An Inquiry Primer

by Alan Colburn

The science education community has embraced no idea more widely than "inquiry," or "inquiry-based instruction." In fact, developing an inquiry-based science program is the central tenet of the *National Science Education Standards.*[1] Similarly, Project 2061's *Benchmarks for Science Literacy* discusses scientific inquiry throughout, and even devotes a section to the topic.[2]

If inquiry is so important, then why aren't more teachers using it in their classrooms? According to one study, the most common reasons include

- confusion about the meaning of inquiry,
- the belief that inquiry instruction only works well with high-ability students,
- teachers feeling inadequately prepared for inquiry-based instruction,
- inquiry being viewed as difficult to manage,
- an allegiance to teaching facts, and
- the purpose of a course being seen as preparing students for the next level.[3]

Let's address some of these issues and explain how you can create your own inquiry-based classroom.

What is inquiry?

Perhaps the most confusing thing about inquiry is its definition. The term is used to describe both *teaching* and *doing* science. The *National Science Education Standards* note this dichotomy:

...Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.[1]

In this article, I will focus on inquiry as a teaching technique.

What is inquiry-based instruction?

My own definition of inquiry-based instruction is "the creation of a classroom where students are engaged in essentially open-ended, student-centered, hands-on activities." This definition embraces several different approaches to inquiry-based instruction, including

- *Structured inquiry*—The teacher provides students with a hands-on problem to investigate, as well as the procedures, and materials, but does not inform them of expected outcomes. Students are to discover relationships between variables or otherwise generalize from data collected. These types of investigations are similar to those known as cookbook activities, although a cookbook activity generally includes more direction than a structured inquiry activity about what students are to observe and which data they are to collect.
- *Guided inquiry*—The teacher provides only the materials and problem to investigate. Students devise their own procedure to solve the problem.
- *Open inquiry*—This approach is similar to guided inquiry, with the addition that students also formulate their own problem to investigate. Open inquiry, in many ways, is analogous to doing science. Science fair activities are often examples of open inquiry.
- *Learning cycle*—Students are engaged in an activity that introduces a new concept. The teacher then provides the formal name for the concept. Students take ownership of the concept by applying it in a different context. (See Figure 1 for a comparison of these different approaches to inquiry-based activities as applied to a unit on electrical circuits.)

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Is inquiry only for bright kids?

The short answer to this question is "No." The slightly longer answer is "Some inquiry activities probably are more effective for advanced kids." Read on, though, for a complete answer.

Over the last generation, many researchers examined learning from a Piagetian perspective. The researchers generally accepted these two conclusions:

1. Inquiry often requires hypothetical/deductive reasoning.
2. Concrete thinkers have a great deal of difficulty developing an understanding of abstract concepts.

Because most middle school students are concrete thinkers, they may have trouble using inquiry to explore abstract concepts. For example, inquiry-based instruction is great for showing students that chemical reaction rates depend on the concentrations of reactants. This is a concrete idea that students can investigate. On the other hand, inquiry-based methods are less effective for helping students understand how scientists explain the phenomena through the kinetic-molecular theory. Similarly, students' understanding of the concept of chemical reaction will vary. Students currently unable to understand some abstract ideas in chemistry will not create a deep understanding of this concept.

The more familiar the activity, materials, and context of the investigation, the easier it is for students to learn through inquiry. To help all middle level students benefit from inquiry-based instruction, the science education research community recommends

- orienting activities toward concrete, observable concepts;
- centering activities around questions that students can answer directly via investigation (which goes a long way toward insuring the activities are oriented toward concrete concepts);
- emphasizing activities using materials and situations familiar to students; and
- choosing activities suited to students' skills and knowledge to ensure success.

There is, however, a caveat to these recommendations. If the activities are too challenging, students will not learn content effectively. On the other hand, if the activities are too easy, students will not develop higher-level thinking skills. Maximum learning probably occurs when the activities are "just right"—cognitively challenging, but still doable. This implies, at least in theory, a classroom where students may not all be doing the same version of an activity at the same time.

