TEACHING SCIENCE THROUGH INQUIRY-BASED INSTRUCTION

THIRTEENTH EDITION

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Pearson

Thirteenth Edition

Teaching Science Through Inquiry-Based Instruction

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THIS BOOK IS DEDICATED to the memory of Dr. Joel E. Bass, who passed away after completing the eleventh edition. Dr. Bass inspired many science educators during his 35 years at Sam Houston State University, and he touched thousands more through his work on the ninth, tenth, and eleventh editions of *Teaching Science as Inquiry.* Joel, your passion for teaching science lives on in our memories, and in this book.

THIS BOOK IS ALSO DEDICATED to the memory of Dr. Arthur A. Carin, author of the first eight editions of the book (then called *Teaching Science as Discovery*). Through five decades of exemplary writing, teaching, research, and service, Dr. Carin had a significant, positive impact on science education. Art, you are remembered and honored.

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Preface

Teaching Science Through Inquiry-Based Instruction provides theoretical and practical advice to elementary and middle school teachers who are expected to help their students learn science. Written during a time of substantive change in science education, this book strives to help readers connect their own prior science education experiences, and their understanding of what school administrators have traditionally expected of teachers who teach science in elementary and middle school classrooms, to the new vision of three-dimensional, student-centered, inquiry-based teaching and learning. For this reason, the book references, the *National Science Education Standards* (NRC, 1996), which still provides the basis for many states' current science standards; *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), which builds on previous science education reform documents, including the NSES and contemporary learning theory; and the *Next Generation Science Standards* (NGSS Lead States, 2013), which were released in April 2013.

Many years of work and research in the science education community have provided a coherent, research-based vision for a new era of science education. This vision is encompassed in the *Next Generation Science Standards*, adopted by many states as we go to press. Reference to the *Framework*, and to the NGSS throughout this book, makes this edition applicable to educators in states that have adopted the NGSS and those that are still making decisions about revising state standards.

Text Organization

Important concepts and skills for new educators and guidance for those who are working to improve and accommodate the new demands of science teaching are addressed in the first ten chapters of this text. These chapters scaffold an understanding of current practices, concepts, and ideas necessary for effective science teaching in elementary and middle schools. They relate traditional methods of science instruction to the emerging strategies suggested by the NRC *Framework* and the *Next Generation Science Standards*.

Chapter 1*: Science and Science Education*, explores the nature of science, its importance in today's world, trends in science education, and national science standards. It discusses "What science is" and "What it means to do science" because it is difficult to effectively teach a subject unless you understand what that subject is and how it is applied.

Chapter 2*: Getting Ready for Inquiry Instruction* and Chapter 3: *Creating a Positive Classroom Environment* discuss initial concerns that both new and veteran teachers may have about science teaching. They include information about how to determine the important science concepts to teach, and discuss strategies that help create positive classroom environments where students are intellectually engaged with science ideas.

Chapter 4*: Learning Science with Understanding* presents contemporary learning theory that relates to science teaching and learning. The focus is on inquiry-based instruction, which is discussed along with its application in science classrooms.

Chapter 5*: Engaging in Inquiry-Based Instruction and Using the 5E Model* clarifies the nature of inquiry-based instruction and the importance of using an instructional model that supports constructivist learning through inquiry-based approaches. This chapter provides foundational information about the 5E instructional model, which is referred to and applied throughout the text. It identifies the essential features of classroom inquiry and elaborates on the 5E instructional model, its phases—Engage, Explore, Explain, Elaborate, and Evaluate—and the functions of each phase. Guidelines express what teachers say and do and what students say and do during each phase of this model.

Chapter 6*: Effective Questioning* explains how teachers first teach students how to ask scientific questions that are testable, and then discusses how questioning changes throughout inquiry from questions that are investigated during the inquiry to those that guide discussions leading to explanations and student learning. Using a variety of questions and approaches, a shift from closed questions to open questions promotes student reasoning that leads to conceptual understanding.

Chapter 7*: Assessing Science Learning* covers appropriate shifts in assessment of inquiry from only assessing student factual knowledge to assessing students' scientific reasoning and what students know, understand, and are able to do to provide evidence of mastery. Both formative and summative assessment strategies are discussed.

