they obtain sensory impressions and data from real objects and events. As a result, the learner can perceive certain stimuli and may be in a better position to make sense of a situation than if he or she had received abstract information about the particular phenomenon solely from a classroom lecture.

Empirically obtained information can be acted upon cognitively by the student and organized in the mind, where patterns may be discovered that are meaningful to the learner. This is how a concept is induced or discovered and how ideas are put forth to describe and explain a phenomenon. The teacher helps bring into the discussion the appropriate terminology for naming the concept or principle and defining it. The inductive approach, which can be thought of as an experience-before-vocabulary approach to learning, has been researched and written about extensively as "the learning cycle" (Lawson, 1995).

DEDUCTIVE ACTIVITIES

The deductive approach is the opposite of the inductive approach and is frequently used in science courses. With the deductive strategy, a concept or principle is defined and discussed using appropriate labels and terms, followed by experiences to illustrate the idea under study. The deductive approach is a vocabulary-before-experience model of teaching in which lecture and discussion precede laboratory or field work.

The deductive approach can be used to promote inquiry sessions and to construct knowledge. The first phase presents the generalizations and rules about the concept or principle at hand, and the second phase requires students to find examples of the concept or principle. Some teachers claim that the deductive approach is useful when introducing complex ideas that do not have perceptible attributes.

PHOTO BY LAUREN BEBEN

GATHERING INFORMATION

Scientific inquiry goes beyond constructing knowledge through hands-on activities. Much of the inquiry that scientists and engineers engage in involves reading and communicating with other people. Many of these professionals probably spend more time gathering ideas and information from literature sources and other individuals than they spend conducting laboratory or field work.

Science teachers must help students obtain information from a variety of sources at many points during the inquiry process. Information gathering can occur during the application phase of the learning cycle, when students are assigned to read about a topic, for example. Reading articles and reading the textbook may be appropriate at this point because students have had related firsthand experiences.

In other instances, the teacher may ask students to bring in newspaper clippings on a topic just as the class begins to study it. Another useful resource is the Internet. Students can search the World Wide Web for information that is available from many locations throughout the world.

PROBLEM SOLVING

The problem-solving approach to science instruction should not be forgotten because it has the potential to engage students in authentic investigations and develop their inquiry skills. This strategy can also make learning more meaningful and relevant for teenagers. Problem solving is often used synonymously with inquiry and science process skill reasoning (Helgeson, 1989, 1994). As such, this concept is associated with the nature of scientific inquiry as well as instructional methodology. One type of problem-solving approach centers on problems that are relevant to students' lives (Dewey, 1938). In this approach, students raise questions, plan procedures, collect information, and form conclusions. These learning experiences can be short or long in duration, taking up to several months to complete.

INQUIRY FOR ALL

With science reform under way, we have an opportunity to transform science classrooms into educational environments that buzz with active learners engaged in inquiry. Fortunately, science teachers have many strategies and techniques to guide student thinking and finding out, such as questions, discrepant events, process skills, inductive and deductive activities, information gathering, and problem solving. Using combinations of these pedagogical tools can make teaching and learning science exciting for teachers as well as students. Furthermore, inquiry-based instruction will help students construct fundamental science concepts that will help them better understand themselves and the world around them. ✧

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