FIGURE 1 **Forms of inquiry**

Structured inquiry—Students are given a step-by-step procedure, including diagrams for making various types of electrical circuits, including series and parallel. Questions prompt students to remove individual bulbs from each circuit and record their observations.

Guided inquiry—Students are given batteries, bulbs, wires, and other materials. Procedures instruct them to make a bulb light as many ways as they can using the supplies provided. Later, they are instructed to make two bulbs light, again, using different combinations of materials. Finally, students are asked to note what happens when they remove individual bulbs from their circuits.

Open inquiry—Students are given batteries, bulbs, wires, and other materials. They are instructed to investigate how bulbs light in electrical circuits.

Learning cycle—Students follow guided inquiry procedures, then the teacher discusses their findings. Concepts such as series and parallel circuits are introduced at this time. Students have experienced the concepts before their introduction. They eventually return to the lab to apply what they have learned to a new situation. For example, they could be given additional equipment, such as ammeters or voltmeters, to quantitatively investigate current and voltage in circuits.

What does the teacher do in a successful inquiry-based classroom?

Successful inquiry-based instruction is more than curriculum materials. Instead, the teacher is the key element in a classroom. He or she must possess certain attitudes and skills to encourage student success in the inquiry-based classroom. First, the teacher must support inquiry-based instruction. He or she must believe in the value of students having some element of control over what they will do and how they will behave. In addition, to be really successful the teacher needs formal operational thinking abilities, knowledge of the subject students are investigating, and some understanding of how students learn (to be able to respond effectively to student statements).

Research has also identified the following teacher behaviors that promote inquiry-based learning:

- Asking open-ended, or divergent, questions (such as "What are you doing?" "Tell me about what you're thinking?" and "What do you think would happen if…?");
- Waiting a few seconds after asking the questions, giving student time to think;
- Responding to students by repeating and paraphrasing what they have said without praising or criticizing (to encourages students to think for themselves, and to stop looking to the teacher for validation);
- Avoiding telling students what to do, praising, evaluating, rejecting, or discouraging student ideas and behaviors; and
- Maintaining a disciplined classroom.

How do you prepare for and manage an inquiry-based classroom?

Inquiry-based instruction often creates a new and complex classroom situation. Both students and teachers alike need time to gradually make a transition from the more classical confirmation-type activities and lectures to open-ended activities characteristic of inquiry-based instruction. The key point is to make changes in your teaching *slowly*, and not continuing on with something new until both you and your students feel comfortable.

A good place to start is by tossing out any preconstructed data tables that accompany lab activities. Have students figure out for themselves what data to record and how to record it. Initial confusion will eventually give way to success. Many teachers have noted that students initially resist open-ended instruction, but after several weeks they grow to like it, or at least appreciate its value.

Once students are accustomed to recording their own data, you can make other modifications. For example, provide them with only some of the procedures. Or, have students attempt the activity before you lecture on the subject matter involved. These simple changes eventually lead to true inquiry.

Can students learn facts in an inquiry-based classroom?

Most studies state that inquiry-based instruction is equal or superior to other instructional modes and results in higher scores on content achievement tests. However, some of these studies focused on students who were studying concrete content, which is the strength of inquiry-based instruction.

Perhaps this is one source of confusion about inquiry-based instruction being only for "advanced" students. This, of course, is a misconception. After all, elementary students learn quite effectively using hands-on, inquiry-based materials in the hands of a skillful teacher.

Still, research seems to support the idea that students can discover concrete concepts that lend themselves to direct observation through inquiry-based instruction. Students will be even more successful if you guide them toward understanding by implementing the kinds of teacher behaviors mentioned earlier in the article. However, there's no such thing as a teacher-proof curriculum, and there are lots of times when inquiry-based instruction is less advantageous than other methods. It's up to you to find the right mix of inquiry and non-inquiry methods that engages your students in the learning of science.

References

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