Chapter 8*: Using Technology Tools and Resources for Science Learning* provides a review of appropriate technology that teachers can use to support data collection during inquiries, along with an explanation about the relationship between science and technology and their link to STEM (Science, Technology, Engineering, and Mathematics) instruction.

Chapter 9*: Connecting Science with Other Subjects* provides an overview of the important links between mathematics and English language arts standards to science education standards. Additionally, connections are made to issue-based learning in social studies and science as a component of STEM teaching and learning.

Chapter 10*: Making Science Accessible for All Learners* focuses on making meaningful science education available for all students, including those with special needs and disabilities, those who need assistance with language acquisition, and those who are identified as needing individual education plans.

The initial ten chapters incorporate valuable pedagogical elements that support readers. They include:

- Clear learning goals provided at the beginning of each chapter that link to each chapter section.
- An introduction to invite the reader to access their prior knowledge.
- Narrative text that develops each learning goal along with self-assessments and embedded links to engage the readers with actual teacher examples.
- Exploration activities interwoven through the text narrative and designed to encourage readers to grapple with science concepts and classroom decision-making.
- Reflective questions, at the end of each Exploration, challenge readers to determine how to help students make connections among the investigations or inquiry activities they do, and also push readers to practice making instructional decisions.
- Links to point-of-use videos (in the Pearson eText) to see science classrooms in action. Marginal notes link e-readers to video segments that illustrate STEM (Science, Technology, Engineering, and Math) teaching, inquiry-based teaching, questioning strategies, cooperative grouping, and the use of technologies.
- Vignettes also present various examples of classroom teachers and the execution of science activities. Online quizzes at the end of each section of the chapter enable readers to self-evaluate their understanding while progressing through the text.
- At the end of each chapter, there is a summary of key ideas organized by Learning Goals and related discussion questions, as well as questions designed for the reader to use during field experiences.

An appendix presents details about the science process skills that have long been an important element of science education. Appendix A is designed to familiarize the reader with science process skills including: observing, measuring inferring, classifying, communicating, predicting, hypothesizing, and experimenting, It includes definitions, descriptions and explanations, and examples of science process skills used in elementary and middle school science classes.

Unique Science Activities Sections

At the end of this text, the reader will find suggested activities for teaching science through inquiry-based instruction, using a three-dimensional approach that reflects the influence of NGSS in organizing inquiry-based activities and incorporating engineering and design skills.

Five additional sections of this enhanced Pearson eText relate to activities designed to support science learning for elementary and middle school students. Section I provides an introduction to the scope and structure of the activities included in the other sections that are organized by the domains of the NGSS Disciplinary Core Ideas: physical sciences, Earth and space sciences, life sciences, and engineering design.

Each of the activities includes and models a complete 5E lesson, including all of the phases of the inquiry-based learning cycle. Each activity begins with a *Framework* context box that specifies Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas emphasized within that lesson. The specific, lesson-based, learning targets and success criteria are identified along with the related performance expectations found in the NGSS documents. The activities themselves are not meant to be a complete lesson but should be a starting point for teachers as they plan for inquiry-based instruction. The activities can be used to:

- Illustrate and expand on learner understanding of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas since they provide examples of the three dimensions of the new science framework that can be intertwined in a lesson.
- Model the 5E lesson procedures, engaging students in constructivist inquiry. The 5E instructional model, clarified in Chapter 5 of the text, serves as a framework for ALL of the activities. By keying each activity to the three dimensions of the framework, the text further provides new and experienced teachers with a solid foundation for science teaching.
- Provide a comprehensive view of how *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* can be used to organize curriculum and inform instruction in elementary and middle school science.
- Demonstrate for readers how to set up activities that weave science and engineering design into their science teaching.
- Prepare for teacher preparation exams and state licensure.
- Draw on a bank of inquiry-based activities that provide significant and critical models for lesson planning.

Enhanced Pearson eText[1]

Teaching Science Through Inquiry-Based Instruction is available as an enhanced eText exclusively from Pearson. The Enhanced Pearson eText provides a rich, interactive learning environment designed to improve student mastery of content with the following multimedia features:

- ***New Classroom Videos*** illustrate STEM (Science, Technology, Engineering, and Math) teaching, inquiry-based teaching, questioning strategies, cooperative grouping, and the use of technologies.
- ***Check Your Understanding*** quizzes are included in each chapter and allow students to gauge their understanding of key learning outcomes.
- An ***Activities Library*** allows students to search suggested activities using specific criteria (more details below).

