Teaching **High School Science** Through **Inquiry** and **Argumentation**

2 Edition

Douglas Llewellyn

Hawker Brownlow
EDUCATION

© Hawker Brownlow Education

Contents

© Hawker Brownlow Education

© Hawker Brownlow Education

© Hawker Brownlow Education

© Hawker Brownlow Education

specific for that grade. These standards help science educators define what students should know and be able to do. Reading the inquiry standards for grades 9–12 can help develop an understanding of the abilities necessary to do scientific inquiry.

At the high school level, according to the NRC (2000a), students should be able to

- identify questions and concepts that guide scientific investigations,
- design and conduct scientific investigations,
- use technology and mathematics to improve investigations and communications,
- formulate and revise scientific explanations and models using logic and evidence,
- recognize and analyze alternative explanations and models, and
- communicate and defend a scientific argument. (p. 19)

Although the *National Science Education Standards* have been replaced by *A Framework for K–12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (*NGSS;* NRC, 2013), science teachers should still become familiar with the *National Science Education Standards.* The Standards can be purchased in softcover, read online, or downloaded as a free PDF version from the National Academy Press (www.nap.edu/bookstore). Readers may also be interested in an excellent accompanying text, *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (NRC, 2000a) that offers stories of high school teachers engaging students in inquiry (see Resource A, the "Print Resources on Scientific Inquiry and Argumentation" section).

What *A Framework for K–12 Science Education* and the *Next Generation Science Standards* Say About Inquiry

In 2012, the National Research Council (NRC) published *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* According to the NRC (2012), the Framework identifies a general description of the science content and skill development that all U.S. students should be familiar with by the end of grade 12. The Framework also lays the foundation for the development of the *Next Generation Science Standards* in 2013.

Like the *NSES,* the Framework identifies and articulates the core ideas in science around which standards should be developed in life sciences, physical sciences, earth and space sciences, and engineering and technology. In addition to the core ideas, crosscutting concepts and science practices are identified and sequenced across the K–12 level. Each of these three dimensions of the Framework inaugurates the vision of the scope and nature of science education as a crucial aspect in fostering scientifically literate citizens for the 21st century. And as with the *NSES,* inquiry, once again, plays a significant role in the advancement of scientific literacy.

Inquiry and Scientific Practices

In the Framework and the *Next Generation Science Standards* the term *practices* is used to represent the term *inquiry.* However, the practices identified in the Framework still strongly reflect certain common qualities to problem-solving and inquiry approaches. According to the NRC (2012), the practices in the Framework document reflect the work that scientists and engineers actually engage in as part of their work. The eight essential practices of science include the following:

© Hawker Brownlow Education

next, download a free copy of the Framework at www.nap.edu/catalog.php?record_id=13165 or view the *Next Generation Science Standards* at www.nextgenscience.org.

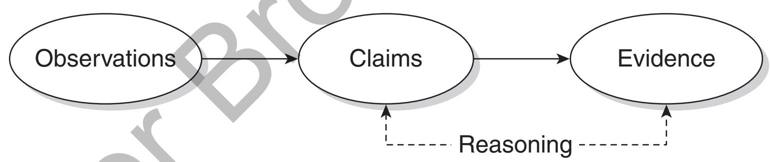
The National Science Teachers Association publishes a summary guide called the *Reader's Guide to A Framework for K–12 Science Education* (Pratt, 2012). That document can be downloaded free at www.nsta.org/store/product_detail.aspx?id=10.2505/9781936959778&lid=ngs.

Together with forming explanation and justifying and defending arguments, all the practices from the Framework and the *NGSS* place a strong emphasis on fostering reasoning skills. We will now turn our focus toward how communicating arguments encourages critical reasoning.

Different Types of Reasoning

There are many categories of reasoning patterns recognized in mathematics and science. Several of these include Jean Piaget's concrete and formal reasoning skills such as conservation reasoning, serration-serial ordering, proportional reasoning, and correlational reasoning. Others contrast inductive and deductive reasoning. Since classroom teachers are not expected to be experts in identifying reasoning patterns, this chapter does not address those capacities—that discussion is left to those who study specific reasoning concepts. This section, however, addresses reasoning as the link between claims and evidence and encourages scientific reasoning skills as an aspect of science inquiries as shown in Figure 2.2.

