Doing Science: The Process of Scientific Inquiry

under a contract from the
National Institutes of Health

National Institute of General Medical Sciences

BSCS
Center for Curriculum Development
5415 Mark Dabling Boulevard
Colorado Springs, CO 80918

BSCS Development Team
Rodger W. Bybee, Principal Investigator
Mark V. Bloom, Project Director
Jerry Phillips, Curriculum Developer
Nicole Knapp, Curriculum Developer
Carrie Zander, Project Assistant
Lisa Pence, Project Assistant
Terry Redmond, Project Assistant
Ted Lamb, Evaluator
Barbara Perrin, Production Manager
Diane Gionfriddo, Photo Researcher
Lisa Rasmussen, Graphic Designer
Stacey Luce, Production Specialist

BSCS Administrative Staff
Carlo Parravano, Chair, Board of Directors
Rodger W. Bybee, Executive Director
Janet Carlson Powell, Associate Director, Chief Science Education Officer
Pamela Van Scotter, Director, Center for Curriculum Development

National Institutes of Health
Alison Davis, Writer (Contractor), National Institute of General Medical Sciences (NIGMS)
Irene Eckstrand, Program Director, NIGMS
Anthony Carter, Program Director, NIGMS
James Anderson, Program Director, NIGMS
Jean Chin, Program Director, NIGMS
Richard Ikeda, Program Director, NIGMS
Bruce Fuchs, Director, Office of Science Education (OSE)
Lisa Strauss, Project Officer, OSE
Dave Vannier, Professional Development, OSE
Cindy Allen, Editor, OSE

AiGroup Staff
Peter Charczenko, President
Judd Exley, Associate Web Designer/Developer
Anuradha Parthasarathy, Web Programmer/Developer
Matt Esposito, Web Programmer/Developer

SAIC Staff
Bach Nguyen, Project Manager
Steve Larson, Web Director
Doug Green, Project Lead
Tommy D'Aquino, Multimedia Director
Paul Ayers, Multimedia Developer
John James, Multimedia Developer
Jeff Ludden, Multimedia Programmer
Pat Leffas, Multimedia Programmer
Craig Weaver, 3D Modeler
Aaron Bell, 3D Animator
Rob King, Graphic Designer
David Kirkpatrick, Graphic Designer
Dave Nevins, Audio Engineer/Senior Web Developer
Jessica Butter, Senior Web Developer
Katie Riley, Web Developer
James Chandler, Web Developer/Usability Specialist
Abdellah Bougrine, Web Developer/Section 508 Specialist
Ginger Rittenhouse, Web Developer/Quality Assurance
Mary Jo Mallonee, Web Developer/Editor

Advisory Committee
Sally Greer, Whitford Middle School, Beaverton, Oregon
Vassily Hatzimanikatis, Northwestern University, Evanston, Illinois
Mary Lee S. Ledbetter, College of the Holy Cross, Worcester, Massachusetts
Scott Molley, John Baker Middle School, Damascus, Maryland
Nancy P. Moreno, Baylor College of Medicine, Houston, Texas

Writing Team
Allison Aclufi, Berendo Middle School, Los Angeles, California
Michelle Fleming, Lasley Elementary School, Lakewood, Colorado
Michael Klymkowsky, University of Colorado, Boulder
Susan Laursen, CIRES, University of Colorado, Boulder
Quinn Vega, Montclair State University, Upper Montclair, New Jersey
Tom Werner, Union College, Schenectady, New York

Field-Test Teachers
Carol Craig, Killingly Intermediate School, Dayville, Connecticut
Janet Erickson, C.R. Anderson Middle School, Helena, Montana
Scott Molley, John Baker Middle School, Damascus, Maryland
Nancy Nega, Churchville Middle School, Elmhurst, Illinois
Kathy Peavy, Hadley Middle School, Wichita, Kansas
Donna Roberts, West Marion Junior High School, Foxworth, Mississippi
Erin Parcher-Wartes, Eagle School of Madison, Madison, Wisconsin
John Weeks, Northeast Middle School, Jackson, Tennessee

Cover Design
Salvador Bru and Medical Arts and Photography Branch, NIH

This material is based on work supported by the National Institutes of Health under Contract No. 263-02-C-0061. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the funding agency.

NIH Publication No. 05-5564

ISBN: 1-929614-20-9

Please contact the NIH Office of Science Education with questions about this supplement at *supplements@science.education.nih.gov*.

Contents

Foreword

This curriculum supplement, from *The NIH Curriculum Supplement Series*, brings cutting-edge medical science and basic research discoveries from the National Institutes of Health (NIH) into classrooms. As the largest medical research institution in the United States, NIH plays a vital role in the health of all Americans and seeks to foster interest in research, science, and medicine-related careers for future generations. The NIH Office of Science Education (OSE) is dedicated to promoting science education and scientific literacy.

We designed this curriculum supplement to complement existing life science curricula at both the state and local levels and to be consistent with the *National Science Education Standards*.[1] The supplement was developed and tested by a team composed of teachers from across the country; scientists; medical experts; other professionals with relevant subject-area expertise from institutes and medical schools across the country; representatives from the NIH National Institute of General Medical Sciences (NIGMS); and curriculum-design experts from Biological Sciences Curriculum Study (BSCS), AiGroup, and SAIC. The authors incorporated real scientific data and actual case studies into classroom activities. A two-year development process included geographically dispersed field tests by teachers and students.

The structure of this module enables teachers to effectively facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements include a conceptual flow of lessons based on BSCS's 5E Instructional Model of Learning, multisubject integration that emphasizes cutting-edge science content, and built-in assessment tools. Activities promote active and collaborative learning and are inquiry-based, to help students develop problem-solving strategies and critical-thinking skills.

Each curriculum supplement comes with a complete set of materials for both teachers and students, including printed materials, extensive background and resource information, and a Web site with interactive activities. These supplements are distributed at no cost to teachers across the United States. All materials may be copied for classroom use, but may not be sold. We welcome feedback from our users. For a complete list of curriculum supplements, updates, and availability and ordering information, or to submit feedback, please visit our Web site at *http://science.education.nih.gov* or write to

Curriculum Supplement Series
Office of Science Education
National Institutes of Health
6705 Rockledge Dr., Suite 700 MSC 7984
Bethesda, MD 20817-1814

We appreciate the valuable contributions of the talented staff at BSCS, AiGroup, and SAIC. We are also grateful to the NIH scientists, advisers, and all other participating professionals for their work and dedication. Finally, we thank the teachers and students who participated in focus groups and field tests to ensure that these supplements are both engaging and effective. I hope you find our series a valuable addition to your classroom, and I wish you a productive school year.

Bruce A. Fuchs, Ph.D.
Director
Office of Science Education
National Institutes of Health
supplements@science.education.nih.gov

[1] In 1996, the National Academy of Sciences published the *National Science Education Standards*, which outlines what all citizens should understand about science by the time they graduate from high school. The *Standards* encourages teachers to select major science concepts that empower students to use information to solve problems rather than stressing memorization of unrelated information.

About the National Institutes of Health

Begun as the one-room Laboratory of Hygiene in 1887, the National Institutes of Health (NIH) today is one of the world's foremost medical research centers and the federal focal point for health research in the United States.

Mission and Goals

The NIH mission is science in pursuit of fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to extend healthy life and reduce the burdens of illness and disability. The goals of the agency are to

- foster fundamental creative discoveries, innovative research strategies, and their applications as a basis for advancing significantly the nation's capacity to protect and improve health;
- develop, maintain, and renew scientific resources — both human and physical — that will ensure the nation's ability to prevent disease;
- expand the knowledge base in medical and associated sciences in order to enhance the nation's economic well-being and ensure a continued high return on the public investment in research; and
- exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science.

NIH works toward meeting those goals by providing leadership, direction, and grant support to programs designed to improve the health of the nation through research in the

- causes, diagnosis, prevention, and cure of human diseases;
- processes of human growth and development;
- biological effects of environmental contaminants;
- understanding of mental, addictive, and physical disorders; and
- collection, dissemination, and exchange of information in medicine and health, including the development and support of medical libraries and the training of medical librarians and other health information specialists.

Organization

Composed of 27 separate institutes and centers, NIH is one of eight health agencies of the Public Health Service within the U.S. Department of Health and Human Services. NIH encompasses 75 buildings on more than 300 acres in Bethesda, Md., as well as facilities at several other sites in the United States. The NIH budget has grown from about $300 in 1887 to more than $28 billion in 2005.

Research Programs

One of NIH's principal concerns is to invest wisely the tax dollars entrusted to it for the support and conduct of this research. Approximately 82 percent of the investment is made through grants and contracts supporting research and training in more than 2,000 research institutions throughout the United States and abroad. In fact, NIH grantees are located in every state in the country. These grants and contracts make up the NIH Extramural Research Program.

Approximately 10 percent of the budget goes to NIH's Intramural Research Programs, the more than 2,000 projects conducted mainly in its own laboratories. These projects are central to the NIH scientific effort. First-rate intramural scientists collaborate with one another regardless of institute affiliation or scientific discipline and have the intellectual freedom to pursue their research leads in NIH's own laboratories. These explorations range from basic biology to behavioral research, to studies on treatment of major diseases.

Grant-Making Process

The grant-making process begins with an idea that an individual scientist describes in a written application for a research grant. The project might be small, or it might involve millions of dollars. The project might become useful immediately as a diagnostic test or new treatment, or it might involve studies of basic biological processes whose clinical value may not be apparent for many years.

Each research grant application undergoes peer review. A panel of scientific experts, primarily from outside the government, who are active and productive researchers in the biomedical sciences, first evaluates the scientific merit of the application. Then, a national advisory council or board, composed of eminent scientists as well as members of the public who are interested in health issues or the biomedical sciences, determines the project's overall merit and priority in advancing the research agenda of the particular NIH funding institutes.

About 38,500 research and training applications are reviewed annually through the NIH peer-review system. At any given time, NIH supports 35,000 grants in universities, medical schools, and other research and research training institutions, both nationally and internationally.

NIH Nobelists

The roster of people who have conducted NIH research or who have received NIH support over the years includes some of the world's most illustrious scientists and physicians. Among them are 115 winners of Nobel Prizes for achievements as diverse as deciphering the genetic code and identifying the causes of hepatitis. You can learn more about Nobelists who have received NIH support at *http://www.nih.gov/about/almanac/nobel/index.htm.*

Impact on the Nation's Health

Through its research, NIH has played a major role in making possible many achievements over the past few decades, including these:

- Mortality from heart disease, the number one killer in the United States, dropped by 36 percent between 1977 and 1999.
- Improved treatments and detection methods increased the relative five-year survival rate for people with cancer to 60 percent.
- With effective medications and psychotherapy, the 19 million Americans who suffer from depression can now look forward to a better, more productive future.
- Vaccines are now available that protect against infectious diseases that once killed and disabled millions of children and adults.
- In 1990, NIH researchers performed the first trial of gene therapy in humans. Scientists are increasingly able to locate, identify, and describe the functions of many of the genes in the human genome. The ultimate goal is to develop screening tools and gene therapies for the general population for cancer and many other diseases.

Science Education

Science education by NIH and its institutes contributes to ensuring the continued supply of well-trained basic research and clinical investigators, as well as the myriad professionals in the many allied disciplines who support the research enterprise. These efforts also help educate people about scientific results so that they can make informed decisions about their own—and the public's—health.

This curriculum supplement is one such science education effort, a collaboration among three partners: the NIH National Institute of General Medical Sciences, the NIH Office of Science Education, and Biological Sciences Curriculum Study.

For more about NIH, visit *http://www.nih.gov.*

About the National Institute of General Medical Sciences

Many scientists across the country are united by one chief desire: to improve our understanding of how life works. Whether they gaze at or grind up, create or calculate, model or manipulate, if their work sheds light on living systems, it may well receive financial support from the National Institute of General Medical Sciences (NIGMS), which funds the research of more than 3,000 scientists at universities, medical schools, hospitals, and other research institutions.

NIGMS is part of the National Institutes of Health (NIH), an agency of the U.S. government that is one of the world's leading supporters of biomedical research. As the "General" in its name implies, NIGMS has broad interests. It funds basic research in cell biology, structural biology, genetics, chemistry, pharmacology, and many other fields. This work teaches us about the molecules, cells, and tissues that form all living creatures. It helps us understand—and possibly find new ways to treat—diseases caused by malfunctions in these biological building blocks. NIGMS also supports training programs that provide the most critical element of good research: well-prepared scientists.

Science is a never-ending story. The solution of one mystery is the seed of many others. Research in one area may also provide answers to questions in other, seemingly unrelated, areas. The anticancer drug cisplatin unexpectedly grew out of studies on the effect of electrical fields on bacteria. Freeze-drying was developed originally by researchers as a way to concentrate and preserve biological samples. And a laboratory technique called the polymerase chain reaction became the basis of "DNA fingerprinting" techniques that have revolutionized criminal forensics.

Similarly, it is impossible to predict the eventual impact and applications of the basic biomedical research that NIGMS supports. But one thing is certain: these studies will continue to supply missing pieces in our understanding of human health and will lay the foundation for advances in disease prevention, diagnosis, and treatment.

For more information, visit the NIGMS Web site: *www.nigms.nih.gov.*

To order print copies of free NIGMS science education publications, visit *http://www.nigms.nih.gov/Publications/ScienceEducation.htm.*

Introduction to Doing Science: *The Process of Scientific Inquiry*

We are living in a time when science and technology play an increasingly important role in our everyday lives. By almost any measure, the pace of change is staggering. Recent inventions and new technologies are having profound effects on our economic, political, and social systems. The past 30 years have seen the

- advent of recombinant DNA technology,
- development of in vitro fertilization techniques,
- cloning of mammals,
- creation of the Internet,
- birth of nanotechnology, and
- mass introduction of fax machines, cell phones, and personal computers.

These advances have helped improve the lives of many, but they also raise ethical, legal, and social questions. If society is to reap the benefits of science while minimizing potential negative effects, then it is important for the public to have the ability to make informed, objective decisions regarding the applications of science and technology. This argues for educating the public about the scientific process and how to distinguish science from pseudoscience.

What Are the Objectives of the Module?

Doing Science: The Process of Scientific Inquiry has four objectives. The first is to help students understand the basic aspects of scientific inquiry. Science proceeds by a continuous, incremental process that involves generating hypotheses, collecting evidence, testing hypotheses, and reaching evidence-based conclusions. Rather than involving one particular method, scientific inquiry is flexible. Different types of questions require different types of investigations. Moreover, there is more than one way to answer a question. Although students may associate science with experimentation, science also uses observations, surveys, and other nonexperimental approaches.

The second objective is to provide students with an opportunity to practice and refine their critical-thinking skills. Such abilities are important, not just for scientific pursuits, but for making decisions in everyday life. Our fast-changing world requires today's youth to be life-long learners. They must be able to evaluate information from a variety of sources and assess its usefulness. They need to discriminate between objective science and pseudoscience. Students must be able to establish causal relationships and distinguish them from mere associations.

The third objective is to convey to students the purpose of scientific research. Ongoing research affects how we understand the world around us and provides a foundation for improving our choices about personal health and the health of our community. In this module, students participate in a virtual investigation that gives them experience with the major aspects of scientific inquiry. The lessons encourage students to think about the relationships among knowledge, choice, behavior, and human health in this way:

Knowledge (what is known and not known) + Choice = Power

Power + Behavior = Enhanced Human Health

The final objective of this module is to encourage students to think in terms of these relationships now and as they grow older.

Why Teach the Module?

Middle school life science classes offer an ideal setting for integrating many areas of student interest. In this module, students participate in activities that integrate inquiry science, human health, and mathematics, and interweave science, technology, and society. The real-life context of the module's classroom lessons is engaging, and the knowledge gained can be applied immediately to students' lives.

What's in It for the Teacher?

Doing Science: The Process of Scientific Inquiry meets many of the criteria by which teachers and their programs are assessed:

- The module is **standards based** and meets science content, teaching, and assessment standards as expressed in the *National Science Education Standards*. It pays particular attention to the standards that describe what students should know and be able to do with respect to **scientific inquiry**. Where appropriate, we use a standards icon to make connections to the standards explicit.
- It is an **integrated** module, drawing most heavily from the subjects of science, social science, mathematics, and health.
- The module has a Web-based **technology component**, which includes interactive graphics and video clips.
- The module includes built-in **assessment** tools, which are noted in each of the lessons with an assessment icon.

In addition, the module provides a means for *professional development*. Teachers can engage in new and different teaching practices such as those described in this module without completely overhauling their entire program. In *Designing Professional Development for Teachers of Science and Mathematics*, Loucks-Horsley et al. write that supplements such as this one "offer a window through which teachers get a glimpse of what new teaching strategies look like in action."[7] By experiencing a short-term unit, teachers can "change how they think about teaching and embrace new approaches that stimulate students to problem-solve, reason, investigate, and construct their own meaning for the content." The use of this kind of supplemental unit can encourage reflection and discussion and stimulate teachers to improve their practices by focusing on student learning through inquiry.

The following table correlates topics often included in science curricula with the major concepts presented in this module. This information is presented to help you make decisions about incorporating this material into your curriculum.

Correlation of *Doing Science: The Process of Scientific Inquiry* to Middle School Science Topics

Topics	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Populations and ecosystems	✓			✓
The nature of science	✓	✓	✓	✓
Natural hazards			✓	✓
Human health and medicine			✓	✓
Relationship of science, technology, and society	✓	✓	✓	✓

Implementing the Module

The four lessons of this module are designed to be taught in sequence over six to eight days (as a supplement to the standard curriculum) or as individual lessons that support and enhance your treatment of specific concepts in middle school science. This section offers general suggestions about using these materials in the classroom. You will find specific suggestions in the procedures provided for each lesson.

What Are the Goals of the Module?

Doing Science: The Process of Scientific Inquiry helps students achieve four major goals associated with scientific literacy:

- to understand a set of basic elements related to the process of scientific inquiry,
- to experience the process of scientific inquiry and develop an enhanced understanding of the nature and methods of science,
- to hone critical-thinking skills, and
- to recognize the role of science in society and the relationship between basic science and human health.

What Are the Science Concepts and How Are They Connected?

The lessons are organized into a conceptual framework that allows students to move from what they already know about scientific inquiry, or think they know, to gaining a more complete and accurate perspective on the nature of scientific inquiry. Students model the process of scientific inquiry using a paper-cube activity (Lesson 1, *Inquiring Minds*). They then explore questions and what distinguishes those questions that can be tested by a scientific investigation from those that cannot (Lesson 2, *Working with Questions*). Students then participate in a computer-based scientific investigation as members of a fictitious community health department. In this investigation, students gain experience with the major aspects of scientific inquiry and critical thinking (Lesson 3, *Conducting a Scientific Investigation*). Students then reflect on what they have learned about the process of scientific inquiry. Continuing in their roles as members of the community health department, students analyze data and prepare investigative reports. They also evaluate reports prepared by others (Lesson 4, *Pulling It All Together*). The table on page 4 illustrates the scientific content and conceptual flow of the four lessons.

How Does the Module Correlate with the *National Science Education Standards*?

NSES

Doing Science: The Process of Scientific Inquiry supports teachers in their efforts to reform science education in the spirit of the National Academy of Sciences' 1996 *National Science Education Standards* (NSES). The content is explicitly standards based. Each time a standard is addressed in a lesson, an icon appears in the margin and the applicable standard is identified. The table on page 5 lists the specific content standards that this module addresses.

Teaching Standards

The suggested teaching strategies in all of the lessons support you as you work to meet the teaching standards outlined in the *National Science Education Standards*. This module helps teachers of science plan an inquiry-based science program by providing short-term objectives for students. It also includes planning tools such as the Science Content and Conceptual Flow of the Lessons table and the Suggested Timeline for teaching the module. You can use this module to update your curriculum in response to students' interest. The focus on active, collaborative, and inquiry-

Science Content and Conceptual Flow of the Lessons

Lesson and Learning Focus*	Topics Covered and Major Concepts
1: Inquiring Minds ***Engage***: Students become engaged in the process of scientific inquiry.	***Scientists learn about the natural world through scientific inquiry.*** • Scientists ask questions that can be answered through investigations. • Scientists design and carry out investigations. • Scientists think logically to make relationships between evidence and explanations. • Scientists communicate procedures and explanations.
2: Working with Questions ***Explore:*** Students consider what makes questions scientifically testable. Students gain a common set of experiences upon which to begin building their understanding.	***Scientists ask questions that can be answered through investigations.*** • Testable questions are not answered by personal opinions or belief in the supernatural. • Testable questions are answered by collecting evidence and developing explanations based on that evidence.
3: Conducting a Scientific Investigation ***Explain/Elaborate:*** Students conduct an investigation in the context of a community health department. They propose possible sources of the health problem and describe how they might confirm or refute these possibilities.	***Scientific explanations emphasize evidence.*** • Scientists think critically about the types of evidence that should be collected. ***Scientists analyze the results of their investigations to produce scientifically acceptable explanations.***
4: Pulling It All Together ***Evaluate:*** Students deepen their understanding of scientific inquiry by performing their own investigation and evaluating one performed by another student.	***Scientific inquiry is a process of discovery.*** • It begins with a testable question. • Scientific investigations involve collecting evidence. • Explanations are evidence based. • Scientists communicate their results to their peers.