Activities Library

In the Pearson eText it is even easier to search for a specific activity. Click on "Activities Library" in the left navigational bar in your eText to explore activities sorted by disciplinary core ideas, scientific and engineering practices, and crosscutting concepts. Clicking on the "Browse Full Library" option will sort all of the activities by appropriate grade level.

You can also do a keyword search using the search box available at the top of the Activities Library page. Each activity is coded by useful criteria, for example, by title, grade level, component idea, or scientific and engineering practice, making it extremely easy to find exactly what you need.

All of the activities are downloadable and printable, so you can save what you'll need for use in your classroom.

[1] Please note that eText enhancements and Activities Library are only available through the Pearson eText and not through eTexts provided by third-parties. The Pearson eText App is available for free on Google Play and in the App Store. Requires Android OS 3.1 – 4, a 7" or 10" tablet, or iPad iOS 5.0 or newer.

Support Materials for Instructors

The following resources are available for instructors to download on www.pearsonhighered.com/Educators. Instructors enter the author, title of the text (13e), or the ISBN of this book and click on the "Resources" tab to log in and download textbook supplements. New users will need to request access to the Instructors' Resource Center in order to download these useful supplements.

Online Instructor's Resource Manual and Test Bank

Free to adopters is an Instructors Manual that provides chapter-by-chapter ideas and resources for enriching each class meeting. Within the Instructors' Manual, there is a test bank, as well as suggested activities, objectives and overviews, suggested readings, and other tools for teaching.

PowerPoint Slides

New to this edition are chapter-by-chapter PowerPoint slides that present key concepts and big ideas. These PowerPoints are also available via the Instructors' Resource Center.

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Terry L. Contant

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I am also grateful for the support and patience of my best friend Michael King who understood the importance of meeting deadlines for this project even when they happened during our vacations. My family has also been there to support me as the work continued into long evenings, holidays, and weekends. I want to thank my sons Matt and Josh, my daughter-in-law Tia, my precious grandson Gavin.

Anne L. Tweed

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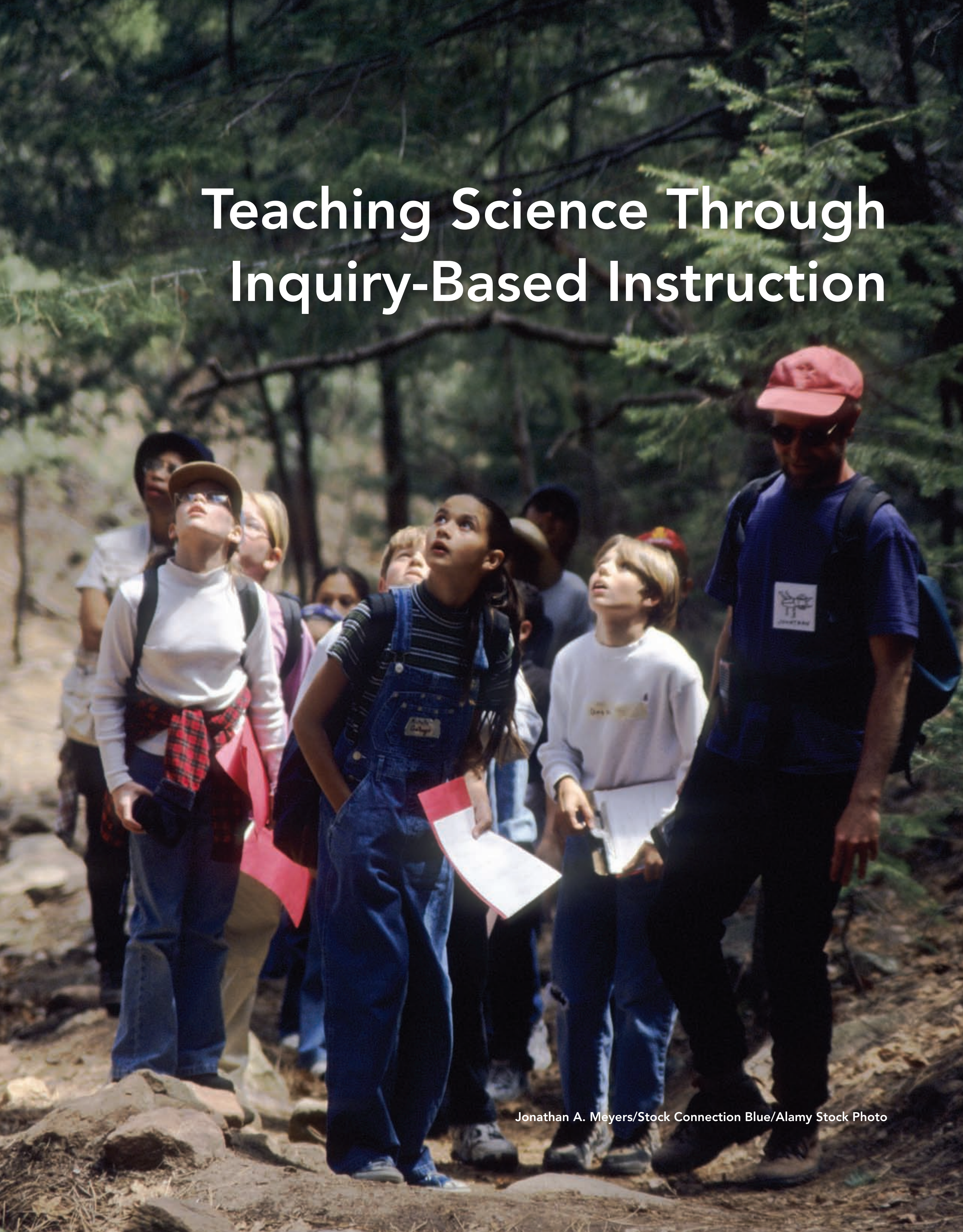
Teaching Science Through Inquiry-Based Instruction



