INQUIRY: Both

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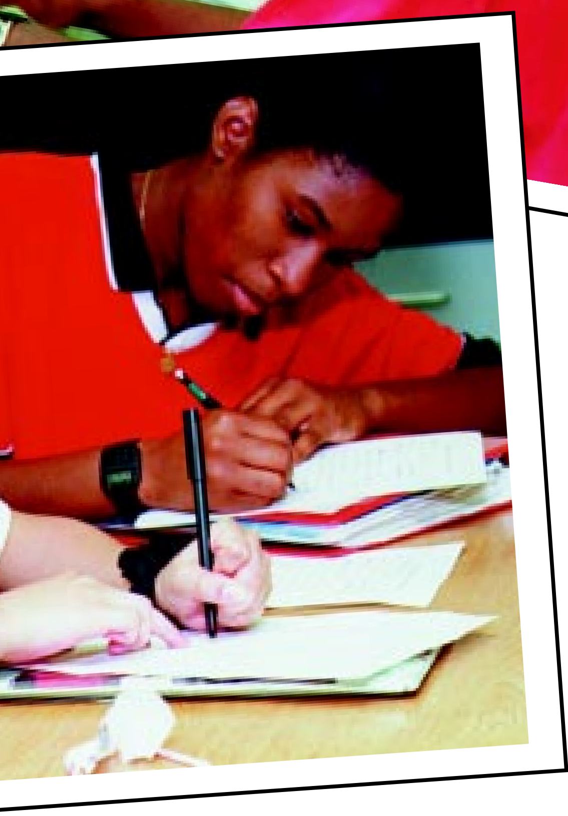
Means *and* Ends

Using the Standards to define inquiry methods and outcome



The method of teaching science as inquiry is revered by some teachers, considered a goal by many, and eschewed by others. For science teachers at all levels, especially those teaching in colleges and universities, inquiry approaches to learning and teaching are easy to talk about but difficult to carry out. Contributing to this dilemma is the fact that "inquiry" often means different things to different people.

Despite the variety of personal conceptions of inquiry, there appears to be a general consensus among science educators that inquiry is important. In fact, many say it is the most fundamental idea in learning and teaching science, and it is the position taken in the *National Science Education Standards* (National Research Council, 1996). The Standards emphasizes the pivotal role of inquiry by including "abilities necessary to conduct inquiry" and the "understanding of scientific inquiry" as integral parts of the science content standards. This article will help clarify the implications of understanding inquiry as part of content and examine the different facets of inquiry through the lens of the Standards.

BOTH MEANS AND ENDS

In the Standards, the term "inquiry" is used in two different ways. First, inquiry refers to teaching methods and strategies. Second, the Standards identifies scientific inquiry as *content* that students should understand and be able to do (Figure 1). When considering science as inquiry, most science teachers focus on teaching methods and strategies, while inquiry as content is poorly understood and not generally accepted as a learning outcome. Professor Robert Yager of the University of Iowa proposes that the inclusion of inquiry abilities in the content standards "opens the door for direct teaching of inquiry skills for their own sake." However, he contends that "students rarely see the importance of such skills [abilities] in any other way than in the context in which they were presented" (Yager, 1997, 8).

With respect to inquiry, one problem that plagues science teachers is their tendency to polarize nearly every issue and rush to take a stand of either/or. It is almost as if there is an unwritten law that teachers must be either totally committed to a particular teaching approach or totally against it—they must either teach science through inquiry, or use direct instructional approaches such as reading and lecture. Although the Standards clearly emphasizes inquiry, it does not claim that inquiry is the only

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worthy approach to teaching science. "Teachers should use different strategies to develop the knowledge, understanding, and abilities described in the content standards. Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry. Attaining the understandings and abilities of scientific inquiry cannot be achieved by any single teaching strategy or learning experience" (National Research Council, 1996, 23–24).

Another mistake teachers make is to confuse inquiry as a means and inquiry as an end or content outcome unto itself. Teachers have probably heard it said: Science processes (abilities to do scientific inquiry) are solely a vehicle to facilitate better understanding of science subject matter. From this perspective, inquiry is clearly a means and understanding of the subject matter is the end. Others proclaim with equal vigor: Process is more important than product; science subject matter should serve as the vehicle for the development of science process skills (abilities to conduct scientific inquiry). In this view, science subject matter is the means and inquiry is the end. In the Standards, inquiry is not presented solely as a means or an end. Instead, depending on the context, inquiry is both a means *and* an end.

INQUIRY AS AN OUTCOME

Consider Figure 2 as a way to organize thinking about inquiry as content, provide context for examples that help clarify means and ends, and avoid the problem discussed by Yager. If teachers were to take snapshots of current practices in science classrooms they would see several different scenarios. Most often they would observe classroom activities associated with the first row in Figure 2. Learning and teaching would be focused on attaining student outcomes in the science subject matter areas of physical, life, Earth, or space science. Mastery of science subject matter clearly would be in the foreground and the desired end. Teaching strategies and student use of inquiry would be the means, while outcomes (ends) for science as inquiry would be in the background. Students would be assessed to determine their levels of understanding of science subject matter.