*See *How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?* on page 6.

based learning in the lessons helps support the development of student understanding and nurtures a community of science learners.

The structure of the lessons enables you to guide and facilitate learning. All the activities encourage and support student inquiry, promote discourse among students, and challenge students to accept and share responsibility for their learning. The use of the 5E Instructional Model, combined with active, collaborative learning, allows you to respond effectively to students with diverse backgrounds and learning styles. The module is fully annotated, with suggestions for how you can encourage and model the skills of scientific inquiry and foster curiosity, openness to new ideas and data, and skepticism.

Assessment Standards

You can engage in ongoing assessment of your instruction and student learning using the assessment components. The assessment tasks are authentic; they are similar to tasks that students will engage in outside the classroom or to practices in which scientists participate.

Content Standards: Grades 5–8

Standard A: Science as Inquiry **As a result of their activities in grades 5–8, all students should develop**	**Correlation to *Doing Science: The Process of Scientific Inquiry***
Abilities necessary to do scientific inquiry	
• Identify questions that can be answered through scientific investigations.	All lessons
• Use appropriate tools and techniques to gather, analyze, and interpret data.	Lessons 1, 3, 4
• Develop descriptions, explanations, predictions, and models using evidence.	Lessons 1, 3, 4
• Think critically and logically to make the relationships between evidence and explanations.	Lessons 1, 3, 4
• Recognize and analyze alternative explanations and predictions.	Lessons 1, 3, 4
• Communicate scientific procedures and explanations.	Lessons 1, 3, 4
• Use mathematics in all aspects of scientific inquiry.	Lessons 3, 4
Understandings about scientific inquiry	
• Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects; and some involve making models.	All lessons
• Mathematics is important in all aspects of scientific inquiry.	Lessons 3, 4
Standard C: Life Science **As a result of their activities in grades 5–8, all students should develop an understanding of**	
Structure and function in living systems	
• Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.	Lessons 3, 4
Populations and ecosystems	
• Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.	Lesson 1
Standard E: Science and Technology **As a result of their activities in grades 5–8, all students should develop**	
Understandings about science and technology	
• Science and technology are reciprocal. Science helps drive technology. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable.	Lessons 2, 3, 4
Standard F: Science in Personal and Social Perspectives **As a result of their activities in grades 5–8, all students should develop an understanding of**	
Personal health	
• The potential for accidents and the existence of hazards imposes the need for injury prevention. Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions.	Lessons 3, 4

Risks and benefits	
• Risk analysis considers the type of hazard and estimates the number of people who might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.	Lessons 3, 4
• Important personal and social decisions are made based on perceptions of benefits and risks.	Lesson 3
Science and technology in society	
• Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact.	Lesson 2
Standard G: History and Nature of Science **As a result of their activities in grades 5–8, all students should develop an understanding of**	
Science as a human endeavor	
• Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skills, and creativity.	All lessons
Nature of science	
• Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.	All lessons

Annotations will guide you to these assessment opportunities and provide answers to questions that will help you analyze student feedback.

How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?

Because learning does not occur by way of passive absorption, the lessons in this module promote active learning. Students are involved in more than listening and reading. They are developing skills, analyzing and evaluating evidence, experiencing and discussing, and talking to their peers about their own understanding. Students work collaboratively with others to solve problems and plan investigations. Many students find that they learn better when they work with others in a collaborative environment than when they work alone in a competitive environment. When active, collaborative learning is directed toward scientific inquiry, students succeed in making their own discoveries. They ask questions, observe, analyze, explain, draw conclusions, and ask new questions. These inquiry-based experiences include both those that involve students in direct experimentation and those in which students develop explanations through critical and logical thinking.

The viewpoint that students are active thinkers who construct their own understanding from interactions with phenomena, the environment, and other individuals is based on the theory of constructivism. A constructivist view of learning recognizes that students need time to

- express their current thinking;
- interact with objects, organisms, substances, and equipment to develop a range of experiences on which to base their thinking;
- reflect on their thinking by writing and expressing themselves and comparing what they think with what others think; and
- make connections between their learning experiences and the real world.

This module provides a built-in structure for creating a constructivist classroom: the 5E Instructional Model. The 5E model sequences learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model leads students through five phases of learning that are easily described using words that begin with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate. The following paragraphs illustrate how the five Es are implemented across the lessons in this module.

Engage

Students come to learning situations with prior knowledge. This knowledge may or may not be congruent with the concepts presented in this module. The Engage lesson provides the opportunity for teachers to find out what students already know, or think they know, about the topic and concepts to be covered. The Engage lesson in this module, Lesson 1, *Inquiring Minds*, is designed to

- pique students' curiosity and generate interest,
- determine students' current understanding about scientific inquiry,
- invite students to raise their own questions about the process of scientific inquiry,
- encourage students to compare their ideas with those of others, and
- enable teachers to assess what students do or do not understand about the stated outcomes of the lesson.

Explore

In the Explore phase of the module, Lesson 2, *Working with Questions*, students investigate the nature of scientifically testable questions. Students engage in short readings and generate their own set of testable questions. This lesson provides a common set of experiences within which students can begin to construct their understanding. Students

- interact with materials and ideas through classroom and small–group discussions;
- consider different ways to solve a problem or frame a question;
- acquire a common set of experiences so that they can compare results and ideas with their classmates;
- observe, describe, record, compare, and share their ideas and experiences; and
- express their developing understanding of testable questions and scientific inquiry.

Explain

The Explain lesson (Lesson 3, *Conducting a Scientific Investigation*) provides opportunities for students to connect their previous experiences with current learning and to make conceptual sense of the main ideas of the module. This stage also allows for the introduction of formal language, scientific terms, and content information that might make students' previous experiences easier to describe. The Explain lesson encourages students to

- explain concepts and ideas (in their own words) about a potential health problem;
- listen to and compare the explanations of others with their own;
- become involved in student-to-student discourse in which they explain their thinking to others and debate their ideas;
- revise their ideas;
- record their ideas and current understanding;
- use labels, terminology, and formal language; and
- compare their current thinking with what they previously thought.

Elaborate

In Elaborate lessons, students apply or extend previously introduced concepts and experiences to new situations. In the Elaborate lesson in this module, Lesson 3, *Conducting a Scientific Investigation*, students

- make conceptual connections between new and former experiences, connecting aspects of their health department investigation with their concepts of scientific inquiry;
- connect ideas, solve problems, and apply their understanding to a new situation;
- use scientific terms and descriptions;
- draw reasonable conclusions from evidence and data;
- deepen their understanding of concepts and processes; and
- communicate their understanding to others.

Evaluate

The Evaluate lesson (Lesson 4, *Pulling It All Together*) is the final stage of the instructional model, but it only provides a "snapshot" of what the students understand and how far they have come from where they began. In reality, the evaluation of students' conceptual understanding and ability to use skills begins with the Engage lesson and continues throughout each stage of the instructional model. When combined with the students' written work and performance of tasks throughout the module, however, the Evaluate lesson provides a summative assessment of what students know and can do.

The Evaluate lesson in this module, Lesson 4, *Pulling It All Together*, provides an opportunity for students to

- demonstrate what they understand about scientific inquiry and how well they can apply their knowledge to carry out their own scientific investigation and to evaluate an investigation carried out by a classmate;
- share their current thinking with others;
- assess their own progress by comparing their current understanding with their prior knowledge; and
- ask questions that take them deeper into a concept.

To review the relationship of the 5E Instructional Model to the concepts presented in the module, see the table titled Science Content and Conceptual Flow of the Lessons, on page 4.

When you use the 5E Instructional Model, you engage in practices that are different from those of a traditional teacher. In response, students learn in ways that are different from those they experience in a traditional classroom. The charts on pages 9–10, What the Teacher Does and What the Students Do, outline these differences.

How Does the Module Support Ongoing Assessment?

Because teachers will use this module in a variety of ways and at a variety of points in the curriculum, the most appropriate mechanism for assessing student learning is one that occurs informally at various points within the lessons, rather than just once at the end of the module. Accordingly, integrated within the lessons in the module are specific assessment components. These embedded assessments include one or more of the following strategies:

- performance-based activities, such as developing graphs or participating in a discussion about risk assessment;
- oral presentations to the class, such as reporting experimental results; and
- written assignments, such as answering questions or writing about demonstrations.

These strategies allow you to assess a variety of aspects of the learning process, such as students' prior knowledge and current understanding; problem-solving and critical-thinking skills; level of understanding of new information; communication skills; and ability to synthesize ideas and apply understanding to a new situation.

An assessment icon and an annotation that describes the aspect of learning being assessed appear in the margin beside each step in which embedded assessment occurs.

How Can Teachers Promote Safety in the Science Classroom?

Even simple science demonstrations and investigations can be hazardous unless teachers and students know and follow safety precautions. Teachers are responsible for providing students with active instruction concerning their conduct and safety in the classroom. Posting rules in a classroom is not enough; teachers also need to provide adequate supervision and advance warning if there are dangers involved in the science investigation. By maintaining equipment in proper working

What the Teacher Does

Stage	That is *consistent* with the BSCS 5E Instructional Model	That is *inconsistent* with the BSCS 5E Instructional Model
Engage	• Piques students' curiosity and generates interest • Determines students' current nderstanding (prior knowledge) of a concept or idea • Invites students to express what they think • Invites students to raise their own questions	• Introduces vocabulary • Explains concepts • Provides definitions and answers • Provides closure • Discourages students' ideas and questions
Explore	• Encourages student-to-student interaction • Observes and listens to the students as they interact • Asks probing questions to help students make sense of their experiences • Provides time for students to puzzle through problems	• Provides answers • Proceeds too rapidly for students to make sense of their experiences • Provides closure • Tells the students that they are wrong • Gives information and facts that solve the problem • Leads the students step-by-step to a solution
Explain	• Encourages students to use their common experiences and data from the Engage and Explore lessons to develop explanations • Asks questions that help students express understanding and explanations • Requests justification (evidence) for students' explanations • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Introduces terminology and alternative explanations after students express their ideas	• Neglects to solicit students' explanations • Ignores data and information students gathered from previous lessons • Dismisses students' ideas • Accepts explanations that are not supported by evidence • Introduces unrelated concepts or skills
Elaborate	• Focuses students' attention on conceptual connections between new and former experiences • Encourages students to use what they have learned to explain a new event or idea • Reinforces students' use of scientific terms and descriptions previously introduced • Asks questions that help students draw reasonable conclusions from evidence and data	• Neglects to help students connect new and former experiences • Provides definitive answers • Tells the students that they are wrong • Leads students step-by-step to a solution
Evaluate	• Observes and records as students demonstrate their understanding of the concepts and performance of skills • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Interviews students as a means of assessing their developing understanding • Encourages students to assess their own progress	• Tests vocabulary words, terms, and isolated facts • Introduces new ideas or concepts • Creates ambiguity • Promotes open-ended discussion unrelated to the concept or skill

What the Students Do

Stage	That is *consistent* with the BSCS 5E Instructional Model	That is *inconsistent* with the BSCS 5E Instructional Model
Engage	• Become interested in and curious about the concept or topic • Express current understanding of a concept or idea • Raise questions such as, What do I already know about this? What do I want to know about this? How could I find out?	• Ask for the "right" answer • Offer the "right" answer • Insist on answers or explanations • Seek closure
Explore	• "Mess around" with materials and ideas • Conduct investigations in which they observe, describe, and record data • Try different ways to solve a problem or answer a question • Acquire a common set of experiences so they can compare results and ideas • Compare their ideas with those of others	• Let others do the thinking and exploring (passive involvement) • Work quietly with little or no interaction with others (only appropriate when exploring ideas or feelings) • Stop with one solution • Demand or seek closure
Explain	• Explain concepts and ideas in their own words • Base their explanations on evidence acquired during previous investigations • Record their ideas and current understanding • Reflect on and perhaps revise their ideas • Express their ideas using appropriate scientific language • Compare their ideas with what scientists know and understand	• Propose explanations from "thin air" with no relationship to previous experiences • Bring up irrelevant experiences and examples • Accept explanations without justification • Ignore or dismiss other plausible explanations • Propose explanations without evidence to support their ideas
Elaborate	• Make conceptual connections between new and former experiences • Use what they have learned to explain a new object, event, organism, or idea • Use scientific terms and descriptions • Draw reasonable conclusions from evidence and data • Communicate their understanding to others	• Ignore previous information or evidence • Draw conclusions from "thin air" • Use terminology inappropriately and without understanding
Evaluate	• Demonstrate what they understand about the concept(s) and how well they can implement a skill • Compare their current thinking with that of others and perhaps revise their ideas • Assess their own progress by comparing their current understanding with their prior knowledge • Ask new questions that take them deeper into a concept or topic area	• Disregard evidence or previously accepted explanations in drawing conclusions • Offer only yes-or-no answers or memorized definitions or explanations as answers • Fail to express satisfactory explanations in their own words • Introduce new, irrelevant topics

order, teachers ensure a safe environment for students.

You can implement and maintain a safety program in the following ways:

- Provide eye protection for students, teachers, and visitors. Require that everyone participating wear regulation goggles in any situation where there might be splashes, spills, or spattering. Teachers should always wear goggles in such situations.
- Know and follow the state and district safety rules and policies. Be sure to fully explain to the students the safety rules they should use in the classroom.
- At the beginning of the school year, establish consequences for students who behave in an unsafe manner. Make these consequences clear to students.
- Do not overlook any violation of a safety practice, no matter how minor. If a rule is broken, take steps to assure that the infraction will not occur a second time.
- Set a good example by observing all safety practices. This includes wearing eye protection during all investigations when eye protection is required for students.
- Know and follow waste disposal regulations.
- Be aware of students who have allergies or other medical conditions that might limit their ability to participate in activities. Consult with the school nurse or school administrator.
- Anticipate potential problems. When planning teacher demonstrations or student investigations, identify potential hazards and safety concerns. Be aware of what could go wrong and what can be done to prevent the worst-case scenario. Before each activity, verbally alert the students to the potential hazards and distribute specific safety instructions as well.
- Supervise students at all times during hands-on activities.
- Provide sufficient time for students to set up the equipment, perform the investigation, and properly clean up and store the materials after use.
- Never assume that students know or remember safety rules or practices from their previous science classes.

How Can Controversial Topics Be Handled in the Classroom?

Teachers sometimes feel that the discussion of values is inappropriate in the science classroom or that it detracts from the learning of "real" science. The lessons in this module, however, are based upon the conviction that there is much to be gained by involving students in analyzing issues of science, technology, and society. Society expects all citizens to participate in the democratic process, and our educational system must provide opportunities for students to learn to deal with contentious issues with civility, objectivity, and fairness. Likewise, students need to learn that science intersects with life in many ways.

In this module, students are given a variety of opportunities to discuss, interpret, and evaluate basic science and health issues, some in light of their values and ethics. As students encounter issues about which they feel strongly, some discussions might become controversial. The degree of controversy depends on many factors, such as how similar students are with respect to socioeconomic status, perspectives, value systems, and religious beliefs. In addition, your language and attitude influence the flow of ideas and the quality of exchange among the students.

The following guidelines may help you facilitate discussions that balance factual information with feelings:

- Remain neutral. Neutrality may be the single most important characteristic of a successful discussion facilitator.
- Encourage students to discover as much information about the issue as possible.

- Keep the discussion relevant and moving forward by questioning or posing appropriate problems or hypothetical situations. Encourage everyone to contribute, but do not force reluctant students to enter the discussion.
- Emphasize that everyone must be open to hearing and considering diverse views.
- Use unbiased questioning to help students critically examine all views presented.
- Allow for the discussion of all feelings and opinions.
- Avoid seeking consensus on all issues. Discussing multifaceted issues should result in the presentation of divergent views, and students should learn that this is acceptable.
- Acknowledge all contributions in the same evenhanded manner. If a student seems to be saying something for its shock value, see whether other students recognize the inappropriate comment and invite them to respond.
- Create a sense of freedom in the classroom. Remind students, however, that freedom implies the responsibility to exercise that freedom in ways that generate positive results for all.
- Insist upon a nonhostile environment in the classroom. Remind students to respond to ideas instead of to the individuals presenting those ideas.
- Respect silence. Reflective discussions are often slow. If a teacher breaks the silence, students may allow the teacher to dominate the discussion.
- At the end of the discussion, ask students to summarize the points made. Respect students regardless of their opinions about any controversial issue.

Using the Student Lessons

The heart of this module is the set of four classroom lessons. These lessons are the vehicles that will carry important concepts related to scientific inquiry to your students. To review the concepts in detail, refer to the Science Content and Conceptual Flow of the Lessons table, on page 000.

Format of the Lessons

As you review the lessons, you will find that all contain common major features.

At a Glance provides a convenient summary of the lesson.

- **Overview** provides a short summary of student activities.
- **Major Concepts** states the central ideas the lesson is designed to convey.
- **Objectives** lists specific understandings or abilities students should have after completing the lesson.
- **Teacher Background** specifies which portions of the background section, Information about the Process of Scientific Inquiry, relate directly to the lesson. This reading material provides the science content that underlies the key concepts covered in the lesson. The information provided is *not* intended to form the basis of lectures to students. Instead, it enhances your understanding of the content so that you can more accurately facilitate class discussions, answer student questions, and provide additional examples.

In Advance provides instructions for collecting and preparing the materials required to complete the activities in the lesson.

- **Web-Based Activities** indicates which of the lesson's activities use the *Doing Science: The Process of Scientific Inquiry* Web site as the basis for instruction.
- **Photocopies** lists the paper copies and transparencies that need to be made from masters, which follow Lesson 4, at the end of the module.
- **Materials** lists all the materials (other than photocopies) needed for each of the activities in the lesson.
- **Preparation** outlines what you need to do to be ready to teach the lesson.

Procedure outlines the steps in each activity of the lesson. It includes implementation hints and answers to discussion questions.

Within the Procedure section, annotations, with accompanying icons, provide additional commentary:

identifies teaching strategies that address specific science content standards as defined by the *National Science Education Standards*.

identifies when to use the Web site as part of the teaching strategy. Instructions tell you how to access the Web site and the relevant activity. Information about using the Web site can be found in Using the Web Site (see page 15). A print-based alternative to Web activities is provided for classrooms in which Internet access is not available.

identifies suggestions from field-test teachers for teaching strategies, class management, and module implementation.

identifies a print-based alternative to a Web-based activity to be used when computers are not available.

identifies when assessment is embedded in the module's structure. An annotation suggests strategies for assessment.

The **Lesson Organizer** provides a brief summary of the lesson. It outlines procedural steps for each activity and includes icons that denote where in each activity masters, transparencies, and the Web site are used.

The lesson organizer is a memory aid you can use after you are familiar with the detailed procedures of the activities. It can be a handy resource during lesson preparation as well as during classroom instruction.

Masters required to teach the activities are located after Lesson 4, at the end of the module.

Timeline for the Module

The following timeline outlines the optimal plan for completing the four lessons in this module. This plan assumes that you will teach the activities on consecutive days. If your class requires more time for completing the activities or for discussing issues raised in this module, adjust your timeline accordingly.

Suggested Timeline

Timeline	Activity
3 weeks ahead	Reserve computers and verify Internet access.
1 week ahead	Copy masters, make transparencies, gather materials.
Day 1 Monday	**Lesson 1** Activity 1: *Mystery Cube* Activity 2: *The Biological Box* Activity 3: *Thinking about Inquiry*
Day 2 Tuesday	**Lesson 2** Activity 1: *What's the Question?* Activity 2: *Questions … More Questions*
Day 3 Wednesday	**Lesson 3** Activity 1: *Unusual Absences*
Day 4 Thursday	**Lesson 3** Activity 2: *What's the Cause?*
Day 5 Friday	**Lesson 3** Activity 3: *What's the Source?*
Day 6 Monday	**Lesson 3** Activity 4: *Reflecting on the Process of Scientific Inquiry*
Day 7 Tuesday	**Lesson 4** Activity 1: *Pulling It All Together*

Using the Web Site

The *Doing Science: The Process of Scientific Inquiry* Web site is a wonderful tool that can engage student interest in learning, and orchestrate and individualize instruction. The Web site features simulations that articulate with two of the supplement's lessons. To access the Web site, type the following URL into your browser: *http://science.education.nih.gov/supplements/inquiry/teacher.* Click on the link to a specific lesson under *Web Portion of Student Activities.*

Hardware/Software Requirements

The Web site can be accessed from Apple Macintosh and IBM-compatible personal computers. The recommended hardware and software requirements for using the Web site are listed in the following table. Although your computer configuration may differ from those listed, the Web site may still be functional on your computer. The most important item in this list is the browser.