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Curiosity and Learning Science

AN INTRODUCTION

"Every year, 5 million children enter kindergarten armed with one word: 'Why?' They continuously ask questions in what seems like an unending loop. On the other side, parents, caretakers, and teachers do their best to come up with answers to manage this kiddie-inquisition. Yet there's no allaying it. Behind that question hides another. And another. And another. And another. As painful as this activity may be for adults, the process is important for children. Their brains are busily creating pathways. They are trying to understand how things work. They are learning—and learning how to learn.

Early-childhood research says that we have a curious scientific nature from the beginning of life. A recent study says that toddlers and preschool children behave like scientists. They are observant and curious as they soak in information about the world. Like little experimenters, they light up when unpredictable events happen, and they can decipher causal relationships.

But something happens as children get older. That curious nature fades, and those 'why' questions grow silent. Students no longer feel that it's OK to ask questions. Somehow, they fail to remember that they started off curious. They fail to remember their inner scientists" (www.edutopia.org/blog/a-case-for-curiosity-ainissa-ramirez).

Why does this happen? Numerous research studies and articles point to the connection between curiosity and student motivation to learn. From the quotation you just read, which appeared in a blog written by Ainissa Ramirez in February 2016, inviting students to ask questions and to be curious should be an essential goal for both science and science teaching. As you learn about inquiry-based instruction in this course, we encourage you to think about how you can support curiosity in your classroom. Remember that students will stay curious when we show them how important it is to wonder about science phenomena and to ask questions. Embrace the process of asking questions and inviting students to generate questions as part of everyday learning. Staying curious leads to both creative and critical thinking abilities, which are foundational student skills leading to a love of science. All kids are naturally curious! If science literacy is our goal, then inviting students to ask questions is a science practice that matters!

chapter

1

Science and Science Education

Hero Images/Getty Images

LEARNING GOALS

After reading this chapter, you should understand that . . .

1. Science is observing, analyzing, and investigating to learn how the natural and physical world works.
2. Educational initiatives related to science education increasingly emphasize student conceptual understanding and student-centered, inquiry-based learning.
3. The *Next Generation Science Standards* provide guidance on what to teach and how to teach to provide students with high-quality science education.
4. It is important for teachers to develop lessons that are inquiry-based and initiate conceptual change.