Figure 2.2



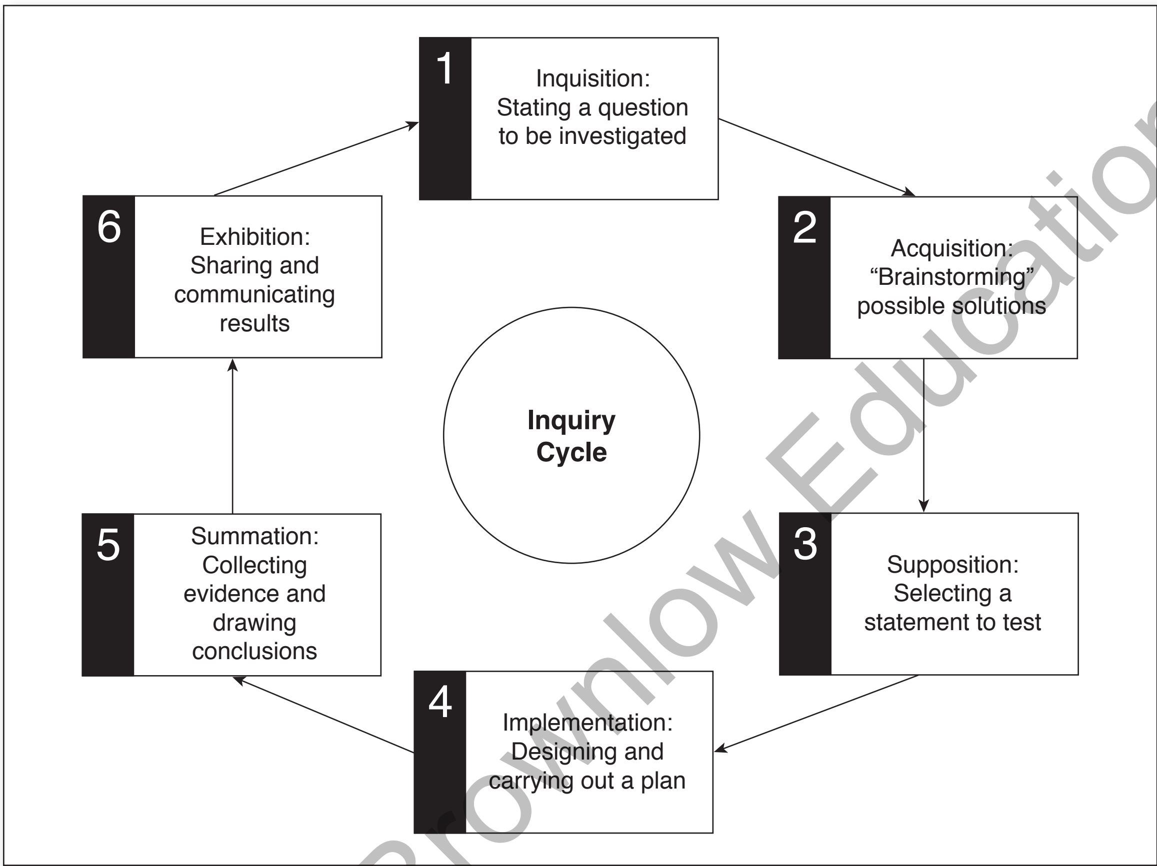
Flaws in Scientific Reasoning

Despite our best efforts in fostering critical-thinking skills, students sometimes exhibit flaws in their logic, reasoning, and arguments. When an individual's argument is faulty, usually those flaws can be (a) an indication of inexperience in using reasoning skills, (b) misconceptions in previously held naive notions about the topic being explored, or (c) backing a claim with another claim. Since research tells us that each student brings to school preconceptions and varying degrees of reasoning skills and abilities to justify his or her theories about how the natural world works, each individual has a unique and distinct cognitive framework that filters reasoning abilities. For that purpose it become necessary for teachers to provide sufficient "think-time" for a student as he or she states an explanation. According to Michaels, Shouse, and Schweingruber (2008),