Getting the Most out of the Web Site

Before you use the Web site, or any other piece of instructional technology in your classroom, it is valuable to identify the benefits you expect the technology to provide. Well-designed instructional multimedia software can

- motivate students by helping them enjoy learning—students want to learn more when content that might otherwise be uninteresting is enlivened;
- offer unique instructional capabilities that allow students to explore topics in greater depth—technology offers experiences that are closer to actual life than print-based media offer;
- support teachers in experimenting with new instructional approaches that allow students to work independently or in small teams—technology gives teachers increased credibility among today's technology-literate students; and

Recommended Hardware and Software Requirements for Using the Web Site*

CPU/processor (PC Intel, Mac)	Pentium III, 600 MHz; or Mac G4
Operating system (DOS/Windows, Mac OS)	Windows 2000 or higher; or Mac OS 9 or newer
System memory (RAM)	256 MB or more
Screen setting	1024 × 768 pixels, 32 bit color
Browser	Microsoft Internet Explorer 6.0 or Netscape Communicator 7.1
Browser settings	JavaScript enabled
Free hard-drive space	10 MB
Connection speed	High speed (cable, DSL, or T1)

*For users of screen-reader software, a multichannel sound card such as Sound Blaster® Live!™ is recommended.

- increase teacher productivity—technology helps teachers with assessment, record keeping, and classroom planning and management.

Ideal use of the Web site requires one computer for each student team. However, if you have only one computer available in the classroom, you can still use the Web site. For example, you can use a projection system to display the monitor image for the whole class to see. Giving selected students in the class the opportunity to manipulate the Web activities in response to suggestions from the class can give students some of the same autonomy in their learning that they can gain from working in small teams. Alternatively, you can rotate student teams through the single computer station. If you do not have the facilities for using the Web site with your students, you can use the print-based alternatives provided for the Lesson 3 and 4 activities.

Collaborative Groups

We designed many of the activities to be done by teams of students working together. Although individual students working alone can complete the activities, this strategy does not stimulate the types of student-student interactions that are part of active, collaborative, inquiry-based learning. Therefore, we recommend that you organize collaborative teams of two to four students each, depending on the number of computers available. Students in groups larger than four often have difficulty organizing the student-computer interactions equitably, leading to one or two students assuming primary responsibility for the computer-based work. Although large groups can be efficient, they do not allow all the students to experience the in-depth discovery and analysis that the Web site was designed to stimulate. Team members not involved directly may become bored or disinterested.

We recommend that you keep your students in the same collaborative teams for all the activities in the lessons. This will allow each team to develop a shared experience with the Web site and with the ideas and issues that the activities present. A shared experience will enhance your students' perceptions of the lessons as a conceptual whole.

If your student-to-computer ratio is greater than four to one, you will need to change the way you teach the module from the instructions in the lessons. For example, if you have only one computer available, you may want students to complete the Web-based work over an extended time period. You can do this in several ways. The most practical way is to use your computer as a center along with several other centers at which students complete other activities. In this approach, students rotate through the computer center, eventually completing the Web-based work that you have assigned.

A second way to structure the lessons if you have only one computer available is to use a projection system to display the desktop screen for the whole class to view. Giving selected students in the class the opportunity to manipulate the Web activities in response to suggestions from the class can give students some of the same autonomy in their learning they would have gained from working in small teams.

Web Activities for Students with Disabilities

The Office of Science Education (OSE) is committed to providing access to the Curriculum Supplement Series for individuals with disabilities, including members of the public and federal employees. To meet this commitment, we will comply with the requirements of Section 508 of the Rehabilitation Act. Section 508 requires that individuals with disabilities who are members of the public seeking these materials will have access to and use of information and data that are comparable to those provided to members of the public who are not individuals with disabilities. The online versions of this series have been prepared to comply with Section 508.

If you use assistive technology (such as a Braille reader or a screen reader) and the format of any materials on our Web site interferes with your ability to access the information, please let us know. To enable us to respond in a manner most helpful to you, please indicate the nature of the problem, the format in which you would like to receive the material, the Web address of the requested material, and your contact information.

Contact us at

Curriculum Supplement Series
Office of Science Education
National Institutes of Health
6705 Rockledge Drive, Suite 700 MSC 7984
Bethesda, MD 20892-7984
supplements@science.education.nih.gov

Doing Science: The Process of Scientific Inquiry 508-Compliant Web Activities

Lesson, activity	For students with hearing impairment	For students with sight impairment
Lesson 3, Activities 1, 2, and 3	No special considerations are required.	Students using screen-magnification or screen-reading software can choose an alternate, text-based version of the activity. The content of the two versions of the activity is equivalent. The "Progress Map" at the bottom of each page keeps track of the student's progress. If the student closes the activity and returns to it later, the activity will resume where the student left it. The last page of the activity provides a summary of all the student's answers. The student can use the Progress Map to return to any page and edit his or her responses. The computer the students use must be connected to the Internet. Supervision is recommended.
Lesson 4, Activity 1	No special considerations are required.	Same as Lesson 3, Activities 1, 2, and 3.

Information about the Process of Scientific Inquiry

1 Introduction

"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."

—National Research Council[9]

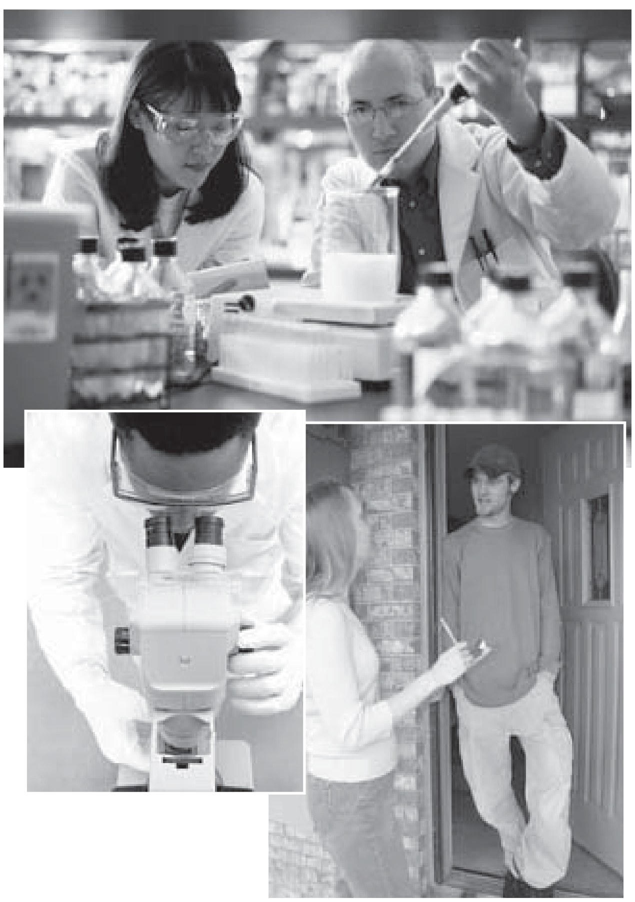


***Figure 1.** Scientific inquiry takes on different forms.*

To a scientist, inquiry refers to an intellectual process that humans have practiced for thousands of years. However, the history of inquiry in American science education is much briefer. Until about 1900, science education was regarded as getting students to memorize a collection of facts. In fact, many of today's teachers and students can confirm that this approach is still with us. In 1910, John Dewey criticized this state of affairs in science education.[11] He argued that science should be taught as a way of thinking. According to this view, science should be taught as a process. During the 1950s and 1960s, educator Joseph Schwab observed that science was being driven by a new vision of scientific inquiry.[12] In Schwab's view, science was no longer a process for revealing stable truths about the world, but instead it reflected a flexible process of inquiry. He characterized inquiry as either "stable" or "fluid." Stable inquiry involved using current understandings to "fill a … blank space in a growing body of knowledge." Fluid inquiry involved the creation of new concepts that revolutionize science.

To help science education reflect the modern practice of science more accurately, Schwab advocated placing students in the laboratory immediately. In this way, students could ask questions and begin the process of collecting evidence and constructing explanations. Schwab described three levels of openness in laboratory instruction. At the most basic level, the educational materials pose questions and provide methods for students to discover relationships for themselves. At the second level, the materials again pose questions, but the methods are left to the students to devise. At the most sophisticated level, the materials present phenomena without posing questions. The students must generate their own questions, gather evidence, and propose explanations based on their work.[2] This approach stands in contrast to the more typical one, where the teacher begins by explaining what will happen in the laboratory session.

The launch in 1957 of the Soviet satellite *Sputnik* alarmed Americans and gave rise to fears that the United States was lagging behind the Soviet Union in science and technology. In response, the U.S. Congress passed the National Defense Education Act in 1958. This legislation provided grants to teachers to study math and science and included funds for the development of new educational materials. The National Science Foundation, which was established in 1950, initially played little role in precollege education. However, during this "golden age" of science education, it created a number of discipline-based curriculum reform efforts including

- Physical Science Study Committee (PSSC physics),
- Chemical Education Materials Study (CHEM-Study),
- Chemical Bond Approach Project (CBA chemistry),
- Biological Sciences Curriculum Study (BSCS biology), and
- Earth Science Curriculum Project (ESCP earth science).

The intent of these curriculum reform efforts was to replace old materials with updated textbooks, inquiry-based laboratory activities, and multimedia packages. Large-scale teacher education programs were begun to help teachers implement the new materials. By the 1970s, however, it was clear that implementation levels for the new programs were not what the reformers had hoped for. The reasons for this relative lack of acceptance vary but include.

- the establishment of President Johnson's Great Society, which rearranged the priorities of the federal government to focus on social issues such as poverty and discrimination against minorities;
- the rise of an environmental movement that sometimes viewed science and technology as a problem and not as a solution;
- an emphasis on curriculum reform that failed to consider other aspects of the educational system, such as professional development;
- an attempt to create "teacher-proof" materials that would work regardless of the teachers' background or teaching method; and
- a focus on specific disciplines that did not adequately take into account existing school science programs.[1]

Despite these problems, the notion that inquiry-based approaches promote student learning continues to this day.

2 Inquiry as a Topic for the Middle School Science Curriculum

Scientific inquiry is a topic well suited to the middle school science curriculum. The *National Science Education Standards* (*NSES*), published in 1996, recognizes the importance of the topic and lists both abilities and understandings of inquiry (see the *NSES*, Inquiry and Educational Research section).[9] As discussed in the *NSES*, middle school students are naturally curious about the world. Inquiry-based instruction offers an opportunity to engage student interest in scientific investigation, sharpen critical-thinking skills, distinguish science from pseudoscience, increase awareness of the importance of basic research, and humanize the image of scientists. The process by which students acquire their understandings and abilities of inquiry continues during their school career. The practice of inquiry cannot be reduced to a simple set of instructions. The purpose of this supplement is to expose students to approaches that emphasize different elements of scientific inquiry. These approaches include

- developing the understandings and abilities of inquiry;
- formulating and testing a hypothesis;
- collecting data and constructing and defending an explanation;
- developing, using, and analyzing models; and
- analyzing historical case studies.

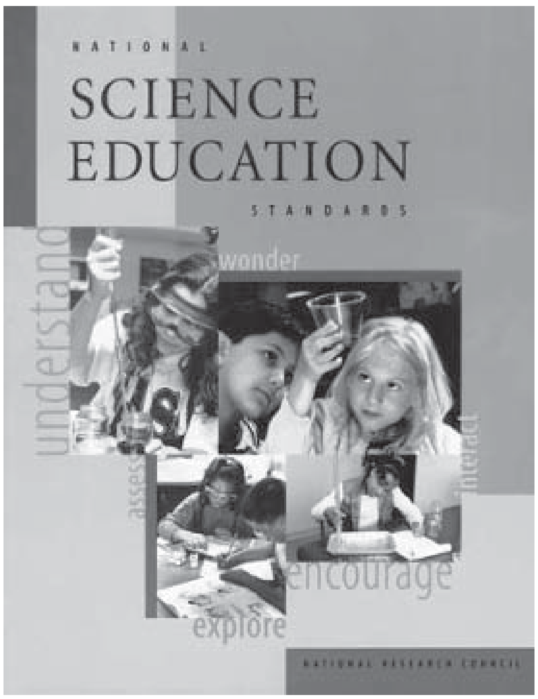


Figure 2. **The National Science Education Standards *lists abilities and understandings of scientific inquiry.***

3 Inquiry and Educational Research

Inquiry is a process that scientists must be comfortable with and use successfully in their work. Does it necessarily follow that middle school students who are learning science should also use the process of inquiry? After all, scientists are experts in their chosen fields, while middle school students are novices by comparison.

Several years ago, the National Research Council (NRC) released the report *How People Learn*.[10] It brought together findings on student learning from various disciplines, including cognition, neurobiology, and child development. Research demonstrates that experts tend to approach problem solving by applying their knowledge of major concepts, or "big ideas." Novices tend to seek simple answers that are consistent with their everyday expectations about how the world works. Science curricula that stress depth over breadth provide the time necessary for students to organize their understandings in a way that allows them to see the big picture.

Some of the findings from the NRC report that are relevant to inquiry are summarized in an addendum to the NSES titled Inquiry and the *National Science Education Standards*.[11] A brief description of these findings follows.

1. Understanding science is more than knowing facts.

   According to noted biologist John A. Moore, science is a way of knowing.[8] More than a collection of facts, science is a process by which scientists learn about the world and solve problems. Scientists, of course, have many facts at their disposal, but how these facts are stored, retrieved, and applied is what distinguishes science from other ways of knowing. Scientists organize information into conceptual frameworks that allow them to make connections between major concepts. They are able to transfer their knowledge from one context to another. These conceptual frameworks affect how scientists perceive and interact with the world. They also help scientists maximize the effectiveness of their use of inquiry.

Understanding science is more than knowing facts.

Students may not perceive science as a way of knowing about their world, but rather as facts that must be memorized. They may view parents, peers, and the media as their primary sources of information about what is happening and what should happen. It is important for students to distinguish science as a way of knowing from other ways of knowing by recognizing that science provides evidence-based answers to questions. Furthermore, decisions should be based on empirical evidence rather than on the perception of evidence.

2. Students build new knowledge and understanding based on what they already know and believe.

   The knowledge and beliefs that students bring with them to the classroom affect their learning. If their understanding is consistent with the currently accepted scientific explanation, then it can serve as a foundation upon which they can build a deeper understanding. If, however, students hold beliefs that run counter to prevailing science, it may be difficult to change their thinking. Student misconceptions can be difficult to overcome. Usually, students have an understanding that is correct within a limited context. Problems arise when they attempt to apply this understanding to contexts that involve factors that they have not yet encountered or considered. Simply telling students the correct answer is not likely to change their way of thinking.

   Inquiry-based instruction provides opportunities for students to experience scientific phenomena and processes directly. These direct experiences challenge deeply entrenched misconceptions and foster dialogue about new ideas, moving students closer to scientifically accepted explanations.

3. Students formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know.

   Two things must occur for students to change their conceptual framework. First, they must realize that their understanding is inadequate. This happens when they cannot satisfactorily account for an event or observation. Second, they must recognize an alternative explanation that better accounts for the event or observation and is understandable to them.

4. Learning is mediated by the social environment in which learners interact with others.

   This finding goes beyond the idea that "two heads are better than one." As is true for scientists, students do not construct their understanding in isolation. They test and refine their thinking through interactions with others. Simply articulating ideas to another person helps students realize the knowledge they feel comfortable with and the knowledge they lack. By listening to other points of view, students are exposed to new ideas that challenge them to revise their own thinking.

5. Effective learning requires that students take control of their own learning.

   Good learners are "metacognitive." This means that they are aware of their own learning and can analyze and modify it when necessary. Specifically, students must be able to recognize when their understanding conflicts with evidence. They must be able to identify what type of evidence they need in order to test their ideas and how to modify their beliefs in a manner consistent with that evidence.

Figure 3. Students refine their thinking through interactions with others.

6. The ability to apply knowledge to novel situations (that is, to transfer learning) is affected by the degree to which students learn with understanding.

   Ideally, students solidify their learning by applying their understanding to new contexts. They receive feedback from experiences in these new situations and modify their learning accordingly. This process is facilitated by doing tasks that students see as useful and that are appropriate to their skill level. Allowing adequate time for students to acquire new information and make connections to their prior knowledge is essential.

The NRC research findings point out similarities between students' natural curiosity and methods of inquiring about the world and scientists' more formal approach to problem solving. As both children and adults learn, they pass through similar stages of discovery. As stated in *How People Learn*,

> An alternative to simply processing through a series of exercises that derive from a scope and sequence chart is to expose students to the major features of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore, explain, extend, and evaluate their progress. Ideas

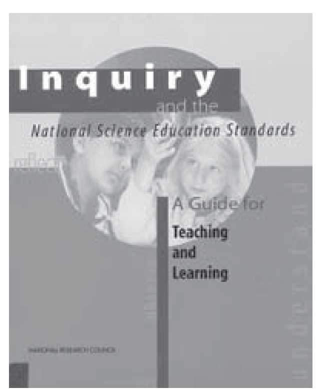


Figure 4. **Inquiry and the National Education Science Standards** ***brought together findings on student learning from many disciplines.***

are best introduced when students see a need or a reason for their use—this helps them see relevant uses of knowledge to make sense of what they are learning.10

This research-based recommendation supports the use of inquiry-based instruction, specifically calling for a structure that allows students to revise their conceptual framework. This structure is consistent with the BSCS 5E Instructional Model used in this supplement.

4 Inquiry in the *National Science Education Standards*

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking and consideration of alternative explanations.[9]

Human inquiry about the natural world exists in a wide variety of forms. The *NSES* recognizes inquiry as both a learning goal and a teaching method. To that end, the content standards for the Science as Inquiry section in the *NSES* include both abilities and understandings of inquiry. The *NSES* identifies five essential elements of inquiry teaching and learning that apply across all grade levels.

1. Learners are engaged by scientifically oriented questions.

   Scientists recognize two primary types of questions.[11] The *existence* questions often ask why. Why do some animals have hair, and why do we sleep? *Causal* questions ask how. How does a mountain form, how does an insect breathe? Sometimes science cannot answer existence questions. The teacher plays a critical role in guiding students to questions that can be answered with means at their disposal. Sometimes this simply involves changing a "why" question to a "how" question.

***Figure 5.* Teachers play a critical role in helping students ask questions that can be answered by scientific investigations.**

2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

   Scientists obtain evidence as scientific data by recording observations and making measurements. The accuracy of data can be checked by repeating the observations or making new measurements. In the classroom, students use data to construct explanations for scientific phenomena. According to the NSES, "explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific."

3. Learners formulate explanations from evidence to address scientifically oriented questions.

This element of inquiry differs from the previous one in that it stresses the path from evidence to explanation, rather than the criteria used to define evidence. Scientific explanations are consistent with the available evidence and are subject to criticism and revision. Furthermore, scientific explanations extend beyond current knowledge and propose new understandings that extend the knowledge base. The same is true for students who generate new ideas by building on their personal knowledge base.

4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

   Scientific inquiry differs from other forms of inquiry in that proposed explanations may be revised or thrown out altogether in light of new information. Students may consider alternative explanations as they compare their results with those of others. Students also should become aware of how their results relate to current scientific knowledge.

Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

---

5. Learners communicate and justify their proposed explanations.

   Scientists communicate their results in such detail that other scientists can attempt to reproduce their work. Replication provides science with an important vehicle for quality control. Other scientists can also use the results to investigate new but related questions. Students, too, benefit by sharing their results with their classmates. This gives them an opportunity to ask questions, examine evidence, identify faulty reasoning, consider whether conclusions go beyond the data, and suggest alternative explanations.

***Figure 6.** Communicating results is an important part of scientific inquiry.*

Inquiry lessons can be described as either full or partial with respect to the five essential elements of inquiry described in the table on page 26. Full-inquiry lessons make use of each element, although any individual element can vary with respect to how much direction comes from the learner and how much comes from the teacher. For example, inquiry begins with a scientifically oriented question. This question may come from the student, or the student may choose the question from a list. Alternatively, the teacher may simply provide the question.