What do you think about when you hear the terms ***Science*** and ***Science Education***? Try this free-association exercise. When you think about the term *science*, what are the first three ideas that come to your mind? Record your thoughts using words or drawings. Repeat this activity when thinking about *science education*. Reflecting on your current thinking about these terms will provide a context for the ideas developed in this chapter.

It is important that you are clear about the differences between science and science education and what it means both to you and to your students. This is a good place for us to start since the two ideas are closely linked. Look at Table 1.1 and compare your ideas to the ones expressed in the table. What do you notice? What additional questions arise when looking at the table?

Now that you have more knowledge about these terms, let's get started. In the twenty-first century, it is important for teachers responsible for helping students learn science to understand the nature of science and the educational standards designed to guide science learning. This chapter presents information and ideas to help you develop these important understandings so that you will be prepared to teach science well.

What Is Science?

Many times on the first day of school, I've asked students the question, "What is science?" I've heard some interesting responses over the years, depending on the age and experiences of the students or adult learners, including: "Science is what scientists do"; "Science is biology, chemistry, and physics"; "Science is hard"; "Science is easy"; "Science is fun", "Science is about doing investigations"; and as a sad commentary on the elementary school schedule, "Science is taught opposite of social studies."

When the word *science* entered the English language from French during the fourteenth century, it referred to "the knowledge (of something) acquired by study," and to "a particular branch of knowledge." It is thought to have been derived from the Latin words *scientia* "knowledge" and *sciens* "to know," or "to separate one thing from another, to distinguish" (*Online Etymology Dictionary*). Table 1.1 lists common attributes of both science and science education. In Exploration 1.1 you have an opportunity to further investigate current definitions for the term science.

TABLE 1.1 Attributes of Science and Science Teaching

Common Attributes of Science	Common Attributes of Science Teaching
Science is more than a collection of facts.	Science teaching is more than lecturing or doing hands-on activites.
Science knowledge is made up of current understandings of our natural systems and is subject to change.	Knowledge of science teaching is based on current understanding of effective teaching and learning and is subject to change as new research becomes available.
The body of scientific knowledge is constantly being revised, extended, and refined.	The body of knowledge about science teaching and learning is constantly being considered, expanded, and refined.

EXPLORATION 1.1

Definitions of Science

Today, there is no single accepted definition of *science*. Use your favorite web browser to find at least four statements that answer the question: *What is science?* Record the statements you select, and cite your sources.

Working alone or with several of your peers, compare, contrast, and synthesize the statements to develop your own definition for *science*.

Reflection Questions:

1. What similarities do you find in all of the statements you selected?
2. How do these statements differ?
3. Based on what you have discovered, which statement do you consider to be the "best" definition of science? Why?
4. What is your current definition of science, in your own words?

Since you may soon be teaching science to children and/or adolescents, really understanding what science is would be beneficial. You probably realize by now that developing a precise definition of *science* is not that simple. So, rather than just defining it, consider the key characteristics of science listed in Table 1.2.

Notice that the left column in Table 1.2 lists typical characteristics of inquiry-based activities that are science. If an inquiry-based activity exhibits all or most of these features, it is reasonable to call it science. Things that don't exhibit most of these characteristics should not be considered to be science.

Other ideas that are often included in a discussion of the "**nature of science**" are

Listen to Nancy Michael's goals for science learning in her 2nd grade class. Consider how they relate to your ideas about what science is.

- Science is based on the premise that the things—**phenomena** in nature—and events that happen occur in consistent patterns that are comprehensible through careful, systematic study.
- Science is a process for generating knowledge. Scientific knowledge is simultaneously reliable and tentative. Having confidence in scientific knowledge is reasonable while realizing that such knowledge may be updated or modified in light of new evidence or reconceptualization of prior evidence and knowledge. For example, the idea that atoms are the smallest particles was changed when subatomic particles were discovered. Or, for another example, the theory of continental drift was replaced with the plate tectonics theory once we had evidence of what occurs along plate boundaries.