In other snapshots, outcomes that develop the abilities necessary to do scientific inquiry would be evident. Students would be performing guided or structured laboratory activities and constructing explanations based on contexts and experiences in which they used strategies to gather data. They would be presenting and defending their explanations based upon logical analysis of evidence. Teachers would be taking time to explicitly emphasize one or more inquiry abilities used in the investigation. For example, teachers and students could examine how each inquiry ability contributed to a better understanding of the science subject matter. In this scenario, inquiry-ability outcomes, or ends, are moved to the foreground and science subject matter melts into the background as the context means. This shift of inquiry to the foreground is important because active involvement in well-designed and well-taught science investigations does not guarantee that students actually develop inquiry abilities. To ensure that students develop these abilities, post-lab discussions should include purposeful reflection on process as well as subject matter. This explicit instruction in inquiry abilities should be conducted in the context of relevant science content.

Occasionally, a snapshot might show students involved in full inquiries that originated with their own questions about the natural world. These investigations would result in explanations based on evidence and its logical analysis. The teacher would facilitate students' inquiries by asking questions about procedures and tests, guiding students to resources, and serving as a sounding board for scientific explanations. In student-originated and -directed inquiries, both inquiry abilities and subject matter understanding are outcomes. Ends and means alternate during the investigation; each alternately appears in the foreground and in the background. Assessment may take the form of an inquiry that is generated, designed, and conducted by students without teacher assistance. The scoring rubric is based on all of the abilities listed in the inquiry standard, which includes understanding of major science concepts.

FIGURE 1.

NSES content standards: science as inquiry for grades 9–12.

Abilities necessary to do scientific inquiry

- Identify questions and concepts that guide scientific investigations
- Design and conduct scientific investigations
- Use technology and mathematics
- Formulate and revise scientific explanations and models using logic and evidence
- Communicate and defend a scientific argument

Understanding about scientific inquiry

- Conceptual principles and knowledge guide scientific inquiries
- Scientists conduct investigations for a variety of reasons including discovering new aspects of the natural world, explaining recently observed phenomena, testing conclusions of prior investigations, and making predictions about current theories
- Scientists rely on technology to enhance the gathering and manipulation of data
- Mathematics is essential in scientific inquiry
- Scientific explanations must adhere to criteria such as logical consistency, rules of evidence, be open to questioning, and be based on historical and current knowledge
- Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communications among scientists

FIGURE 2.

Teaching and assessment strategies to support student attainment of content outcomes.

NSES content outcomes	Teaching strategies	Assessment strategies
Physical, life, and Earth science concepts	Guided or structured lab investigations focus on the development of a science concept involving the use of one or more inquiry abilities.	Measures to assess understanding of science concepts—may include performance assessment.
Abilities necessary to do scientific inquiry (See Figure 1 for a description of specific inquiry abilities)	Guided or structured lab investigations focus on a science concept. Students present and defend their explanations. Students conduct a full inquiry stemming from their questions and resulting in an explanation based on evidence.	Students conduct a task in which they use their data to form an explanation. Students conduct an inquiry without direction or assistance. A rubric lists specific inquiry abilities.
Understanding about scientific inquiry (Figure 1)	Post-lab discussions reflect on how specific abilities were used and what they have in common with the way scientists conduct investigations. Students read and discuss historical case studies of scientific inquiry (for example, Darwin, Galileo, and Lavoisier).	Given a brief account of a scientific discovery, students are asked to describe the use of logic, evidence, criticism, and modification.

Finally, teachers would look for a snapshot of a classroom in which students are reflecting back on several related or linked investigations and comparing their own use of specific inquiry abilities with the way scientists conduct investigations. Students might read or the teacher might present related historical case studies of scientific inquiry and discovery. Afterward, students discuss the question investigated, how the scientists collected and used evidence, how scientists developed an explanation, the role of skepticism, how modifications were made based upon new information, and how the scientists defended their explanation in the science community. Students can draw parallels between their own science inquiries and those of scientists at work. This explicit learning and teaching is conducted in the context of relevant and meaningful science subject matter, and inquiry is both a means and an end.

So, how does this all come together? Science curriculum and instructional materials should be based on the logical and sequential development of fundamental science concepts and also should provide opportunities for students to develop understandings about inquiry and abilities to conduct scientific inquiry. But teachers do not have to meet all of these objectives in one lesson, at one time, or in one class period.

ACHIEVING IT ALL

Science teachers can select strategies that support student attainment of both science subject matter and science as inquiry outcomes. Assessments should be consistent with the outcomes—both scientific inquiry and science subject matter. Guided and structured investigations should be based on engaging questions about the natural world. These questions can come from instructional materials, the teacher, and from the students themselves. The source of questions may be less important than their ability to mentally engage the students and encourage them to take intellectual ownership of the questions.

Standards-based thinking provides a positive perspective for improving the quality of student learning in the science classroom. Teachers should keep in mind that while scientific inquiry is both a means and an end, teachers are responsible for balancing the desired content outcomes. Teachers should not be seduced into taking an either/or stance with respect to process versus product. It is best to consider scientific inquiry from the perspective of both means and ends. After all, school science and science by scientists is both! ✧

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