Inquiry lessons are described as partial when one or more of the five essential elements of inquiry are missing. For example, if the teacher demonstrates how something works rather than allowing students to discover it for themselves, then that lesson is regarded as partial inquiry. Lessons that vary in their level of direction are needed to develop students' inquiry abilities. When young children are first introduced to inquiry lessons, they are not developmentally or academically ready to benefit from full inquiry lessons. Partial or guided inquiry lessons usually work for them then. Guided inquiry may also work well when the goal is to have students earn some particular science concept. In contrast, a

Essential Features of Classroom Inquiry and Their Variations

Essential Feature	Variations			
Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies a question provided by the teacher, materials, or other source	Learner engages in a question provided by the teacher, materials, or other source
Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner is directed to collect certain data	Learner is given data and asked to analyze	Learner is given data and told how to analyze
Learner formulates explanations from evidence	Learner formulates explanations after summarizing evidence	Learner is guided in process of formulating explanations from evidence	Learner is given possible ways to use evidence to formulate explanation	Learner is provided with evidence
Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner is directed toward areas and sources of scientific knowledge	Learner is given possible connections	
Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanation	Learner is coached in development of communication	Learner is provided broad guidelines to use to sharpen communication	Learner is given steps and procedures for communication

More <--------------------------- Amount of Learner Self-Direction ------------------------------> Less
Less <--------------------- Amount of Direction from Teacher or Material ----------------------> More

Source: National Research Council. 2002. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington, D.C.: National Academy Press.

full or open inquiry is preferred when the goal is to have students hone their skills of scientific reasoning. The following Content Standards for Science as Inquiry, Grades 5–8, table lists abilities and understandings about inquiry appropriate for middle school students that are taken from the *NSES* content standards for Science as Inquiry.[9]

Content Standards for Science as Inquiry, Grades 5–8

Fundamental Abilities Necessary to Do Scientific Inquiry

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Use mathematics in all aspects of scientific inquiry.

Fundamental Understandings about Scientific Inquiry

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science advances through legitimate skepticism.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

Source: National Research Council. 1996. *National Science Education Standards.* Washington, D.C.: National Academy Press.

5 Misconceptions about Inquiry-Based Instruction

Despite the consensus found in educational research, teachers may have different ideas about the meaning of inquiry-based instruction. At one extreme are teachers who believe they are practicing inquiry by posing questions to their students and guiding them toward answers. At the other extreme are teachers who feel they are not practicing inquiry unless they allow their students to engage in a lengthy open-ended process that directly mimics scientific research. Given these two extremes, it is not surprising that misconceptions about inquiry-based instruction abound. Some of the more prevalent misconceptions have been wrongly attributed to the *NSES*.[11] These mistaken notions about inquiry serve to deter efforts to reform science education. The materials in this curriculum supplement have been designed to dispel misconceptions about inquiry-based instruction.

Misconception 1: Inquiry-based instruction is the application of the "scientific method."
Teachers have a tendency to teach their students in the same way that they were taught. Many teachers learned as students that science is a method for answering questions and solving problems. They were told that the process of science can be reduced to a series of five or six simple steps. This concept of the scientific method in American science education goes back to John Dewey during the first part of the 20th century. In reality, there is no single scientific method. Scientists routinely use a variety of approaches, techniques, and processes in their work. The notion that scientific inquiry can be reduced to a simple step-by-step procedure is misleading and fails to acknowledge the creativity inherent in the scientific process.

In reality, there is no single scientific Method.

Misconception 2: Inquiry-based instruction requires that students generate and pursue their own questions. For some teachers, open-ended inquiry seems to best mirror the process of inquiry practiced by scientists. They may believe that if such open-ended inquiry is not possible, then they should resort to more traditional forms of instruction. In fact, there is no single form of inquiry that is best in every situation. In many instances, the educational goal is to have students learn some specific science content. In such cases, it is the questions themselves, rather than their source, that are most important. Even if the teacher provides the student with a question, an inquiry-based approach to the answer is still possible.

Misconception 3: Inquiry-based instruction can take place without attention to science concepts. During the 1960s, it became fashionable to promote the idea of process over substance. Teachers were sometimes told that they (and their students) could learn the process of inquiry in isolation and then apply it on their own to subject matter of their choice. However, this elevation of process over substance negates lessons learned from research on student learning. Students first begin to construct their learning using their prior knowledge of the topic and then inquire into areas that they do not yet understand.

Misconception 4: All science should be taught through inquiry-based instruction. Inquiry-based instruction is a tool used by teachers to help them attain educational goals for their students. Despite its usefulness, inquiry is not the most appropriate tool for every instructional situation. Teaching science, as well as the practice of science, requires varied approaches. Using any single method exclusively is less effective than using a combination of methods. Ultimately, using a single method becomes boring for the student. Inquiry-based instruction is perhaps most appropriate when teaching concepts that do not conform to common student preconceptions or that require students to analyze discrepant information. Students tend to need more time to construct their understandings of abstract concepts than they need for more concrete information.

Misconception 5: Inquiry-based instruction can be easily implemented through use of hands-on activities and educational kits. Such lessons and materials help teachers implement inquiry-based instruction in the classroom. They also help students focus their thinking in appropriate areas. However, there is no guarantee that student learning will go beyond performing the tasks at hand. It is possible for a student to successfully complete an experiment and yet not understand the science concept it is designed to teach. Inquiry-based instruction requires students to actively participate by gathering evidence that helps them develop an understanding of a concept. The teacher must evaluate how well the lesson or materials incorporate the essential features of inquiry and use them accordingly.

Figure 7. Hands-on activities help engage students' interest. Their use, however, does not guarantee that science concepts are understood.

Misconception 6: Student interest generated by hands-on activities ensures that inquiry teaching and learning are occurring. Student engagement in the topic is a critical first step in learning. Many students certainly prefer hands-on activities to sitting through a lecture. This enthusiasm does not necessarily translate into learning. The teacher must assess the students' level of mental engagement with inquiry, challenge naive conceptions, ask probing questions, and prompt students to revise, refine, and extend their understanding.

Misconception 7: Inquiry-based instruction is too difficult to implement in the classroom. Teachers unfamiliar with inquiry-based instruction may be uncomfortable trying something new. They may reason that they were not taught using these methods and question why their students should be any different. Common excuses for not using inquiry are that it takes too much time, does not work with large classes, or does not work with less-capable students. These frustrations typically result from improper use of inquiry methods rather than from any inherent problem with the inquiry approach itself. When teachers understand the essential features of inquiry, its flexibility in the classroom, and students' willingness to embrace it, they usually come to regard it as an essential strategy in their teaching.

Students first begin to construct their learning using their prior knowledge of the topic and then inquire into areas that they do not yet understand.

6 Important Elements of Scientific Inquiry for this Module

Teaching the process of scientific inquiry might seem different from teaching content-related material in the life or physical sciences. As the basis for Content Standard A in the *National Science Education Standards*, scientific inquiry can be broken down into discrete steps or methods that students can practice, just as content can be broken down into distinct concepts that students can explore. The process of scientific inquiry involves generating questions, designing investigations to answer questions, making predictions based on scientific concepts, gathering data, using evidence to propose explanations, and communicating scientific explanations (see the Essential Features column in the table on page 26).

It is important to recognize that the process of scientific inquiry is not linear. When students learn about the process, they often try to simplify it into a series of steps to follow. Teachers, too, often teach inquiry as the "scientific method" with a lock-step linear process. Why do students and teachers try to make inquiry a step-by-step process? They are misled by the formal, orderly way scientific research is published. Students and teachers may believe that scientists went about answering their questions in the same orderly fashion. In fact, that is not how science is done. Aspects of scientific inquiry interact in complex ways. New evidence, new observations, and new lines of questioning can lead scientists in a circuitous route, the end of which, they hope, is a good explanation for a set of phenomena. For example, questions lead to the design of an investigation, and the evidence gathered through the investigation may lead to more questions.[5]

This module focuses on three elements of scientific inquiry: science as a way of knowing, scientifically testable questions, and scientific evidence and explanations. Although these elements are the focus, students are exposed to other elements, such as conducting investigations, using mathematics in inquiry, and communicating scientific explanations.

6.1 The Nature of Scientific Inquiry: Science as a Way of Knowing

An important aspect of scientific inquiry is that science is only one of many ways people explore, explain, and come to know the world around them. There are threads of inquiry and discovery in almost every way that humans know the world. All of the ways of knowing contribute to humanity's general body of knowledge.

Each way of knowing addresses different issues and answers different questions. Science is a way of knowing that accumulates data from observations and experiments, draws evidence-based conclusions, and tries to explain things about the natural world. Science excludes supernatural explanations and personal wishes.[8]

In some ways of knowing, the meaning of statements or products is open to interpretation by any viewer. Science is different because it is characterized by a specific process of investigation that acquires evidence to support or reject a particular explanation of the world. While the meaning of the evidence can be debated, the evidence itself is based on careful measurement and can be reproducibly collected by any individual using appropriate techniques.

Science is often presented as a collection of facts, definitions, and step-by-step procedures. However, science is much more than this. Through science we ask questions, collect data, and acquire new knowledge that contributes to our growing understanding of the natural world.

6.2 Scientifically Testable Questions

Students are naturally curious and often spontaneously ask questions. Questions foster students' interest in science, leading them to make observations and conduct investigations.[6] Asking questions is part of the process of scientific inquiry, but not all questions can be answered using scientific investigations. Questions can be divided into two categories: existence and causal. Existence questions, which often begin with why, generally require recall of factual knowledge.[4, 6] Causal questions, which begin with *how, what if, does*, and *I wonder*, can be addressed through scientific investigations.[6] True cause and effect is very difficult to prove scientifically. Often, scientists rely on statistical and other analytical methods to determine the likelihood that certain relationships exist.

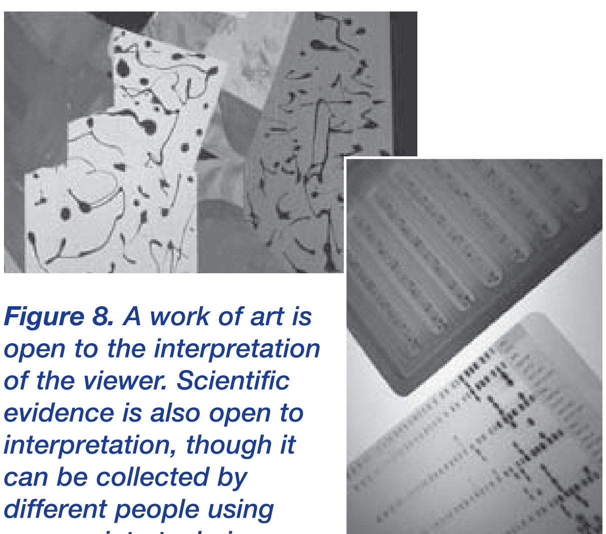


***Figure 8.** A work of art is open to the interpretation of the viewer. Scientific evidence is also open to interpretation, though it can be collected by different people using appropriate techniques.*

Science answers questions that are different from those answered by other ways of knowing. Testable questions are answered through observations or experiments that provide evidence. Students need guidance and practice to be able to distinguish questions that are testable from those that are not. A testable question meets these criteria:

- The question centers on objects, organisms, and events in the natural world.
- The question connects to scientific concepts rather than to opinions, feelings, or beliefs.
- The question can be investigated through experiments or observations.
- The question leads to gathering evidence and using data to explain how the natural world works.

As students develop their understanding of scientific inquiry, they should be able to generate their own testable questions. Students who are inexperienced with scientific inquiry ask factual questions more frequently because they are easy to generate. Students ask more meaningful questions once they have had more experience asking questions and have learned how questions influence the design of an investigation.[3,5] Teachers can improve the questioning skills of students through the following strategies:

- providing examples of testable questions,[5]
- encouraging students to formulate their own questions and responding positively to students' spontaneous questions,[4]
- providing materials that stimulate questions,[3, 4]

- providing students with opportunities to explore information related to their questions,[5] and
- providing students with feedback and the opportunity to change factual questions into testable questions or to generate new questions.[4, 5]

Through science we ask questions, collect data, and acquire new knowledge that contributes to our growing understanding of the natural world.

6.3 Scientific Evidence and Explanations

Scientists conduct investigations for a variety of reasons. They might want to discover why a particular phenomenon happens, explain something they only recently observed, or test conclusions of other investigations that they or their peers have conducted. Investigations might involve experiments, observations, or modeling. All these investigations provide evidence for the patterns, relationships, or phenomena that scientists are studying. Evidence is free of opinion and can be gathered by others with similar results.

Scientific explanations are based on a body of evidence and use scientific principles.[9] Scientists use evidence to establish relationships and causes of phenomena. They recognize that scientific explanations must be based on evidence. Knowing when they cross the line into explanations that are not consistent with their evidence is part of what makes an effective scientist and what makes science different from other ways of knowing about the world.

7 Teaching Scientific Inquiry

When teaching inquiry, keep the abilities and understandings of inquiry in the foreground and scientific content in the background. That is not always easy to do. In Lesson 3 of this module, you might be tempted to focus on the potential health problem described in the scenario. However, to teach inquiry effectively, you will need to focus, instead, on questions such as,

- How do we know?
- What is the evidence?
- What can we do to find out?

This does not mean that you should ignore content. You want students to understand that the process of inquiry results in a greater understanding of the subject matter. However, the subject matter must be simple enough that it does not obscure or detract from the students' ability to learn how to conduct investigations. The ultimate goal is for students to recognize that they should be accomplishing both—learning science as they are doing science. If they aren't, they aren't doing true inquiry.

Figure 9. *When teaching inquiry, keep the abilities and understandings of inquiry in the foreground.*

7.1 Posing Questions in the Inquiry Classroom

Questions are not only an important part of abilities and understandings of inquiry for students; they are also a valuable tool for teachers. Teachers' questions engage and motivate students, assess prior knowledge and preconceptions, focus and clarify class discussions, keep students on task, and guide student problem solving. Knowing how and when to ask questions is an important aspect of teaching inquiry.[6]

Students may be inexperienced at making observations. Questions (such as, What do you notice about … ?) help students figure out how to start making observations. Broadly focused questions allow students to decide what they should look for on their own, while narrowly focused questions help students recognize details that they might miss.[4] During student investigations, ask action questions that get students to think and respond at higher cognitive levels. Questions may include, What do you think will happen if you try … ? and What do you think you should do next?[6]

During inquiry lessons, students participate in class discussions in which they are asked to provide explanations. Initially, students may provide vague or general explanations. Encourage them to better articulate their thoughts by asking them 1) to be more specific by providing an example or 2) to explain the significance of their statement. Also use follow-up questions to redirect students. Follow-up questions may contain clues to steer students to a conclusion when they are having difficulty coming up with an answer.[6]

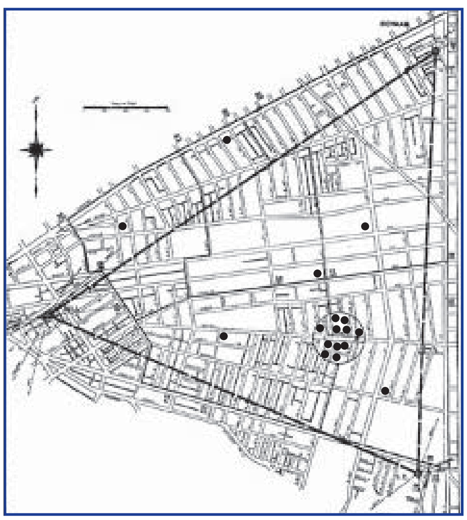


***Figure 10.** Epidemiologists seek explanations for clusters of disease.*

8 An Example of Scientific Inquiry: Epidemiology

When students are learning the abilities and understanding of inquiry, it is helpful for them to experience a good model for inquiry. In Lesson 3 of this module, students play the role of epidemiologists for a community health department. Epidemiology is a branch of medical science that deals with the incidence and distribution of diseases. Epidemiologists investigate the cause of a disease, how it spreads, and what can be done to control and prevent it. Like all scientists, epidemiologists use the process of scientific inquiry in their work.

As students role-play epidemiologists, they are guided through the process of inquiry. Guided inquiry is a helpful way to introduce students to the understandings and abilities of inquiry (see Inquiry in the *National Science Education Standards* on page 24). Guide students through the process of inquiry by directing them to specific questions and providing them with specific information to investigate. As students gain more experience with this type of guided inquiry, they will, over time, be able to conduct more of the process on their own.

In this module, students see that they are following the process of scientific inquiry by asking questions, making observations, gathering evidence, and proposing explanations based on their evidence. When students recognize this in their investigations as epidemiologists, they are more inclined to learn about the process.

References

1. Bybee, R.W. 1997. *Achieving Scientific Literacy: From Purposes to Practices*. Portsmouth, NH: Heinemann.

2. Bybee, R.W. 2000. Teaching science as inquiry. In *Inquiring into Teaching Inquiry Learning and Teaching in Science*. Washington, DC: American Association for the Advancement of Science.

3. Chin, C., Brown, D.E., and Bertram, C.B. 2002. Student-generated questions: a meaningful aspect of learning in science. *International Journal of Science Education*, 24(5): 521–549.

4. Harlen, W. (Ed.) 2001. *Primary Science: Taking the Plunge* (*2nd ed.*). Portsmouth, NH: Heinemann Educational Books.

5. Krajcik, J., Blumenfeld, P. C., Marx, R.W., Bass, K.M., and Fredricks, J. 1998. Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences*, 7: 313–350.

6. Llewellyn, D. 2002. Inquire Within: *Implementing Inquiry-Based Science Standards*. Thousand Oaks, CA: Corwin Press.

7. Loucks-Horsley, S., Hewson, P., Love, N., and Stiles, K. 1998. *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, CA: Corwin Press.

8. Moore, J.A. 1993. *Science as a Way of Knowing: The Foundations of Modern Biology*. Cambridge, MA: Harvard University Press.

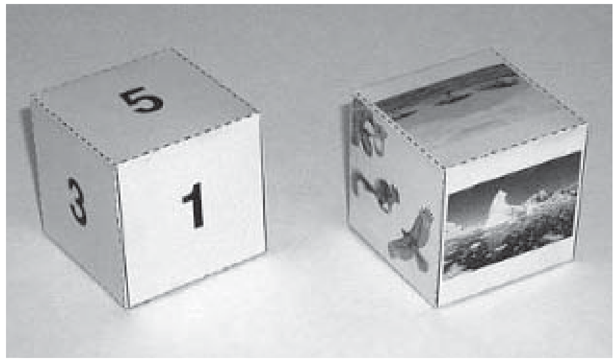
9. National Research Council. 1996. *National Science Education Standards*. Washington, DC: National Academy Press.

10. National Research Council. 1999. *How People Learn: Brain, Mind, Experience, and School*. Washington, DC: National Academy Press.

11. National Research Council. 2000. *Inquiry and the* National Science Education Standards: *A Guide for Teaching and Learning*. Washington, DC: National Academy Press.

12. Schwab, J. 1966. *The Teaching of Science*. Cambridge, MA: Harvard University Press.

Inquiring Minds



Lesson 1
Engage
Explore

At a Glance

Overview

Lesson 1 introduces students to basic aspects of scientific inquiry and the nature of science. In this lesson, students begin developing their own understanding of the process of scientific inquiry. Although students model the process of *scientific inquiry*, they are not introduced to the term scientific inquiry until the next lesson. Explicit connections to scientific inquiry are made in Lessons 2 and 3.

In the first activity, students are presented with a numbered paper cube and guided to ask, What is on the bottom of the cube? After making observations and sharing information, students propose explanations and defend their reasoning. In the second activity, students are presented with another paper cube that displays information of biological interest. As before, they are asked to propose an explanation for what is on the bottom of the cube. This activity helps students relate the more abstract concepts presented in the first activity to a biological context. The final activity allows students to reflect on the process they used in their investigations of the cubes.

Major Concepts

The process that scientists use to learn about the natural world is characterized by

- asking questions that can be answered through investigations,
- designing and carrying out scientific investigations,
- thinking logically to make relationships between evidence and explanations, and
- communicating procedures and explanations.

Objectives

After completing this lesson, students will be able to

- show their current understanding of the process of scientific inquiry,
- recognize that science uses a process as a means of learning about the natural world,
- identify the major components of the process by which scientists learn about the world, and
- appreciate that experiments help scientists test predictions.