TABLE 1.2 **Some Characteristics of Science with Examples and Non-Examples**

Characteristics of Science	Example	Non-Example
It focuses on explaining the physical and natural (not the supernatural) world.	Investigating why tides vary in height at different locations along the shore.	Investigating the effect of prayer on the growth of crops during droughts.
It involves testable ideas using investigation and inquiry approaches.	Investigating the relationship between the number of coils of wire in an electromagnet and its strength.	Investigating what the world would be like without sunlight.
It relies on evidence determined by observation and analysis.	The investigators based their conclusions on statistically significant evidence.	The investigators based their conclusions on their beliefs.
It involves the scientific community in communication and argumentation processes.	The investigators presented their research to their peers at an international conference and appreciated the feedback they received.	The researcher refused to publish or share his results.
It utilizes scientific behaviors to intellectually engage in the systematic study of a question or problem.	The investigators reported their results, even though their evidence was insufficient to support their hypothesis.	The investigators deleted data from their data set in order to get the results that they had predicted.

Source for left column: "What is science?", 2012.

Appendix H, "Understanding the Scientific Enterprise: The Nature of Science," in the *Next Generation Science Standards*, presents grade-level understandings about the nature of science for each of these themes. It is available online at www.nextgenscience.org/next-generation-science-standards.

- There is an expectation that scientific results can be replicated by other investigators when they follow similar procedures. When this does not happen, the validity of the initial results and inferences is questioned. In 2011, physicists were astonished when they found evidence of neutrinos (one kind of subatomic particle) traveling at speeds greater than the speed of light. Before immediately reconsidering Einstein's theory—that matter cannot travel faster than light—to be invalid, other researchers repeated the experiment. The initial results were not confirmed by other research teams, and it was discovered that an equipment malfunction (a loose connection) explained the original, unexpected findings.
- "Science is characterized by the systematic gathering of information through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. The principal product of science is knowledge in the form of naturalistic concepts and the laws and theories related to those concepts" (National Science Teachers Association [NSTA], 2000).
- While science and technology do impact each other, basic scientific research is not directly concerned with practical outcomes, but rather with gaining an understanding of the physical and natural world for its own sake.
- The scientific questions asked, the observations made, the evidence gathered, and the conclusions in science are to some extent influenced by the existing state of scientific knowledge, the social and cultural context of the researcher, and the observer's experiences and expectations. After all, scientists are human.

Scientists display certain attitudes and **habits of mind** when doing science. During science class, you should model these and explicitly teach them, since children should also acquire and display scientific attitudes and habits of mind as they do science. Some of these attitudes are

- ***Curiosity***—an enduring interest and fascination about the physical, natural, and human-constructed worlds is a vital, yet personal, ingredient in the production of scientific knowledge.
- ***Desire for Knowledge***—an urge, even "rage" (Judson, 1980), to know and understand the world (intrinsic motivation to learn).
- ***Placing a Priority on Evidence***—using data as the basis for testing ideas, engaging in analysis to determine evidence, and respecting scientific facts as they accrue.
- ***Willingness to Modify Explanations***—changing initial conceptions and explanations when the evidence suggests different ones.
- ***Cooperation in Investigating Questions and Solving Problems***—working in collaboration and more importantly, cooperatively—with a shared goal—with others, is fundamental to the scientific enterprise.
- ***Honesty***—presenting data as they are observed, not as the investigator expects or wishes them to be (National Center for Improving Science Education, 1989).

Teachers can **engage children in investigations and inquiry-based learning** that provide opportunities to develop the same habits of mind scientists exhibit. As you watch this video clip, identify the scientific attitudes that teachers encourage children to use while doing inquiry-based activities and investigations.

Can you think of other characteristics or terms you would need to teach and model? It is important to clarify for students the language of science in particular for terms that have a scientific explanation and another definition when used in everyday language like the terms *communication* or *argumentation*. You will learn more about this later in the chapter and throughout the course.

When used in the context of science, certain common words have specialized meanings. You should be aware of these nuanced meanings so that you consistently use appropriate terminology and encourage your students to do the same. Certainly there are many technical terms specific to the various science disciplines, but that is academic vocabulary you learn in science courses. Some of the words that describe the main product of science, knowledge in its various forms, are clarified in Table 1.3.