> In order to process, make sense of, and learn from their ideas, observations, and experiences, students must talk about them. Talk, in general, is an important and integral part of learning, and students should have regular opportunities to talk through their ideas, collectively, in all subjects. (p. 88)

© Hawker Brownlow Education

Figure 3.4 The Inquiry Cycle



© Hawker Brownlow Education

During the supposition phase, students consolidate the information under study to propose a testable statement or an "I think" statement. This phase may include stating one or more hypotheses to test the question being investigated.

During the implementation phase, students design a plan to test their proposed statement(s) and carry out appropriate procedures.

During the summation phase, students record and analyze their observations and data to answer to the original "What if" statement. They also look for patterns and relationships among the variables and extract evidence from the data to make appropriate claims.

Finally, during the exhibition phase, students communicate and justify their question, claim, and evidence to the class. New information and explanations are presented in the form of argument-based written reports, poster displays, argument-based oral presentations, and PowerPoint presentations.

The inquiry cycle can serve as a general format for teachers planning inquiry and argument-based investigations for their students. We should be reminded that the model serves as a general approach to raising and answering questions. Following the inquiry cycle, students often enter and reenter the phases at different aspects of their inquiry process. Thus the cycle serves as a model to guide students through their science inquiries and investigations.

© 2014 Hawker Brownlow Education • 9781743307533 • CO7533

9. Posing "What if . . ." and "I wonder . . ." questions facilitates assimilation and accommodation.
10. Allowing students to work in groups to share and communicate knowledge through argumentation, and to test ideas and theories against one another, makes learning a personal and social experience.

Historical Perspectives of Constructivism

At many science education conferences, workshops, and seminars on learning theory, one of the most talked about topics among science educators today is constructivism. Although the theory is not new, recent developments about how the brain works have strengthened the constructivist model. Aspects of constructivist principles date back to the works of Socrates, Plato, and Aristotle. Perhaps the first recorded constructivist was the Neapolitan philosopher Giambatista Vico, who worked in the field as early as 1710. Have you ever posed a question to a student and heard the response, "I know it, but I just can't explain it"? According to most constructivists, we know something only when we can explain it.

We begin our look at the process of learning by turning our attention to epistemology—the structure and origin of knowledge. We must first understand how knowledge is engendered to appreciate the potential of inquiry and argumentation as a means of attaining and negotiating conceptual meaning through scientific investigations. By first developing a sound understanding about how high school students learn science, we take a quantum leap into the practice and implementation of inquiry as a constructivist-based teaching strategy.

The latter half of the 20th century produced an interest in understanding cognitive psychology and metacognition. During this century, recent advances in medicine and research have opened the door to understanding how the brain works in attaining new knowledge. The latest generation of theorists argues that learning develops within multiple structures of the brain. This new era has affixed merit to the theory of constructivism. Next, we will examine the research and philosophy of several cognitive scientists.

John Dewey

John Dewey (1859–1952) is considered one of the twentieth century's most influential educational reformers and was one of the first modern American constructivists. From his research at the University of Chicago, Dewey (1900, 1902, 1916) believed that learning and experience go hand in hand and that knowledge emerges from a personal interaction between the learner and the external environment. He felt that posing problems of significant interest that draw upon the student's prior knowledge activates the learning process. Dewey felt that teaching should be an active process, including solving problems that interest students. He believed that problems posed to pupils too often involved the interests of the teacher rather than the interests of the students. Dewey's model for learning also incorporates the student's prior knowledge. He insisted that subject matter requires relevance to the learner. His teachings have also had a profound influence on environmental and outdoor education. Therefore, many inquiry science teachers align themselves to Deweyian philosophy.

© Hawker Brownlow Education