Teacher Background

Consult the following sections in Information about the Process of Scientific Inquiry:

3 *Inquiry and Educational Research* (pages 21–24)
4 *Inquiry in the* National Science Education Standards (pages 24–27)
5 *Misconceptions about Inquiry-Based Instruction* (pages 27–29)
6.1 *The Nature of Scientific Inquiry: Science as a Way of Knowing* (pages 29–30)
6.2 *Scientifically Testable Questions* (pages 30–31)
7 *Teaching Scientific Inquiry* (pages 31–32)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 1.1, *The Mystery Cube Template* (Make 1 copy per team of 4.)	1 Mystery Cube per student team 1 pair of scissors 1 roll of transparent tape
2	No	Master 1.2, *The Biological Box Template* (Make 1 copy per team of 4.)	1 Biological Box per student team 1 pair of scissors 1 roll of transparent tape 1 metric ruler per student team
3	No	Master 1.3, *Thinking about Inquiry* (Make 1 copy per student.)	No materials except photocopies

Preparation

Use scissors to cut out the cube templates from the copies of Masters 1.1 and 1.2. Assemble each template into a cube and use transparent tape to secure. Tabs are provided on the templates to make this easier. Constructing the cubes out of regular copy paper can be difficult. If possible, use a thicker (card) stock. To prevent students from looking at the bottom of the cube, you can glue the cube to a piece of cardboard. Organize the class into teams of four for Activities 1 and 2.

You can use a single, large cube for this activity instead of several smaller cubes. To construct a large cube, multiply the dimensions of the cube template on Master 1.1 by a factor of 3 or 4 and trace it on a large piece of poster board. Draw numbers on the template and add shading, as depicted on Master 1.1. Use a razor knife to score the lines on the poster board that will be folded. Fold the poster board into a cube and fasten with tape. Place the large cube on a table at the center of the room in full view of the class.

Activity 1: *Mystery Cube*

Procedure

Note to teachers: This activity is designed to give students a brief introduction to the major aspects of scientific inquiry. Proceed through the activity at a steady pace. Do not allow students to spend too much time on any particular aspect of the model.

Before students take their seats, arrange the desks or chairs such that each team of students will be able to view their Mystery Cube, which you have placed in a central location. During the activity, students in each team should sit on different sides of the table so that each student sees a different side of the cube. Place the cube for each team on a desk or table so that the side displaying the number 2 is on the bottom.

1. **As students take their seats, instruct them not to touch the cubes.**

   If you are concerned that some students may look at the bottom of their cube despite of your instruction, consider gluing the cubes to a piece of cardboard so that the bottoms are not visible.

2. **Divide the class into teams of four. Begin by asking the class, "What is science?"**

   Quickly generate a list of student responses. Write their responses on the board or on an overhead transparency. If possible, try to relate the students' responses to the idea that science is one way in which we learn about the natural world.

Note to teachers: Asking this question requires students to call on their prior knowledge and to engage their thinking. At this point, do not critique student responses. Appropriate comments are short and positive, such as, "Good," and "What else?" Other appropriate responses include, "Why do you believe that?" and "How do you know that?" Such questions allow you to assess students' current knowledge about the topic and help you adjust the lesson accordingly. They also provide a springboard to "Let's find out" or "Let's investigate." In general, it is time to move forward when you see that thinking has been engaged.

Assessment:
Listening to student responses will help you assess their current understandings and misconceptions of inquiry.

3. **Ask the class, "How do scientists go about their work? How do they investigate things?"**

   As before, quickly generate a list of student responses. Write their responses on the board or an overhead transparency. Students may respond that scientists make observations and perform experiments. Students may define a scientific investigation as a process that follows the scientific method or that involves collecting and analyzing information.

4. **Announce that the students will perform an investigation of their own. Designate one student for each team to write down the team's questions, observations, and conclusions.**

Note to teachers: Instruct the students not to touch the cube or move from their seats while examining it. It is critical that students make observations about only what they can see of the cube. Because students cannot move around the cube, each must communicate his or her observations with the other team members to learn more about the cube.

5. **Ask, "What questions do you have about the cube?"**

   Each team should develop one or two questions. Students' questions may include the following:
   - What is on the bottom of the cube?
   - What is inside the cube?

NSES

Content Standard A: Identify questions that can be answered through scientific investigations. Think logically and critically to make the relationships between evidence and explanations. Communicate scientific procedures and explanations. Different kinds of questions suggest different kinds of scientific investigations.

6. **Guide the discussion to focus on the question, What is on the bottom of the cube? Explain to students that they will develop an explanation of what is on the bottom of the cube and that their explanation must be based on evidence.**

7. **Ask the teams, "What do we mean by evidence?"**

   Students often think that evidence is information acquired through personal experience or from people they know. Clarify for students that evidence refers to observations or the results of experiments.

8. **Ask the teams, "How do you think an explanation based on evidence is different from other explanations?"**

   Students may respond that an evidence-based explanation also supplies a reason for the explanation. Guide the discussion to bring out the idea that such a reason (evidence) is objective and does not merely reflect a personal preference. Another important point is that evidence provided by one source can be verified by another source. Since this will probably not be obvious to students at this time, consider making this point again during Step 10.

9. **Instruct the teams to make and share observations about the cube and develop an answer to the question, What is on the bottom of the cube?**

   Student observations likely will include the following:
   - The cube has six sides.
   - The cube has five exposed sides.
   - The exposed sides have numbers 1, 3, 4, 5, and 6.
   - The numbers on opposite sides add up to 7.

- The even-numbered sides are shaded.
- The odd-numbered sides are not shaded.
- The numbers are black.

10. Ask several student teams to share their answers to the question and to explain their reasoning.

Use this discussion as an opportunity to make the point that an explanation is strengthened by being supported by more than one type of observation or line of reasoning. For example, students may reason that the number 2 is on the bottom of the cube because that number is missing from the sequence 1, _, 3, 4, 5, 6. The observation that the numbers on opposite sides of the cube add up to seven (1 + 6, 3 + 4, and _ + 5 = 7) also supports the explanation that 2 is on the bottom of the cube. Additionally, students may suggest that the bottom of the cube is shaded, since 2 is an even number and the other even numbers, 4 and 6, are on shaded faces.

Ask students whether they are convinced that their answer is correct and to explain why or why not. Emphasize that their answer should be consistent with all the evidence. You could also extend the discussion by asking whether they can think of any evidence that would contradict their answer.

Assessment: This activity allows you to assess students' scientific reasoning skills.

11. Ask the teams how their investigation of the cube is similar to a scientific investigation.

Student answers will vary. Some may suggest that their investigation was scientific because it involved making observations and reaching explanations based on evidence. Others may point out that their investigation was not scientific because they were not able to conduct an experiment to see what was on the bottom of the cube.

12. Explain that different scientific investigations may require different approaches. Some use laboratory experimentation, while others do not.

In some investigations, performing experiments may not be an option because it is not possible to manipulate the phenomenon being studied. In such cases, investigators may proceed by making observations and measurements that can address the question. Examples of such studies are found in behavioral sciences, where, for instance, investigators may study the influence of various factors on behavioral choices, such as nutrition and physical activity. Other examples are found in ecological and population studies, or in the study of disease patterns.

13. **Conclude the activity by picking up the cubes without letting the students see the bottom face.**

    If students complain that they want to see the bottom of the cube, explain that the process of scientific inquiry often fails to provide a definite answer to a question. The results of the investigation provide a possible explanation that is consistent with the available evidence. The investigation may suggest additional questions that, when answered, may lead to a better explanation. You may also consider allowing the students to see the bottom of the Mystery Cube but not the bottom of the Biological Box used in the next activity.

Activity 2: *The Biological Box*

1. **Keep the class formed into the same teams as in the previous activity. Place a Biological Box in front of each team. The side displaying the grass, question mark, and lion should be on the bottom. Do not glue or tape down the cubes.**

   The orientation of the Biological Box was chosen so that students would be able to see two environments that are easy to identify (arctic and forest) and organisms that represent a food chain within each environment (fish, seal, and polar bear; acorn, squirrel, and hawk). The third environment, the savanna, is also visible, but it may be harder for students to identify. If necessary, you can identify it for the students as an African savanna.

Note to teachers: As before, instruct the students not to touch the cube or move from their seats while examining it. This second cube provides an opportunity for students to reinforce their skills of making observations, sharing information, and proposing explanations in a biological context.

2. **As in Activity 1, instruct teams to make and share observations about the box and develop an answer to the question, What is on the bottom of the box? Encourage students to record their observations and the evidence that supports their answers.**

   Give the teams a few minutes to complete their tasks. Student observations will likely include the following:
   - The box has six sides.
   - The box has five exposed sides.
   - Three exposed sides depict an environment (arctic, savanna, and forest).
   - Two exposed sides display three images (acorn, squirrel, and hawk; fish, seal, and polar bear).
   - Environments and the organisms that live in them are found on opposite sides.

- The exposed faces with three images on them represent food chains.

3. **Ask a member of each team to share the team's answer to the question and to explain its reasoning.**

   The patterns on the exposed box faces should allow students to propose that the bottom face shows three images that together depict a food chain found in a savanna.

4. **Ask the teams, "What experiment could you perform to determine what is on the bottom of the cube?"**

   Students may suggest simply picking up the cube and looking at the bottom.

5. **Explain that each team will be able to perform one "experiment" to learn more about what is on the bottom of the cube:**
   - Give each team a metric ruler.
   - Ask teams to select one corner of the bottom face they would like to see.
   - Designate one student from each team to slide the cube toward the edge of the table until the corner they selected extends no more than 2 centimeters off the edge of the table.
   - Instruct another student to glance up at the exposed corner and share his or her observation with teammates.

   Students should be able to explain why they chose the corner that they did. Explain that sliding the cube along the table represents an experiment being performed that produces evidence needed to help them answer the question, What is on the bottom of the cube?

6. **After teams have performed their experiment, ask them to share the evidence they collected with the rest of the class. Can they now conclude what is on the bottom of the cube?**

   Depending on which corner of the cube they exposed, students will report that they see nothing, a clump of grass, or a lion. The image at the center of the bottom face should not be visible. Students should conclude that the bottom face contains three images that depict a food chain found on the savanna. The first organism of the food chain is grass, and the third organism is a lion. Students can only guess at the identity of the middle member of the food chain. Animals eaten by lions include zebras, wildebeests, impalas, gazelles, antelopes, and warthogs. They should reason that it must be an animal that eats grass and is itself eaten by lions. Students may suggest animals such as zebras or antelopes. The cube actually displays a question mark. This, too, relates to the nature of science, where an investigation may point to more than one equally correct, evidence-based answer.

Assessment: Listening to student responses will allow you to determine how well students are now able to reason scientifically.

NSES

Content Standard A: Students develop abilities necessary to do scientific inquiry. Students develop understandings about scientific inquiry.

Content Standard C: Students develop an understanding of populations and ecosystems.

Content Standard G: Students develop an understanding of science as a human endeavor. Students develop an understanding of the nature of science.

7. **Conclude the activity by asking the teams to consider how their experience with the cubes is similar to the process that scientists use to learn about the natural world. Guide the discussion to make connections between the cube activities and the following abilities and understandings about scientific inquiry from the *National Science Education Standards*:**

- **Ability: Identify questions that can be answered through scientific investigations.**

  Students asked testable questions about the cube, such as, What is on the bottom of the cube?

- **Ability: Use appropriate tools and techniques to gather, analyze, and interpret data.**

  Students performed an experiment to obtain information that either supported or refuted their proposed explanation.

- **Ability: Develop descriptions, explanations, predictions, and models using evidence.**

  Students used their observations about the cube to recognize patterns and propose an explanation for what is on the bottom of the cube.

- **Ability: Communicate scientific procedures and explanations.**

  Students communicated their results by speaking to the class.

- **Understanding: Different kinds of questions suggest different kinds of scientific investigations.**

  The cube investigation relied on students making observations and recognizing patterns. Other types of investigations rely on collecting specimens, performing experiments, making models, and seeking more information.

- **Understanding: Scientific explanations emphasize evidence; have logically consistent arguments; and use scientific principles, models, and theories.**

  The more students made observations that supported their proposed explanation, the stronger their explanation—even though they could not confirm the answer by examining the bottom of the cube.

Activity 3: *Thinking about Inquiry*

1. **To wrap up the lesson, give the class a brief homework assignment. Give each student a copy of Master 1.3, *Thinking about Inquiry.* Ask students to list the specific characteristics of the Biological Box activity that model the process scientists use to learn about the natural world.**

   As you progress through the rest of the module, relate aspects of the student activities to these elements of scientific inquiry. The abilities and understandings about scientific inquiry reappear throughout the module and provide a foundation for students to build on as they use inquiry during the rest of the school year and, indeed, during their continuing education. Remember that students do not need to recognize the term scientific inquiry in this lesson. Scientific inquiry is defined for students in the lessons that follow.

Assessment:
The homework will help you determine what students learned as well as whether misconceptions have been corrected.

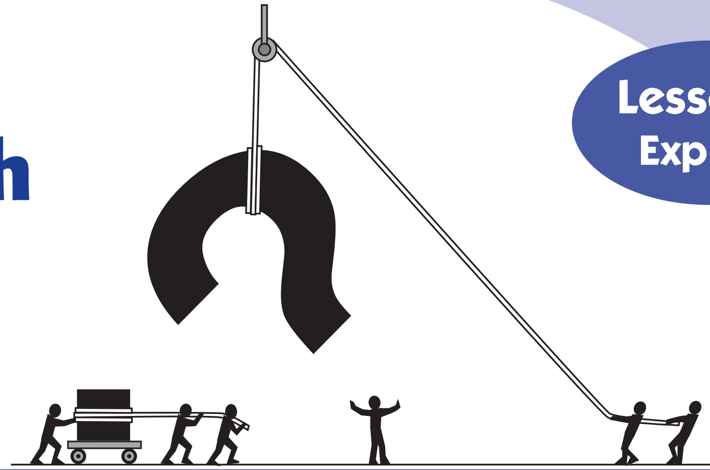
Lesson 1 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *Mystery Cube*	
Instruct students not to touch the cubes.	Page 37 Step 1
Divide class into teams of four. Ask, • "What is science?" • "How do scientists go about their work?" • "How do they investigate things?"	Page 37 Steps 2 and 3
Announce that teams will conduct their own investigation about the cube. Ask, • "What questions do you have about the cube?"	Page 38 Steps 4 and 5
Explain to students that they will develop an evidence-based explanation of what is on the bottom of the cube.	Page 38 Step 6
Ask the teams, • "What do we mean by evidence?" • "How do you think an evidence-based explanation is different from other explanations?"	Page 38 Steps 7 and 8
Instruct teams to make and share observations about the cube.	Pages 38–39 Step 9
Have several teams share their answers with the class. Ask them to explain their reasoning.	Page 39 Step 10
Compare the student investigations with scientific investigations. Explain that scientific investigations use different approaches.	Page 39 Steps 11 and 12
Collect cubes without letting students see the bottom face.	Page 40 Step 13
Activity 2: *The Biological Box*	
Place a Biological Box, in the proper orientation, in front of each team. Explain that they will develop an evidence-based explanation of what is on the bottom of the cube.	Page 40 Step 1
Instruct teams to make and share observations about the cube.	Pages 40–41 Step 2
Have several teams share their answers with the class. Ask them to explain their reasoning.	Page 41 Step 3
Ask the teams what experiment they could perform to determine what is on the bottom of the cube.	Page 41 Step 4

Have teams perform an experiment: • They select one corner of the cube to observe. • They slide that corner of the cube off the edge of the table and observe what it reveals.	Page 41 Step 5
Have several teams share their answers with the class. Ask them to provide their evidence and explain their reasoning.	Page 41 Step 6
Ask students to compare their experience with the cubes with the process used by scientists. Make connections to abilities and understandings from the *National Science Education Standards*.	Page 42 Step 7
Activity 3: *Thinking about Inquiry*	
Give each student a copy of Master 1.3, *Thinking about Inquiry*. As a homework assignment, instruct students to list characteristics of the Biological Box activity that model the process of scientific inquiry.	Page 43 Step 1 M

M = Involves copying a master.

Working with Questions



At a Glance

Overview
In Lesson 2, students explore questions in a scientific context. They consider what makes questions testable. Students evaluate questions and then pose testable questions about scientific problems. After reading short scenarios, students come up with their own testable questions about the reading. They also consider the types of evidence needed to answer their questions.

Major Concepts
- Scientists ask questions that can be answered through scientific investigations.
- Testable questions are answered by collecting and analyzing evidence and developing explanations based on that evidence.
- Questions that cannot be answered through scientific investigation are those that relate to personal preference, moral values, the supernatural, or unmeasurable phenomena.

Objectives
After completing this lesson, students will be able to
- identify questions that depend on personal preferences or moral values, or that relate to the supernatural or phenomena that cannot be measured;
- identify questions that can be tested;
- ask questions that can be answered through investigations; and
- identify the type of evidence needed to answer the questions.

Teacher Background
Consult the following sections in Information about the Process of Scientific Inquiry:

4 *Inquiry in the* National Science Education Standards (pages 24–27)

6.2 *Scientifically Testable Questions* (pages 30–31)

6.3 *Scientific Evidence and Explanations* (page 31)

In Advance

Activity	Web Component?	Photocopies	Materials
1	No	Master 2.1, *Working with Questions* (Make 1 copy per student and prepare an overhead transparency.)	No materials except photocopies and transparencies
2	No	Master 2.2, *Letters to the Editor* (Make 1 copy per student.) Master 2.3, *Question and Investigation Form* (Make 1 copy per student.)	No materials except photocopies

Preparation

No preparations are needed except for making photocopies and transparencies.

Procedure

Note to teachers: The goal of this lesson is to help students appreciate that although we all ask questions about the world, scientists ask questions in ways that are testable. The question, How is bug blood different from human blood? is an interesting one, and it does define a general problem. As stated, this question is not specific enough to be tested directly. However, one can ask a number of testable questions that can be investigated to produce data (evidence) that answer the more specific questions. For instance, a scientist might ask, "Do bug blood and human blood contain the same things? Do they contain the same kinds of cells? Do they contain the same chemicals?" Of course, there are some questions that simply ask for information. Are you going to the movies Saturday night? is a question that implies no problem about which testable questions can be asked.

In this module, students learn how to ask testable questions—questions that can be answered through investigations. The intention is not to present a complex set of criteria that define a scientific question, but rather to introduce students to the idea that scientists identify a problem, ask testable questions, collect and analyze evidence, and reach conclusions based on that evidence. If this module is taught near the beginning of the school year, it can serve as an introduction to scientific ways of thinking that students will practice and refine throughout the school year and into the future.

Activity 1: *What's the Question?*

1. **Remind students that they asked questions about cubes in the first lesson. Ask students, "Why do you ask questions?"**

   Students likely will respond, "To get answers or to get more information."

2. **Explain that scientists also ask questions to get answers, but they must ask their questions in ways that can be tested through a scientific investigation. This means that some questions are more easily answered than others. Ask students, "To a scientist, what makes a question a good question?"**

   Accept all answers. Write student responses on the board or on an overhead transparency. Some students may believe that good questions do not ask about something really obvious, ask only about things that are real, or allow us to gain necessary information. The objective is not to be overly critical, but rather to engage student thinking about questions.

3. **Explain that scientists continually ask questions and that they try to ask questions that can be answered through investigations. Challenge students to describe some questions that are not suitable for a scientific investigation.**

   Students' answers will vary. Write some of their responses on the board. Try to elicit the following characteristics of questions that are not scientifically testable:
   - Their answers depend on personal preference.
   - Their answers depend on moral values.
   - They relate to the supernatural.
   - They relate to phenomena that cannot be measured.

4. **Explain that in this activity, students will investigate how to ask questions in the ways that scientists do.**
   - **Divide the class into teams of three.**
   - **Give each student one copy of Master 2.1, *Working with Questions*.**
   - **Display a transparency of Master 2.1 at the same time.**
   - **Read the list of questions with the students.**

   Each question defines a general problem. As written, none of the questions is directly testable. Two of the questions (3 and 6) are not appropriate for a scientific investigation because they involve personal preference (Question 3) and moral values (Question 6). The other questions are appropriate to scientific investigation but need to be rephrased in a more specific form.

Assessment: Through questioning, you can assess your students' previous knowledge and misconceptions.

NS
ES

Content Standard A: Students will develop the abilities necessary to do scientific inquiry.

5. **Explain that scientists may ask questions that have to be rephrased in the form of specific questions that can be tested through investigation.**

   To get students started, give them one example of a testable question such as, Does what you eat influence the appearance of pimples? or, Does eating chocolate contribute to acne?