When teaching science, keep in mind that "Science is both a body of knowledge that represents current understanding of physical and natural systems and the process whereby that body of knowledge has been established and is being continually extended, refined and revised" (National Research Council [NRC], 2007, p. 26). Remember that science has certain characteristics, often referred to as the nature of science, that distinguish it from other ways of knowing and that scientists are expected to apply certain habits of mind as they work. Exploration 1.2 challenges you to consider examples of the major themes related to understanding the nature of science. Also, recall that in science some words have specific meanings that may be different than their common meanings. As you provide your class with numerous opportunities to develop science concepts, skills, and practices by letting your students "be" scientists, explicitly model and point out examples of scientific attitudes, actions, and terminology. Over time, your students will better understand what science is, the nature of science, how scientists reason, and how to properly use of the language of science.

EXPLORATION 1.2

Nature of Science Themes

During the development of the *Next Generation Science Standards* **(NGSS)**, which you will learn more about later in this chapter, the writers described eight major themes or categories related to understanding the nature of science. On the following chart, those listed in the left column are associated with Scientific and Engineering Practices, while those in the right column are associated with Crosscutting Concepts:

Nature of science themes related to Scientific and Engineering Practices	Nature of science themes related to Crosscutting Concepts
Scientific investigations use a variety of methods.	Science is a way of knowing.
Scientific knowledge is based on empirical evidence.	Scientific knowledge assumes an order and consistency in natural systems.
Scientific knowledge is open to revision in light of new evidence.	Science is a human endeavor.
Science models, laws, mechanisms, and theories explain natural phenomena.	Science addresses questions about the natural and material world.

Source: Achieve, 2013a.

Look back at the information presented earlier in the chapter for examples that relate to each theme. Discuss your ideas with a partner or a small group of your peers.

Reflection Questions:

1. What examples did you find related to the various themes?
2. In what ways do the themes help you understand the enterprise of science as a whole?
3. Why do you think that K–8 students should develop an understanding of the nature of science? What are the implications for teachers?

TABLE 1.3 Some Words That Have Special Meanings in Science

Word	Meaning in Science	Everyday Meaning
Theory	A complex explanation about how nature works that has been well tested and is supported by a wide body of evidence. A theory is so well established that it is unlikely that new evidence will totally discredit it.	An untested idea or conjecture. A guess, speculation, opinion, or belief.
Law	A description of what happens naturally under very specific conditions. It will predict what will happen as long as those conditions are met. A scientific law only describes; it doesn't explain.	An enforceable rule. Something that must be followed and may have legal consequences.
Hypothesis	A testable prediction (idea) that may contribute to the development of a scientific theory.	(Not generally used outside of science.)
Data	Observations, measurements, or inferences recorded for later analysis.	Information in the form of numbers.
Evidence	The cumulative body of data or observations of a phenomenon that have been analyzed.	What detectives look for and use to solve a crime.
Claim	Always based on evidence. May or may not stand the test of time; some will eventually be shown to be false.	Anything people say is true and it may represent their beliefs.

(Table 1.3 continued)

(Table 1.3 continued)

Word	Meaning in Science	Everyday Meaning
Fact	An understanding based on confirmable observations and is subject to test and rejection (Bybee, 1997). An example of a scientific fact is: *The speed of light is 186,000 miles per second.* Evidence and claims related to phenomena can contribute to the generation of scientific facts.	Anything that is considered true and may be based on the trust given to an individual who said it was a fact. (Unfortunately, some information is considered factual because it appeared in the newspaper, it was on the Internet, or an authority says so!)
Communication	Scientists share their explanations in such a way that their experiments can be reproduced. This sharing helps to resolve contradictions and solidifies arguments.	Anything that is shared with others either verbally, in writing or nonverbally.
Argumentation	Logical descriptions of a scientific idea and the evidence for or against it. The process can precede any evidence relevant to it, and other times the evidence helps inspire the idea.	The process of reasoning systematically to present ideas logically. This occurs in education and everyday lives and often is about contrary points of view.

CHECK YOUR UNDERSTANDING 1.1

Click here to gauge your understanding of the concepts in this section.

Science Education in Elementary and Middle Schools

Science surrounds us, all day, every day. True, you don't have to understand science ideas and concepts for them to affect you, but understanding science and the processes used to inquire can be very useful. For example, here on Earth, gravity will pull you down whether you know the related equations or not. And when a cold front comes through, carrying your umbrella is a good idea. Meteorologists analyze weather data so their predictions can advise you to act on them. Science knowledge can affect the quality of your life. Consider the following additional examples.