6. **Assign each team a question from Master 2.1. Ask the teams to do the following:**
   - **Decide whether their question can be answered through a scientific investigation.**
   - **If their question can be answered through an investigation, come up with two testable questions that relate to the problem described in their assigned question.**
   - **If their question cannot be answered through an investigation, be able to explain why not and come up with two testable questions that relate to their question's topic.**

   Give student teams 5 to 10 minutes to work with their questions. Students probably do not have the background to generate questions that show insight into each of the scientific problems. Students working with the same question may ask different testable questions. The purpose of this step is to develop critical-thinking skills and to give students practice writing testable questions. Because the purpose of this lesson is to develop students' understanding of testable questions, avoid critiquing the problems they identify. Instead, focus on the students' ability to phrase a question in a way that makes it testable. Look for questions that focus on the natural world, scientific ideas, and quantitative relationships. Questions should not relate to personal beliefs, moral values, or the supernatural.

Assessment:
Determine students' depth of understanding of how scientific questions are formulated and evaluated.

7. **Reconvene the class. Ask teams first to state whether or not their question can be answered through a scientific investigation. If they determined that their question can be answered through an investigation, what two testable questions did they ask?**

   Write the teams' questions on the board or a transparency. As questions are put on the board, ask students if they agree that the question is testable. If they do not agree, ask that they restate the question so that it is testable.

Note to teachers: Questions 3 (Is rock music better than hip-hop music?) and 6 (Is vegetarianism better than eating meat?) imply a preference and as such are not testable. However, when students are confronted with questions expressing or implying a preference, they should probe deeper to be able to generate a testable question. For instance, if students are told or if they read that vegetarian diets are better than meat-containing diets, they might begin by asking, "Better in what ways?" This may lead to the notion that one diet is better than another in terms of nutritional content or long-term health consequences. From these clarifications, students can generate testable questions. Students can treat the issue of "better music" in a similar manner. In what ways might one type of music be better than another? Does one produce greater sales or greater alertness?

Tip from the field test: Some questions generated by teachers for this activity include the following:

- Do all bugs have blood?
  Does bug blood contain white blood cells and red blood cells?
  What is the composition of bug blood?

- What happens to your fingers if you soak them in other liquids, such as dish-washing detergents?
  Do fingers wrinkle faster in hot or cold water?
  How long do you have to soak your fingers before they wrinkle?

- Does rock music make more money than hip-hop music?
  How do music sales vary by geographical distribution and by type of music?
  How do music sales vary by age and gender of the buyer and by type of music?

- What physiological changes trigger sneezing?
  Do sunglasses prevent sneezing?
  Does breathing through your mouth versus breathing through your nose make a difference in sneezing when you are exposed to bright light?

- Are septic workers unhappy? (subjective)
  Changed to: Do results of psychological tests designed to measure happiness show that sanitation workers score lower than other types of workers?
  Do people who work in florist shops have fewer psychological problems than those who work in less pleasantly fragrant environments?

- Do vegetarians experience fewer heart attacks than meat eaters do?
  Does a vegetarian diet contain the same vitamins and minerals as a meat-containing diet?
  How do vegetarian and meat-containing diets compare nutritionally?

A teacher-generated question related to Question 5 on Master 2.1 was considered "subjective." This question was changed so that its answer doesn't rely on asking people a general question about their own feelings. These examples point out what you should look for with your students' questions: are they stated specifically enough to be tested as stated, or are they too general and not testable directly? If a question is too "big," students may have to break off a smaller piece in the form of a more specific question.

8. **Lead a discussion asking students to list characteristics that distinguish testable questions from questions that cannot be tested.**

   Guide the discussion to focus on the following criteria:
   - Testable questions ask about objects, organisms, and events in the natural world.
   - Testable questions can be answered through investigations that involve experiments, observations, or surveys.
   - Testable questions are answered by collecting and analyzing evidence that is measurable.
   - Testable questions relate to scientific ideas rather than personal preference or moral values.
   - Testable questions do not relate to the supernatural or to nonmeasurable phenomena.

Note to teachers: Students need to come away with the understanding that scientifically testable questions are centered on objects and phenomena in the natural world. These objects and phenomena can be described and explained by scientific investigations. Testable questions do not relate to the supernatural. Testable questions lead to scientific investigations that gather measurable evidence. Mention to students that different kinds of investigations may be appropriate depending on the question. Some questions lead to observations, while others lead to experiments.

Activity 2: *Questions . . . More Questions*

Note to teachers: In Activity 2, students practice analyzing readings and writing questions as an introduction to the next lesson. This activity provides an opportunity to assess students' understanding of testable questions. To save time, you may select just one of the readings and discuss it with the class. Alternatively, you may assign the activity as homework.

1. **Give each student one copy of Master 2.2, *Letters to the Editor*, and Master 2.3, *Question and Investigation Form*. Explain that each of the three letters on Master 2.2 features an individual expressing a different point of view about the same topic.**

2. **Instruct students to**
   - **read each of the three letters,**
   - **select one letter and develop two scientific questions that relate to the point of view expressed in the letter, and**
   - **for each question, describe an investigation and the evidence that could be used to answer it.**

Look for questions that meet the criteria given in Step 8 of Activity 1. Student questions should be worded in a way that suggests that they can be answered through investigations. Their questions should not be based on opinions or personal beliefs. Examples of acceptable questions and investigations follow.

Fast Food and Cancer?

Example Question: Does food served at Quick and Tasty contain chemicals that can lead to cancer?

Example Investigation: Test food from Quick and Tasty for chemicals that are associated with cancer.

Example Question: Is cancer more common today than in the past?

Example Investigation: Compare the incidences of several types of cancer today and 20 or 50 years ago.

Healthy Diet? It's Up to You!

Example Question: Do obese people select different food items at Quick and Tasty compared with people of normal weights?

Example Investigation: Observe and record the food choices at Quick and Tasty of obese and normal-weight people.

Example Question: Are the salads served at Quick and Tasty as nutritious as similar salads served at more expensive restaurants?

Example Investigation: Obtain comparable salads from Quick and Tasty and several more expensive restaurants. Analyze them for their nutritive content.

NSES

Content Standard A: Students will develop understandings about scientific inquiry.

Content Standard E: Students will develop understandings about science and technology.

Content Standard F: Students will develop an understanding of science and technology in society.

Content Standard G: Students will develop an understanding of the nature of science and of science as a human endeavor.

Assessment: Evaluating students' questions and investigations allows you to determine their understanding of scientific questioning.

Weight a Minute!

Example Question:	Does a typical meal at Quick and Tasty contain more calories than recommended for an average person?
Example Investigation:	Determine the number of calories in several of the Quick and Tasty meals and compare this with recommended calorie intakes.
Example Question:	Are the food portions served at Quick and Tasty larger than those recommended for a healthy diet?
Example Investigation:	Obtain various food items from Quick and Tasty. Compare their portion sizes with the recommended ones.

Lesson 2 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *What's the Question?*	
Remind students that they asked questions about cubes during the first lesson. Ask, • "Why do you ask questions?"	Page 49 Step 1
Explain that scientists ask questions that are answerable through scientific investigations. • Ask, "To a scientist, what makes a question a good question?" • Challenge students to describe questions that cannot be answered through scientific investigations.	Page 49 Steps 2 and 3
Divide the class into teams of 3. Give each student a copy of Master 2.1, *Working with Questions*. • Display a transparency of Master 2.1 • Read the list of questions aloud.	Page 49 Step 4 M T
Explain that questions may have to be rephrased in the form of a more specific question that can be tested through investigation.	Page 50 Step 5
Assign each team a question from Master 2.1. Ask teams to • decide whether their question can be answered through a scientific investigation and • come up with two testable questions that relate to the problem described in their assigned question.	Page 50 Step 6
Reconvene the class. Ask several teams to share their conclusions. • What two testable questions did they ask?	Pages 50–52 Step 7
Ask students to list characteristics that distinguish testable questions from questions that cannot be tested.	Page 52 Step 8
Activity 2: *Questions … More Questions*	
Give each student a copy of Master 2.2, *Letters to the Editor*, and Master 2.3, *Question and Investigation Form*.	Page 52 Step 1 M
Instruct students to • read each letter, • select one letter and write two testable questions that relate to it, and • for each question, describe an appropriate investigation and the evidence needed to answer the question.	Pages 53–54 Step 2

M = Involves copying a master. T = Involves making a transparency.

Lesson 3
Explain
Elaborate

Conducting a Scientific Investigation

At a Glance

Overview

In Lesson 3, students role-play as members of a team from a community health department. The student teams develop testable questions and investigate a possible health problem in the local school district. Students develop their understanding of inquiry by looking for patterns in attendance data, comparing dates of activities with the onset of increased absences, and analyzing maps, graphs, and data tables. Students complete their investigation by proposing possible sources of the health problem and describing how the sources might be confirmed or refuted.

Major Concepts

- Scientific explanations emphasize evidence.
- Scientists think critically about what evidence should be collected in their investigations.
- Scientists analyze the results of their investigations to produce scientifically acceptable explanations.

Objectives

After completing this lesson, students will be able to

- formulate testable questions,
- use graphs and data tables to analyze and interpret data,
- develop explanations and predictions based on evidence, and
- explain how a scientific investigation is conducted.

Teacher Background

Consult the following sections in Information about the Process of Scientific Inquiry:

4 *Inquiry in the* National Science Education Standards (pages 24–27)
6.2 *Scientifically Testable Questions* (pages 30–31)
6.3 *Scientific Evidence and Explanations* (page 31)

In Advance

Activity	Web Component?	Photocopies	Materials
1	Yes	Master 3.1, *Investigative Report Form** (Make 1 copy per student.) Master 3.2, *Letter from Principal* (Make an overhead transparency.) Master 3.3 *First Memo from Director* (Make an overhead transparency.) Masters 3.4a, b, c, *Attendance Data* (Make 1 copy per team.)	No materials except photocopies and, for print version, transparencies
2	Yes	Master 3.1, *Investigative Report Form** (Make 1 copy per student.) Master 3.5, *Second Memo from Director* (Make an overhead transparency.) Master 3.6, *Interview Summary* (Make 1 copy per team.) Masters 3.7a, b, *Quotes from Interviews* (Make 1 copy per team.) Masters 3.8a, b, c, d, *School Calendars* (Make 1 copy per team.)	No materials except photocopies and, for print version, transparencies
3	Yes	Master 3.1, *Investigative Report Form** (Make 1 copy per student.) Master 3.9, *Third Memo from Director* (Make an overhead transparency.) Masters 3.10a, b, *Activity Tables* (Make 1 copy per team.) Masters 3.11a, b, *Activity Maps* (Make 1 copy per team.)	No materials except photocopies and, for print version, transparencies
4	None	Master 3.12, *Analyzing Evidence** (Make 1 copy per student.)	No materials except photocopies

* Masters needed for Web version. Print version uses all the masters.

Preparation

During the first activity of this lesson, students ask testable questions as part of their investigation. As a reminder, consider writing aspects of testable questions on the board:

- Testable questions ask about objects, organisms, and events in the natural world.
- Testable questions can be answered through investigations that involve experiments, observations, or surveys.
- Testable questions are answered by collecting and analyzing evidence that is measurable.
- Testable questions relate to scientific ideas rather than personal preference or moral values.
- Testable questions do not relate to the supernatural or to nonmeasurable phenomena.

For classes using the *Web-based version*:
Verify that the computer lab is reserved for your classes or that classroom computers are ready to use. Bookmark the student Web site at *http://science.education.nih.gov/supplements/inquiry/student*.
Make photocopies.

For classes using the *print version:*
No preparations are needed except for making photocopies and transparencies.

Procedure

For classes using the *Web-based version* of Lesson 3:

Activity 1: *Unusual Absences*

Note to teachers: The following procedure describes how to conduct the Web-based version of this lesson, the preferred form of instruction. Instructions for conducting the alternative, print-based version start on page 71.

Tip from the field test: Consider summarizing the procedure instructions on the board or on a student handout. This helps keep the students focused and reduces the need to give them instructions while they are working on the computers.

1. **Explain to the class that they will carry out a scientific investigation using materials on the Web. In this investigation, they will be working as members of an investigative team from the local community health department.**

   Throughout this activity, you will act as team supervisor for all the student teams.

2. **Give each student a copy of Master 3.1, *Investigative Report Form*. Explain that students will use this form to record the progress of their investigation.**

Each day, students will write notes about their investigation on a separate copy of the Investigative Report Form.

3. **Divide the class into teams of three and direct each team to a computer. Instruct students to proceed to *http://science.education.nih.gov/supplements/inquiry/student* and click on "Activity 1—Unusual Absences."**

   This link displays the home page of the intranet site for a fictitious community health department.

4. **Have students click on the link for "You have (1) New Message" and read the e-mail message from the director of the health department.**

   The e-mail contains an attached letter from a principal of a local school and a link to the school district's Web site. The principal states that this past week, an unusual number of students were absent from the band class. She is concerned that the school may be facing an outbreak of flu. As members of the investigative team, students first read the letter and write a testable question (Step 5). Only then do they proceed with their investigation by clicking on the link to the school district Web site.

NSES

Content Standard A: Identify questions that can be answered through scientific investigations.

Note to teachers: The community health department Web site simulates an internal (intranet) Web site used by employees of the health department. As such, it contains information that is not directly relevant to the classroom lesson. If students explore the site, however, they will find that it provides realistic information about public health and scientific inquiry.

5. **After teams have read the e-mail message from the director and the attached letter from Principal Parsons, discuss what testable questions they can ask as they begin their investigations to determine whether a health problem exists.**

   Students should record their testable questions on their *Investigative Report Form* (Master 3.1) and be prepared to share them with the class. Circulate among the teams as they work to develop their testable questions. Remind students of the aspects of testable questions listed on the board.

   Students should ask questions that will help them determine whether the school absences indicate a health problem. Ideally, they should be able to answer their questions by examining the school attendance data provided at the school district's Web site. Examples of testable questions they might ask include
   - Is the number of absences in the last week more than in previous weeks?

NSES

Content Standard A: Different kinds of questions suggest different kinds of scientific investigations.

- Are more students absent from one type of class than the others?
- Are there more absences in one school than the others?

6. **After the teams have developed their testable questions, have them return to the director's e-mail message and click on the link to the school district's Web site. At this site, they can access attendance data for the community's four middle schools.**

   The only active link on the school district's Web site is the "Attendance Data" link.

7. **Once students have viewed the attendance data, explain that they need to export the data to the health department's Web site, where the data can be displayed in graphic form. To export the data to the health department's Web site, students click on the "Export Data" button and type "cohd.org" into the "Export Destination" box.**

   Students now have access to the "Data Analysis" section of the health department's Web site. If students click on "View Data," they can see the same data tables that are on the school district's Web site. If students click on "Create Graphs," they are given a menu of 16 graphs from which to choose. Students can view from one to four graphs at a time. After they have made their selections, students click on "Display Graphs" to view them. Students may also print the graphs either individually (to fill the page) or in groups of up to four at a time.

   Tip from the field test: Write the export destination, "cohd.org," on the board.

Note to teachers: Students may have difficulty deciding which graphs to display. Suggest that they view four graphs at once. Students should select graphs that will help them make comparisons and answer their testable questions. They can choose from 16 graphs. Each school has four graphs of the number of absences plotted against time (in days): total absences for the seventh grade, physical education (PE) absences, art absences, and band absences. Point out to students that the scales on the graphs are not always the same.

8. **Instruct teams to use the graphs and data sheets to analyze the attendance data. Students should record their findings on their *Investigative Report Form*. Explain that they will share their results with the class later.**

   The graphs and data sheets provide evidence that teams will use to propose explanations for the student absences. Students should look for sudden increases in absences that might indicate a

NSES

Content Standard A: Use appropriate tools and techniques to gather, analyze, and interpret data.

NSES

Content Standard A: Use mathematics in all aspects of scientific inquiry.

Content Standard E: Science and technology are reciprocal. Science helps drive technology. Technology is essential to science.

health problem and for comparisons that help them answer their testable questions. They should note the patterns they observe in the attendance data for each school. Students should observe the following:

- There was an unusually high number of absences during the last week among students in band classes at both Truman and Jackson middle schools.
- Absences among students in art and PE classes, as well as for the entire seventh grade, were not higher during the last week for both Truman and Jackson middle schools.
- Roosevelt and Kennedy middle schools had fairly constant numbers of absences throughout the last month in every category.

Tip from the field test: Remind students to record their evidence as they review the data and graphs. Help students develop their explanations. Ask, "How can you explain the evidence you have collected?"

9. Instruct teams to exit the Web site after they have completed their analyses and recorded their findings.

NSES

Content Standard A: Develop descriptions, explanations, predictions, and models using evidence.

10. Acting as team supervisor, facilitate a class discussion to summarize the findings from all the teams. Consider which steps the investigation should take next. Guide the discussion to focus on the following questions:

- **What is the reason for the higher number of absences among students in band classes at Truman and Jackson middle schools?**
- **If these absences are due to an illness, do band members from the two affected schools share the same symptoms?**
- **Have band members from the two schools been in recent contact with each other?**

Students should have recorded the testable question for their team on their Investigative Report Form. When filling out the form, students should write down under "Evidence Collected" anything that they feel may have a bearing on their investigation now or in the future. The summary of findings should be included in the "Analysis and Explanation of Evidence" space. The next steps for the investigation should be phrased as a question and entered into the space on the form labeled "Next Questions."

Activity 2: *What's the Cause?*

Tip from the field test: As in the first activity, consider summarizing the procedures on the board or on a student handout. This helps keep the students focused and reduces the need to give them instructions while they are working.

Note to teachers: Make sure that students have available their Investigative Report Forms from the previous activity. This helps them recall the progress of their investigation.

1. **Explain to the class that they will continue their investigation into the school absences among band members at Truman and Jackson middle schools. Specifically, they will answer the testable questions that were developed at the conclusion of Activity 1:**
   - **What is the reason for the higher number of absences among students in band classes at Truman and Jackson middle schools?**
   - **If these absences are due to an illness, do band members from the two affected schools share the same symptoms?**
   - **Have band members from the two schools been in recent contact with each other?**

2. **Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct students to write the testable questions developed at the end of the previous activity in the "Testable Question" space on their form.**

3. **Reconvene students in their teams from Activity 1. Direct each team to a computer and instruct students to proceed to *http://science.education.nih.gov/supplements/inquiry/student* and click on "Activity 2: What's the Cause?"**

   As in the beginning of Activity 1, the teams are alerted that they have a new e-mail message to read.

4. **After reading the new e-mail from the director, the teams click on the link to the tables that list results of interviews.**

   Information in the tables was obtained from interviews with the students' parents. The table for Truman Middle School shows that there were 10 students from band class absent during the past week. One student was away on a family vacation. The other nine students all have an illness that displays stomach-related symptoms. The table for Jackson Middle School lists eight absent students. One student has a broken leg. The remaining seven students have an illness that presents stomach-related symptoms.

5. **Have the teams read portions of the interviews with the parents on the Web site and record their conclusions on their Investigative Report Form. They should be prepared to share their findings with the rest of the class.**

NSES

Content Standard A:
Think critically and logically to make relationships between evidence and explanations.

Content Standard A: Recognize and analyze alternative explanations and predictions.

The parents report the same symptoms listed in the tables. Some parents volunteer reasons for the illnesses, such as food poisoning or the flu. These conflicting reasons may confuse some students. You may point out that the reasons given by the parents are opinions and not diagnoses from a doctor, which are based on medical evidence.

6. **After the teams have examined the results of the interviews and read portions of the parent interviews, have them click on the link to the calendars of school events.**

   Circulate among the teams as they look at the school calendars. Remind students that they are looking for evidence that will help them develop better explanations about the cause of the health problem. Make sure that students understand why they are looking at the school calendars. An illness is involved. If there are contacts between the students from the two schools, then such contacts may help explain how an illness was contracted or passed from student to student. A healthcare worker makes a subtle but important point during one of the parent interviews. The worker mentions that with food poisoning, a person becomes ill in a day or two, while a stomach virus takes about five days before the illness strikes. Students should use this information to help decide what type of illness may be associated with which activities of the band members.

7. **Have students compare the two school calendars and write down their conclusions.**

Content Standard A: Think critically and logically to make the relationships between evidence and explanations.

   A comparison of the Truman and Jackson middle school calendars reveals that the seventh-grade bands from both schools were together three times in the past month:

   - On May 5, both bands performed at a May Day parade. Students should note that May 5 was likely too long ago to be associated with the current illness. It is interesting that the band from Roosevelt Middle School was also at the parade and yet its band members did not become ill.
   - Students from the two bands were together on May 15 for a planning meeting about the upcoming Battle of the Bands.
   - The bands competed at the Battle of the Bands event on May 19.

   Tip from the field test: Remind students to review their evidence and explanations from the previous activity.

8. **Instruct teams to exit the Web site after they have completed their analyses and recorded their findings.**

9. **Acting as team supervisor, facilitate a class discussion to summarize the findings from all the teams. Think ahead to the next steps for the investigation. Guide the discussion to focus on the following questions:**
   - **Is there a common reason for the absences of the band students at Truman and Jackson middle schools?**
   - **What are possible causes for the student illnesses?**
   - **How could students from both bands be exposed to a disease-causing organism at the same time?**
   - **Assuming that the students from the two bands are suffering from the same illness, when were they most likely exposed to the disease-causing organism?**

Encourage students to ask questions about the activities the band members might have participated in during the planning meeting and at the Battle of the Bands. Students should be concerned about activities the sick band members have in common. If not brought out by a student, call attention to the fact that people become sick about five days after being exposed to a stomach virus, while they become sick within a day or two after eating contaminated food. At this point, we can speculate that students were either exposed to a stomach virus during the planning meeting or to food poisoning at the Battle of the Bands. Students will be provided with details about band activities in Activity 3.

Activity 3: *What's the Source?*

Note to teachers: Make sure that students have available their Investigative Report Forms from the previous two activities. This helps them recall the progress of their investigation.

1. **Explain to the class that they will continue their investigation into the school absences among band members at Truman and Jackson middle schools. Specifically, they will explore the activities students engaged in during the Battle of the Bands event to see whether they can pinpoint how the students became ill.**

2. **Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct them to write the testable questions developed at the end of the previous activity in the "Testable Question" space on their form.**

3. **Reconvene students in the same teams as before. Direct each team to a computer, and instruct students to proceed to *http://science.education.nih.gov/supplements/inquiry/student* and click on "Activity 3—What's the Source?"**

NSES

Content Standard A: Develop descriptions, explanations, predictions, and models using evidence.

Assessment: Making a quick visual scan of the Investigative Report Forms offers a brief formative assessment of students' progress to this point.

Content Standard C: Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

Content Standard A: Recognize and analyze alternative explanations and predictions. Use appropriate tools and techniques to gather, analyze, and interpret data.

As in the beginning of the previous activities, the teams are alerted that they have a new e-mail message to read. The memo informs the teams that a nearby community has reported that its water supply may be contaminated by bacteria that cause a stomach-related illness.

4. **After reading the latest e-mail from the director, the teams click on the "Activity Tables" link that provides information about the activities that took place on the day of the Battle of the Bands event.**

The activity tables provide information about the activities that band members from both schools participated in on the day of the Battle of the Bands event. The tables include information about activity participation by band members who became ill and those who did not become ill. This page also contains a menu that allows students to select maps that indicate the locations of each activity.

Tip from the field test: The students' knowledge about disease transmission is limited. Make sure that they understand that food poisoning and illness from contaminated water are not contagious. However, a stomach virus can be passed from one person to another.

5. **As the teams examine the activity tables, remind them also to examine the maps that depict where the activities took place. Encourage students to use the tables to compare the activities of the students who did and did not get sick.**

From the Activity Maps menu, students can select maps that depict

- a street map that includes the locations for the various student activities,
- students from Truman Middle School who became ill and the activities in which they participated,
- students from Jackson Middle School who became ill and the activities in which they participated, and
- students from both Truman and Jackson middle schools who became ill and the activities in which they participated.

6. **Instruct the teams to write down their conclusions about which activities may have exposed the students to disease. They should be prepared to share their conclusions with the other teams.**

Analysis of the activity data suggests that either eating at the Cheep Chicken Hut restaurant or swimming in the lake made the band members ill.

7. **Instruct teams to exit the Web site after they have completed their analyses and recorded their findings.**

8. **Acting as team supervisor, facilitate a class discussion to summarize the findings from all the teams. Guide the discussion to focus on how the teams think the band members became ill. Ask the teams to explain their evidence and reasoning.**

   Students should conclude from their analyses of the activity tables that two possibilities exist: 1) students got food poisoning at the Cheep Chicken Hut and 2) students were infected while swimming in the lake. Without additional information, it is not possible to eliminate either possibility from suspicion. A third possibility also exists. Students could have contracted a stomach virus while attending the planning meeting on May 15. Explain to students that the process they followed is similar to that used by scientists conducting an investigation. Investigations do not always reach a single conclusion. They often raise more questions that need to be investigated.

9. **Ask students to consider what next steps they could take to reach a firm conclusion about the cause of the student illnesses. What evidence would they like to collect?**

   Student suggestions may include
   - visit the various restaurants and take food samples for testing,
   - visit the lake and take water samples for testing,
   - have the illnesses of the sick students diagnosed by a doctor,
   - investigate activities (such as eating) that took place during the planning meeting, and
   - survey other people (not students) who ate at the Cheep Chicken Hut or swam in the lake to see whether they also became sick.

10. **Collect from students their three Investigative Report Forms.**

    These forms will be used in the next activity and as an assessment tool for you.

Activity 4: *Reflecting on the Process of Scientific Inquiry*

Note to teachers: Make sure that students have available their Investigative Report Forms from the previous three activities. This helps them recall the progress of their investigation.

NSES

Content Standard A:
Communicate scientific procedures and explanations.

Content Standard F:
Risk analysis considers the type of hazard and estimates the number of people who might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risk.

Assessment:
Use the completed Investigative Report Forms as a summative assessment.

NSES

Content Standard G: Science requires different abilities, depending on such factors as the field of study and type of inquiry.

1. **Explain to the class that they will review the process used during the community health department investigation from the previous activity. Ask, "How did your investigation begin?"**

   Student responses will vary. Bring out the idea that the investigation began with a problem that prompted the asking of a testable question.

2. **Ask students, "What testable question began your investigation?"**

   Students will report different questions. Appropriate questions deal with whether or not the school absences noticed by the principal are unusually high. Students may have asked a question such as, Is the number of school absences in the last week more than in previous weeks?

3. **Ask students, "As your investigation went along, did you ask other testable questions? What were they?" Write their questions on the board.**

   Students will report a number of different questions. Try to guide the discussion so that the questions are brought up in the order that they appear in the investigation. Examples of questions that students may report are the following:
   - Are more students absent from one class than the others?
   - Are there more absences in one school than the others?
   - What is the reason for the higher number of absences among students in band class at Truman and Jackson middle schools?
   - Are the absent students suffering from the same illness?
   - Have band members from the two schools been in contact with each other?
   - What is the cause of the disease?
   - What is the source of the disease-causing organism?

4. **Next, turn the discussion to the collection and analysis of evidence. Ask students, "What evidence did you collect and analyze to answer your questions?"**

   Students will mention various types of evidence collected.

5. **Ask, "Was all of the evidence you analyzed helpful in answering your questions?"**

   Student responses will vary. Some will report that all evidence was helpful because it helped them answer a question or choose between alternative explanations. Other students may feel that some evidence was not helpful because it could not definitively answer their question.

6. **Explain to students that they will now reconsider the evidence used in their investigation, consider what information the evidence provided, and explain how that evidence was used to answer a question or to choose between alternative explanations.**

7. **Give each student one copy of Master 3.12, *Analyzing Evidence*. Explain that they have about 15 minutes to**
   - **consider the evidence used in their investigation,**
   - **write down the information they learned from it, and**
   - **explain how it helped, or did not help, them to answer a question or choose between alternative explanations.**

   While the students are working, circulate among them and guide their progress. Some students may not understand why some pieces of evidence were included in the investigation. For example, the interviews with the parents of the sick students are necessary to confirm their reasons for absence from school.

8. **After students have completed their work on Master 3.12, ask for volunteers to share their answers with the class.**

   As students report their answers, guide the discussion to raise the points made in the following sample answers for Master 3.12.

   1. Memos from the director of the community health department

      The first memo suggests a possible health problem at a local school. The second memo provides access to information about the student absences and student band activities. The third memo raises the possibility that the local water supply is contaminated.

   2. Attendance data for seventh-grade students at four middle schools

      The attendance data reveal that students in band classes at Truman and Jackson middle schools were absent during the past week at rates several times higher than normal. This is considered to be evidence of a possible health problem. It remains possible, however, that all or some of the absent students were missing from school for reasons other than illness.

   3. Summaries of interviews from parents of absent students

      Interviews with parents of the missing students confirmed that the students were indeed absent from school and supply reasons for their absences. The parent information summarized in the tables indicates that all but two of the missing students were ill with a stomach-related illness. This information rules out the explanation that students were absent from school because they were truant.

NSES

Content Standard A:
Communicate scientific procedures and explanations.

Content Standard G:
Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

Assessment:
Assess students' understanding by listening to their explanations and reasoning.

4. Transcripts from interviews with parents of absent students

   The interviews with parents provide additional information about the student absences. For example, one parent states that her child has the flu while another attributes his child's illness to food poisoning. These comments are included to suggest possible causes for the illnesses. These comments are opinions, however, and must not be treated as necessarily factual.

   We also learn from the interviews that it usually takes about five days to become sick after being exposed to a stomach virus. In contrast, a person who eats contaminated food usually gets sick within the next day or two. This information becomes important when trying to decide which contacts between students from the two schools might be associated with the illnesses. For example, a stomach virus may have been contracted from sick students at the planning meeting, or stomach illness may have been spread during an activity at the band event such as swimming in contaminated water or eating contaminated food.

5. School calendars

   Since the available evidence suggests that the absent students may all be suffering from the same illness, it is important to investigate whether the affected students from the two schools were in recent contact with each other. Such contacts provide opportunities for a disease-causing organism to pass among the students. Assuming that eating is involved, such shared experiences are also consistent with illness resulting from food poisoning.

   A comparison of the school calendars reveals that band students from the two schools came into contact with each other three times in the past month. The first occasion was the May Day parade on May 5. It is unlikely that the illnesses resulted from this contact because it occurred so long ago. Further supporting this view is the fact that the band from Roosevelt Middle School also attended the parade but its students did not become ill.

   Students from the two bands were also together for the Battle of the Bands planning meeting held on May 15. It is possible that a student with a stomach virus spread the illness to others at this meeting. Assuming that students would become sick five days later, they would be absent from school starting on May 20, which is what was observed. Students from the two schools also were together at the Battle of the Bands event on May 19. It is possible that students ate contaminated food at the event and became sick the next day.

6. Student activity tables

   At this point, the most likely explanation for why the students became ill is that they either contracted a stomach virus at the planning meeting or got food poisoning at the Battle of the Bands. These tables provide information about which students participated in which activities at the Battle of the Bands. This information may help identify a source of exposure to a disease-causing organism. Information from the tables reveals that the majority of students who became ill ate at the Cheep Chicken Hut restaurant and swam in the lake. This means that students may have eaten contaminated food at the restaurant. It also raises the possibility that students became ill by swimming in contaminated water. Consistent with this new possibility is information contained in the third memo from the health department director, which mentions that a nearby community suspects that its water supply is contaminated with bacteria that cause a stomach-related illness.

7. Activity maps

   These maps show where the various activities associated with the Battle of the Bands event took place. The final map depicts the activities attended by students from both schools who later became ill. This information suggests that the illnesses were related to eating at the Cheep Chicken Hut restaurant or swimming in the lake.

9. **Explain that in the next lesson, students will continue in their roles as members of the investigative team. They will take charge of another investigation dealing with a community health problem.**

NSES

Content Standard F:
The potential for accidents and the existence of hazards imposes the need for injury prevention. Important personal and social decisions are made based on perceptions of benefits and risks.

For classes using the *print version* of Lesson 3:

Activity 1: *Unusual Absences*

1. **Explain to the class that they are about to carry out a scientific investigation. In this investigation, they will be working as members of an investigative team from the local community health department.**

   Throughout this activity, you will act as team supervisor for all the student teams.

2. **Divide students into teams of three students. Explain that they will investigate a possible health problem in the community.**

3. **Give each student one copy of Master 3.1, *Investigative Report Form*. Explain that students will use this form to record the progress of their investigation.**

Each day, students will write notes about their investigation on a separate copy of the *Investigative Report Form*.

4. **Display an overhead transparency of Master 3.2, *Letter from Principal*. Read the letter aloud to the class.**

   The letter is from the principal of a local middle school. She states that this past week, there was an unusual number of student absences from the band class. She is concerned that the school may be facing an outbreak of flu.

5. **Display an overhead transparency of Master 3.3, *First Memo from Director.* Read the letter aloud to the class.**

   The memo from the director of the health department asks the investigative team to look into the matter and see if a health problem exists at the school.

6. **Instruct students to discuss with their teammates what testable questions they can ask to help them determine whether a health problem exists.**

   Students should record their testable questions on their *Investigative Report Form* and be prepared to share them with the class. Circulate among the teams as they work to develop their testable questions. Remind students of the aspects of testable questions listed on the board.

   Students should ask questions that will help them determine whether the school absences indicate a health problem. Ideally, their questions should be answerable by examining the school attendance data provided by the school district. Examples of testable questions they might ask are the following:
   - Is the number of absences in the last week more than in the previous weeks?
   - Are more students absent from one type of class than the others?
   - Are there more absences in one school than the others?

NSES

Content Standard A:
Identify questions that can be answered through scientific investigations.

7. **Give each team one copy of Masters 3.4a–c, *Attendance Data*. Instruct teams to use the graphs and data sheets to analyze the attendance data for the past month. Students should record their findings on their Investigative Report Form. Explain that they will share their results with the class later.**

   For each of four middle schools, the data show student absences for the entire seventh grade, and for absences in seventh-grade physical education (PE), art, and band classes. Some students may have trouble seeing patterns in the data sheets. Explain that graphs visually display large amounts of data and make it easier to see patterns. Point out that the scales on the graphs are not all the same and that the dates don't include weekends.

Students should look for sudden increases in absences that might indicate a health problem and for comparisons that help them answer their testable questions. Students should note what patterns they observe in the attendance data for each school. Students should observe the following:

- There were an unusually high number of absences during the last week among students in band classes at both Truman and Jackson middle schools.
- Absences among students in art and PE classes, as well as for the entire seventh grade, were not higher during the last week for both Truman and Jackson middle schools.
- Roosevelt and Kennedy middle schools had fairly constant numbers of absences throughout the last month in every category.

NSES

Content Standard A: Use appropriate tools and techniques to gather, analyze, and interpret data.

8. **Acting as team supervisor, facilitate a class discussion to summarize the findings from all the teams. Consider which steps the investigation should take next. Guide the discussion to focus on the following questions:**
   - What is the reason for the higher number of absences among students in band class at Truman and Jackson middle schools?
   - If these absences are due to an illness, do band members from the two affected schools share the same symptoms?
   - Have band members from the two schools been in recent contact with each other?

   Students should have recorded the summary and the questions from their teams on their Investigative Report Form. When filling out the form, students should write down under "Evidence Collected" anything that they feel may have a bearing on their investigation now or in the future. The summary of findings should be included in the "Analysis and Explanation of Evidence" space. The next steps for the investigation should be phrased as a question and entered into the space on the form labeled "Next Questions." You may want to record the summary and questions from the teams on the board or a large piece of paper that can be viewed later.

NSES

Content Standard A: Develop descriptions, explanations, predictions, and models using evidence.

Activity 2: *What's the Cause?*

Note to teachers: Make sure that students have available their Investigative Report Form from the previous activity. This helps them recall the progress of their investigation.

1. Explain to the class that they will continue their investigation into the school absences among band members at Truman and Jackson middle schools. Specifically, they will answer the questions that were asked at the conclusion of Activity 1:
   - **What is the reason for the higher number of absences among students in band class at Truman and Jackson middle schools?**
   - **If these absences are due to an illness, do band members from the two affected schools share the same symptoms?**
   - **Have band members from the two schools been in recent contact with each other?**

2. Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct students to write the testable questions developed at the end of the previous activity in the "Testable Question" space on their form.

3. Reconvene students in their teams from Activity 1. Display an overhead transparency of Master 3.5, *Second Memo from Director*. Read the memo aloud to the class.

NSES

Content Standard A: Use mathematics in all aspects of scientific inquiry.

4. Give each team one copy of Master 3.6, *Interview Summary*, and Masters 3.7a and b, *Quotes from Interviews*. Instruct students to review the information.

Information in the tables came from interviews with the students' parents. The table for Truman Middle School shows that there were 10 students from band class absent during the past week. One student was away on a family vacation. The other nine students all have an illness that displays stomach-related symptoms. The table for Jackson Middle School lists eight absent students. One student has a broken leg. The remaining seven students have an illness that presents stomach-related symptoms.

The quotes from the parent interviews report the same symptoms listed in the tables. Some parents volunteer reasons for the illnesses such as food poisoning or the flu. These conflicting reasons may confuse some students. You may point out that the reasons given by the parents are opinions and not diagnoses from a doctor, which are derived from medical evidence. A subtle but important point is made by a healthcare worker during one of the parent interviews. The worker mentions that with food poisoning, a person becomes ill in a day or two, while a stomach virus takes about five days before the illness strikes. Students should use this information to decide what type of illness may be associated with which activities of the band members.

5. **Give each team one copy of Masters 3.8a–d, *School Calendars*. Instruct students to review the information.**

   Circulate among the teams as they look at the school calendars. Remind students that they are looking for evidence that will help them develop better explanations about the cause of the health problem. Make sure that students understand why they are looking at the school calendars. An illness is involved. If there are contacts between students from the two schools, then such contacts may help explain how an illness was contracted or passed from student to student.

6. **Have students compare the two school calendars and write down their conclusions.**

   A comparison of the Truman and Jackson middle school calendars reveals that the seventh-grade bands from both schools were together three times in the past month:
   - On May 5, both bands performed at a May Day parade. Students should note that May 5 was likely too long ago to be associated with the current illness. It is interesting that the band from Roosevelt Middle School was also at the parade and yet its band members did not become ill.
   - Students from the two bands were together on May 15 for a planning meeting about the upcoming Battle of the Bands.
   - The bands competed at the Battle of the Bands event on May 19.

7. **Acting as team supervisor, facilitate a class discussion to summarize the findings from all the teams. Think ahead to the next steps for the investigation. Guide the discussion to focus on the following questions:**
   - **Is there a common reason for the absences of the band students at Truman and Jackson middle schools?**
   - **What are possible causes for the student illnesses?**
   - **How could students from both bands be exposed to a disease-causing organism at the same time?**
   - **Assuming that the students from the two bands are suffering from the same illness, when were they most likely exposed to the disease-causing organism?**

   Encourage students to ask questions about the activities the band members might have participated in during the planning meeting and at the Battle of the Bands. Students should be concerned about activities the sick band members have in common. If not brought out by a student, call attention to the fact that people become sick about five days after being exposed to a stomach virus, while they become sick the next day or two after eating contaminated food.

NSES

Content Standard A:
Think critically and logically to make relationships between evidence and explanations.

NSES

Content Standard A:
Develop descriptions, explanations, predictions, and models using evidence.

NSES

Content Standard C: Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

At this point, we can speculate that students were either exposed to a stomach virus during the planning meeting or to food poisoning at the Battle of the Bands. Students will be provided with details about band activities in Activity 3.

Activity 3: *What's the Source?*

Note to teachers: Make sure that students have available their Investigative Report Forms from the previous two activities. This helps them recall the progress of their investigation.

1. **Explain to the class that they will continue their investigation into the school absences among band members at Truman and Jackson middle schools. Specifically, they will explore the activities students were engaged in during the Battle of the Bands event to see whether they can pinpoint how the students became ill.**

2. **Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct them to write the testable questions developed at the end of the previous activity in the "Testable Question" space on their form.**

3. **Continue with students in the same teams as in the previous activities. Display a transparency of Master 3.9, *Third Memo from Director*. Read the memo aloud to the class.**

   The memo informs the teams that a nearby community has reported that its water supply may be contaminated by bacteria that cause a stomach-related illness.

   Tip from the field test: The students' knowledge about disease transmission is limited. Make sure that they understand that food poisoning and illness from contaminated water are not contagious. However, a stomach virus can be passed from one person to another.

4. **Give each team one copy of Masters 3.10a and b, *Activity Tables*. Ask students to review the information and record their findings on their Investigative Report Form.**

   The Activity Tables provide information about the activities that band members from both schools participated in on the day of the Battle of the Bands event. The tables include information about activity participation by band members who became ill and those who did not become ill.