- In a collision, the heavily loaded moving van nearly always "wins" against an economy car. Knowing a little bit of physics and practicing defensive driving based on an understanding the laws of motion and about unbalanced forces might save your life if you are the car's driver.
- Realizing that germs that cause the common cold can survive on surfaces provides the rationale for frequent hand washing when those around you are sneezing.

In the modern world, some knowledge of science is essential for everyone (NRC, 2007). Young students should begin to learn science in kindergarten or even pre-K.

Science Education

Science education is about teaching and learning that involves students in inquiry-based investigations in which they interact with their teachers and peers; establish connections between their current knowledge of science and scientific understandings; apply science concepts to new questions; engage in problem solving, planning, reasoning from evidence, and group discussions; and experience an active approach to learning science.

The National Science Teachers Association (NSTA) has advocated for years that inquiry-based science instruction must be a basic part of the daily curriculum of every elementary school student at every grade level because of the importance of early experiences in science in developing problem-solving skills needed to be productive citizens in the twenty-first century (NSTA, 2002).

NSTA also considers middle school to be a critical time in students' science learning journey. Studies indicate that if students aren't interested in and excited by science by seventh grade, they may never be. It is important that middle school teachers present science concepts in ways that are both age appropriate and engaging so that students continue to build on their prior knowledge and attain the necessary background to participate successfully and responsibly in our highly scientific and technological society (NSTA, 2003).

Scientific Literacy

Another reason to start teaching science in elementary school is to begin early to build **scientific literacy**. Learning to think scientifically and to understand the scientific view of the physical and natural world takes time. Science experiences from the earliest grades are essential for helping students to learn to think and understand. Many learning progressions begin with foundational concepts that are best understood in the early primary grades.

Some of your students will likely choose careers in a scientific, technical, or health-care profession, but *all* of them will need to be scientifically literate to take an active role in recognizing problems, contributing to solutions, and making informed decisions about local, state, national, and global issues.

The *National Science Education Standards* **(NSES)** define scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity" (NRC, 1996, p. 22).

According to the NSES, "Lifelong scientific literacy begins with understandings, attitudes, and values established in the earliest years" (NRC, 1996, p. 114). More recently, the National Research Council's *A Framework for K–12 Science Education* defined science literacy by all K–12 students by identifying the Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas that will enable all students to make scientifically sound decisions about the world in which they live (NRC, 2012, p. 3). Whether from the NSES or the ***Framework*** and NGSS documents, all definitions of scientific literacy indicate that it is important for literate citizens to have both knowledge of science facts and concepts and the skills to "do" science and then use the information for personal decision making about societal issues.

National Concerns

Many people believe that what happens in elementary science today can have potentially dramatic effects, not only on the lives of children, but also on the economic future of our nation. A prestigious panel sponsored by the National Academies of Science produced a report, *Rising Above the Gathering Storm* (National Academies of Science, 2006), that details some of the global issues our nation faces.

The report noted that the "high quality of life" in the United States, "our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities" is derived, in large part, from "the steady stream of scientific and technological innovations" produced in this country since World War II. But there are indications that our global leadership position in science and technology is changing. Among the findings of the committee and recent followup reports are these:

- Since the early 1990s, the United States has been a net importer of high-technology products.
- Other nations are graduating considerably more engineers, computer scientists, and information technologists than the United States.
- Lower labor costs and the availability of highly trained scientists and engineers have led to the location of factories by U.S. companies in foreign countries and the outsourcing of many jobs.
- International assessments in math and science indicate that U.S. K–12 students lag behind students from other industrialized countries and we now rank 22nd in graduation rates and 14th in numbers of students 25 through 34 years of age with 2- or 4-year college degrees (OECD, 2012, p. 26).
- The National Science Foundation recently reported that there are between 2 and 3 million STEM (Science, Technology, Engineering, and Mathematics) positions that are unfilled.
- The Department of Commerce studies show for more than a decade, STEM jobs grew at three times the rate of non-STEM jobs, which is a trend likely to continue and accelerate (Langdon et al., 2011).

In response to such findings, recommendations from the reports and from White House initiatives suggested, among other things, that the United States vastly improve science and math education to