5. **Give each team one copy of Masters 3.11a and b, *Activity Maps*. Ask students to review the information and record their findings on their Investigative Report Form.**

   The Activity Maps show the street locations for the various student activities. The maps depict
   - students from Truman Middle School who became ill and the activities in which they participated,
   - students from Jackson Middle School who became ill and the activities in which they participated, and
   - students from both Truman and Jackson middle schools who became ill and the activities in which they participated.

6. **Instruct the teams to record their conclusions about which activities may have exposed the students to disease. They should be prepared to share their conclusions with the other teams.**

   Analysis of the activity data suggests that either eating at the Cheep Chicken Hut restaurant or swimming in the lake made the band members ill.

7. **Acting as team supervisor, facilitate a class discussion to summarize the findings from all the teams. Guide the discussion to focus on how the teams think the band members became ill. Ask the teams to explain their evidence and reasoning.**

   Students should conclude from their analyses of the activity tables that two possibilities exist: 1) students got food poisoning at the Cheep Chicken Hut and 2) students were infected while swimming in the lake. Without additional information, it is not possible to eliminate either possibility from suspicion. A third possibility also exists. Students could have contracted a stomach virus while attending the planning meeting on May 15. Explain to students that the process they followed is similar to that used by scientists conducting an investigation. Investigations do not always reach a single conclusion. They often raise more questions that need to be investigated.

8. **Ask students to consider what next steps they would take to reach a firm conclusion about the cause of the student illnesses. What evidence would they like to collect?**

   Students' suggestions may include
   - visit the various restaurants and take food samples for testing,
   - visit the lake and take water samples for testing,
   - have the illnesses of the sick students diagnosed by a doctor,
   - investigate activities (such as eating) that took place during the planning meeting, and

NSES

Content Standard A: Recognize and analyze alternative explanations and predictions.

Content Standard E: Science and technology are reciprocal. Science helps drive technology. Technology is essential to science.

Content Standard A: Communicate scientific procedures and explanations.

Assessment:
Use the completed Investigative Report Forms as a summative assessment.

- survey other people (not students) who ate at the Cheep Chicken Hut or swam in the lake to see whether they also became sick.

9. **Collect from students their three Investigative Report Forms.**

   These can be used as an assessment tool.

Activity 4: *Reflecting on the Process of Scientific Inquiry*

Note to teachers: Make sure that students have available their Investigative Report Forms from the previous three activities. This helps them recall the progress of their investigation.

NSES

Content Standard G:
Science requires different abilities, depending on such factors as the field of study and type of inquiry.

1. **Explain to the class that they will review the process used during the community health department investigation from the previous activity. Ask, "How did your investigation begin?"**

   Student responses will vary. Bring out the idea that the investigation began with a problem that prompted the asking of a testable question.

2. **Ask students, "What testable question began your investigation?"**

   Students will report different questions. Appropriate questions deal with whether or not the school absences noticed by the principal are unusually high. Students may have asked a question such as, Is the number of school absences in the last week more than in previous weeks?

3. **Ask students, "As your investigation went along, did you ask other testable questions? What were they?" Write their questions on the board.**

   Students will report a number of different questions. Try to guide the discussion so that the questions are brought up in the order that they appear in the investigation. Examples of questions that students may report are the following:
   - Are more students absent from one class than the others?
   - Are there more absences in one school than the others?
   - What is the reason for the higher number of absences among students in band class at Truman and Jackson middle schools?
   - Are the absent students suffering from the same illness?
   - Have band members from the two schools been in contact with each other?
   - What is the cause of the disease?
   - What is the source of the disease-causing organism?

4. **Next, turn the discussion to the collection and analysis of evidence. Ask students, "What evidence did you collect and analyze to answer your questions?"**

   Students will mention various types of evidence collected.

5. **Ask, "Was all of the evidence you analyzed helpful in answering your questions?"**

   Student responses will vary. Some will report that all evidence was helpful in that it helped them answer a question or choose between alternative explanations. Other students may feel that some evidence was not helpful because it could not definitively answer their question.

6. **Explain to students that they will now reconsider the evidence used in their investigation, consider what information the evidence provided, and explain how that evidence was used to answer a question or to choose between alternative explanations.**

7. **Give each student one copy of Master 3.12, *Analyzing Evidence*. Explain that they have about 15 minutes to**
   - **consider the evidence used in their investigation,**
   - **write down the information they learned from it, and**
   - **explain how it helped, or did not help, them to answer a question or choose between alternative explanations.**

   While the students are working, circulate among them and guide their progress. Some students may not understand why some pieces of evidence were included in the investigation. For example, the interviews with the parents of the sick students are necessary to confirm their reasons for absence from school.

8. **After students have completed their work on Master 3.12, ask for volunteers to share their answers with the class.**

   As students report their answers, guide the discussion to raise the points made in the following sample answers for Master 3.12.

   1. Memos from the director of the community health department

      The first memo suggests a possible health problem at a local school. The second memo provides access to information about the student absences and student band activities. The third memo raises the possibility that the local water supply is contaminated.

   2. Attendance data for seventh-grade students at four middle schools

NSES

Content Standard A: Recognize and analyze alternative explanations and predictions. Communicate scientific procedures and explanations.

Assessment: Assess students' understanding by listening to their explanations and reasoning.

The attendance data reveal that students in band classes at Truman and Jackson middle schools were absent during the past week at rates several times higher than normal. This is considered to be evidence of a possible health problem. It remains possible, however, that all or some of the absent students were missing from school for reasons other than illness.

3. Summaries of interviews from parents of absent students

   Interviews with parents of the missing students confirmed that the students were indeed absent from school and supply reasons for their absences. The parent information summarized in the tables indicates that all but two of the missing students were ill with a stomach-related illness. This information rules out the explanation that students were absent from school because they were truant.

4. Transcripts from interviews with parents of absent students

   The interviews with parents provide additional information about the student absences. For example, one parent states that her child has the flu while another attributes his child's illness to food poisoning. These comments are included to suggest possible causes for the illnesses. These comments are opinions, however, and must not be treated as necessarily factual.

   We also learn from the interviews that it usually takes about five days to become sick after being exposed to a stomach virus. In contrast, a person who eats contaminated food usually gets sick within the next day or two. This information becomes important when trying to decide which contacts between students from the two schools might be associated with the illnesses. For example, a stomach virus may have been contracted from sick students at the planning meeting or stomach illness may have been spread during an activity at the band event such as swimming in contaminated water or eating contaminated food.

5. School calendars

   Since the available evidence suggests that the absent students may all be suffering from the same illness, it is important to investigate whether the affected students from the two schools were in recent contact with each other. Such contacts provide opportunities for a disease-causing organism to pass among the students. Assuming that eating is involved, such shared experiences are also consistent with illness resulting from food poisoning.

   A comparison of the school calendars reveals that band students from the two schools came into contact with each other three times in the past month. The first occasion was the May Day parade on

May 5. It is unlikely that the illnesses resulted from this contact because it occurred so long ago. Further supporting this view is the fact that the band from Roosevelt Middle School also attended the parade but its students did not become ill.

Students from the two bands were also together for the Battle of the Bands planning meeting held on May 15. It is possible that a student with a stomach virus spread the illness to others at this meeting. Assuming that students would become sick five days later, they would be absent from school starting on May 20, which is what was observed. Students from the two schools also were together at the Battle of the Bands event on May 19. It is possible that students ate contaminated food at the event and became sick the next day.

6. Student activity tables

   At this point, the most likely explanation for why the students became ill is that they either contracted a stomach virus at the planning meeting or got food poisoning at the Battle of the Bands. These tables provide information about which students participated in which activities at the Battle of the Bands. This information may help identify a source of exposure to a disease-causing organism. Information from the tables reveals that the majority of students who became ill ate at the Cheep Chicken Hut restaurant and swam in the lake. This means that students may have eaten contaminated food at the restaurant. It also raises the possibility that students became ill by swimming in contaminated water. Consistent with this new possibility is information contained in the third memo from the health department director, which mentions that a nearby community suspects that its water supply is contaminated with bacteria that cause a stomach-related illness.

7. Activity maps

   These maps show where the various activities associated with the Battle of the Bands event took place. The final map depicts the activities attended by students from both schools who later became ill. This information suggests that the illnesses were related to eating at the Cheep Chicken Hut restaurant or swimming in the lake.

9. Explain that in the next lesson, students will continue in their roles as members of the investigative team. They will take charge of another investigation dealing with a community health problem.

NSES

Content Standard F: The potential for accidents and the existence of hazards imposes the need for injury prevention. Important personal and social decisions are made based on perceptions of benefits and risks.

Lesson 3 Organizer: Web Version

What the Teacher Does	Procedure Reference
Activity 1: *Unusual Absences*	
Explain to students that they will carry out a scientific investigation. They will be working as members of an investigative team from the local community health department.	Page 59 Step 1
Give each student one copy of Master 3.1, *Investigative Report Form*.	Pages 59–60 Step 2 M
Divide the class into teams of three and direct them to computers. Have students log onto the Web site and click on "Activity 1—*Unusual Absences*."	Page 60 Step 3
Instruct teams to read the new message and come up with a testable question about the student absences.	Pages 60–61 Steps 4 and 5
Instruct teams to click on the link to the school district Web site and • export the attendance data to the community health department Web site, • display the data in graphic form, • analyze the graphs and record their findings on Master 3.1, and • when finished, log off the Web site.	Pages 61–62 Steps 6–9
Facilitate a class discussion. Focus on the following questions: • What is the reason for the higher number of absences among students in band class at Truman and Jackson middle schools? • If these absences are due to an illness, do band members from the two affected schools share the same symptoms? • Have band members from the two schools been in contact with each other?	Page 62 Step 10
Activity 2: *What's the Cause?*	
Explain that teams will continue their investigations, focusing on the questions asked at the end of the previous activity.	Page 63 Step 1
Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct students to write down the testable questions asked during the last activity.	Page 63 Step 2 M
Direct each team to a computer and have them log onto the Web site and click on "Activity 2—What's the Cause?"	Page 63 Step 3

M = Involves copying a master.

Instruct teams to • read the new message, • read the results of interviews, • read the available portions of the parent interviews, and • record their findings on Master 3.1.	Pages 63–64 Steps 4–6
Instruct teams to compare the two school calendars and record their findings on Master 3.1. • When finished, teams should log off the Web site.	Page 64 Steps 7 and 8
Facilitate a class discussion. Focus on the following questions: • Is there a common reason for the absences of the band students at Truman and Jackson middle schools? • What are possible causes for the student illnesses? • How could students from both bands be exposed to a disease-causing organism at the same time? • Assuming that the students from the two bands are suffering from the same illness, when were they most likely exposed to the disease-causing organism?	Page 65 Step 9
Activity 3: *What's the Source?*	
Explain that teams will continue their investigations, focusing on the questions asked at the end of the previous activity.	Page 65 Step 1
Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct students to write down the testable questions asked during the last activity.	Page 65 Step 2 M
Direct teams to computers. Have students log onto the Web site and click on "Activity 3—What's the Source?"	Pages 65–66 Step 3
Instruct teams to • read "New Message," • examine "Activity Tables," • examine "Activity Maps," • record their findings on Master 3.1, and • when finished, log off the Web site.	Pages 66–67 Steps 4–7
Facilitate a class discussion to summarize findings. Ask teams to explain their evidence and reasoning.	Page 67 Step 8
Ask teams to consider what steps they would take next to reach a firm conclusion. What evidence would they collect?	Page 67 Step 9
Collect all Investigative Report Forms.	Page 67 Step 10

Activity 4: *Reflecting on the Process of Scientific Inquiry*

Explain that students will review the process used during their investigation. Ask, • "How did your investigation begin?" • "What testable question began your investigation?" • "As your investigation went along, did you ask other testable questions? What were they?" • "What evidence did you collect and analyze to answer your questions?" • "Was all of the evidence you analyzed helpful in answering your question?"	Page 68 Steps 1–5
Explain that they will reexamine the evidence used in their investigation.	Page 69 Step 6
Give each student one copy of Master 3.12, *Analyzing Evidence*. Give them 15 minutes to • consider the evidence they used, • write down what they learned from it, and • explain how it helped, or did not help, them to answer a question or choose between alternative explanations.	Page 69 Step 7 M
Ask for volunteers to share their answers with the class.	Pages 69–71 Step 8
Explain that in the next lesson, students will take charge of another investigation for the community health department.	Page 71 Step 9

Lesson 3 Organizer: Print Version

What the Teacher Does	Procedure Reference
Activity 1: *Unusual Absences*	
Explain to students that they will carry out a scientific investigation. They will be working as members of an investigative team from the local community health department.	Page 71 Step 1
Divide the class into teams of three students. Explain that they will investigate a potential health problem.	Page 71 Step 2
Give each student one copy of Master 3.1, *Investigative Report Form*.	Pages 71–72 Step 3 M
Display a transparency of Master 3.2, *Letter from Principal*. Read it aloud.	Page 72 Step 4 T
Display a transparency of Master 3.3, *First Memo from Director.* Read it aloud.	Page 72 Step 5 T
Instruct teams to discuss testable questions that will help them in their investigation.	Page 72 Step 6
Give each team one copy of Masters 3.4a–c, *Attendance Data*. Instruct teams to analyze data and record their findings.	Pages 72–73 Step 7 M
Facilitate a class discussion. Focus on the following questions: • What is the reason for the higher number of absences among students in band class at Truman and Jackson middle schools? • If these absences are due to an illness, do band members from the two affected schools share the same symptoms? • Have band members from the two schools been in contact with each other?	Page 73 Step 8
Activity 2: *What's the Cause?*	
Explain that teams will continue their investigations, focusing on the questions asked at the end of the previous activity.	Page 74 Step 1
Give each student one copy of Master 3.1, *Investigative Report Form*. Instruct students to write down the testable questions asked during the last activity.	Page 74 Step 2 M
Display a transparency of Master 3.5, *Second Memo from Director.* Read it aloud.	Page 74 Step 3 T

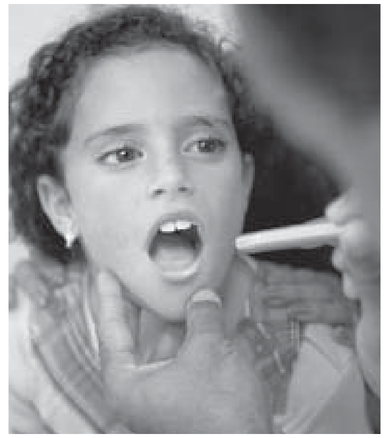
M = Involves copying a master. T = Involves making a transparency.

Give each team one copy of Master 3.6, *Interview Summary*, and Masters 3.7a and b, *Quotes from Interviews*. Instruct teams to review the information.	Page 74 Step 4	M
Give each team one copy of Masters 3.8a–d, *School Calendars*. Instruct teams to compare the two calendars and write down their conclusions.	Page 75 Steps 5 and 6	M
Facilitate a class discussion. Focus on the following questions: • Is there a common reason for the absences of the band students at Truman and Jackson middle schools? • What are possible causes for the student illnesses? • How could students from both bands be exposed to a disease-causing organism at the same time? • Assuming that the students from the two bands are suffering from the same illness, when were they most likely exposed to the disease-causing organism?	Pages 75–76 Step 7	
Activity 3: *What's the Source?*		
Explain that teams will continue their investigations, focusing on the questions asked at the end of the previous activity.	Page 76 Step 1	
Give each student a copy of Master 3.1, *Investigative Report Form*. Instruct students to write down the testable questions asked during the last activity.	Page 76 Step 2	M
Display a transparency of Master 3.9, *Third Memo from Director*. Read it aloud.	Page 76 Step 3	T
Give each team one copy of Masters 3.10a and b, *Activity Tables*, and Masters 3.11a and b, *Activity Maps*. Instruct teams to review the information and write down their conclusions.	Pages 76–77 Steps 4–6	M
Facilitate a class discussion to summarize findings. Ask teams to explain their evidence and reasoning.	Page 77 Step 7	
Ask teams to consider what steps they would take next to reach a firm conclusion. What evidence would they collect?	Pages 77–78 Step 8	
Collect all Investigative Report Forms.	Page 78 Step 9	

Activity 4: *Reflecting on the Process of Scientific Inquiry*

Explain that students will review the process used during their investigation. Ask, • "How did your investigation begin?" • "What testable question began your investigation?" • "As your investigation went along, did you ask other testable questions? What were they?" • "What evidence did you collect and analyze to answer your questions?" • "Was all of the evidence you analyzed helpful in answering your questions?"	Pages 78–79 Steps 1–5
Explain that they will reexamine the evidence used in their investigation.	Page 79 Step 6
Give each student one copy of Master 3.12, *Analyzing Evidence*. Give them 15 minutes to • consider the evidence they used, • write down what they learned from it, and • explain how it helped, or did not help, them to answer a question or choose between alternative explanations.	Page 79 Step 7 M
Ask for volunteers to share their answers with the class.	Pages 79–81 Step 8
Explain that in the next lesson, students will take charge of another investigation for the community health department.	Page 81 Step 9

Pulling It All Together



Lesson 4
Evaluate

At a Glance

Overview

In this final lesson, you have an opportunity to assess what students have learned about scientific inquiry. Students continue in their roles as members of the community health department investigative team. The class is divided into two groups. Teams from each group review different data about the same health problem and prepare an investigative report. Teams trade reports, and each team evaluates one prepared by a team from the other group. The lesson allows students to apply what they have learned in the previous lessons and to use critical-thinking skills in performing and evaluating scientific investigations.

Major Concepts

- Scientific inquiry is a process of proposing explanations.
- Scientific inquiry begins with a testable question.
- Scientific investigations involve collecting evidence.
- The results of scientific investigations are used to develop evidence-based explanations.
- Scientists communicate the results of their investigations to their peers.

Objectives

After completing this lesson, you will be able to assess students' knowledge of scientific inquiry by having them

- identify a testable question,
- describe the evidence needed to answer the question,
- assess whether or not evidence is adequate to answer the question, and
- display critical-thinking skills as they evaluate alternative explanations.

Teacher Background

Consult the following sections in Information about the *Process of Scientific Inquiry*:

3 *Inquiry and Educational Research* (pages 21–24)
4 *Inquiry in the* National Science Education Standards (pages 24–27)

5 *Misconceptions about Inquiry-Based Instruction* (pages 27–29)
6.1 *The Nature of Scientific Inquiry: Science as a Way of Knowing* (pages 29–30)
6.2 *Scientifically Testable Questions* (pages 30–31)
7 *Teaching Scientific Inquiry* (pages 31–32)

In Advance

Activity	Web Component?	Photocopies	Materials
1	Yes	Master 4.1, *Memo from Director* (Prepare an overhead transparency.) Masters 4.2a and b, *Data from Investigation* (Make 1 copy of Master 4.2a for half of the teams and 1 copy of Master 4.2b for the other half.) Master 4.3, *Report Form** (Make 1 copy per student.) Master 4.4, *Evaluation Form** (Make 1 copy per student.)	No materials except photocopies and transparencies

* Masters needed for Web version. Print version uses all the masters.

Preparation

For classes using the *Web-based version*: Verify that the computer lab is reserved for your classes or that classroom computers are ready to use. Bookmark the student Web site at *http://science.education.nih.gov/supplements/inquiry/student*. Make photocopies.

For classes using the *print version*: No preparations are needed except for making photocopies and transparencies.

Procedure

Activity 1: *Pulling It All Together*

Note to teachers: The following activity again has students playing the role of investigators for the community health department. This time, the students are given data collected by another investigator and asked to write a brief report about the investigation. In the second part of the activity, the students review reports of investigative work of other students and critique them. This activity allows you to evaluate what students have learned about the process of scientific inquiry.

The outbreak of chicken pox that serves as the basis for the investigations in this activity is based on a real outbreak that occurred in 2003 at a school in Michigan.

Tip from the field test: Some teachers commented that their students experienced a letdown when they used a print-based lesson after working on the Web during Lesson 3. For this investigation, we have placed the initial memo from the director and the data on the Web site. You can either instruct the students to retrieve this information from the Web site or supply it as print material.

1. **Explain to the class that they are still members of the community health department investigative team. This time, they will analyze data provided by investigators in the field and prepare an investigative report.**

   As before, throughout this activity, you will act as team supervisor for all the student teams.

2. **Display a transparency of Master 4.1, *Memo from Director*. Read the memo aloud to the class.**

   Alternatively, you can instruct students to proceed to *http://science.education.nih.gov/supplements/inquiry/student* and click on "Lesson 4—*Pulling It All Together*." Students then click on "You Have (1) New Message" and read the memo. Answer any questions students have about the memo.

3. **Divide the students into teams of two. Give half of the teams one copy of Master 4.2a, *Data from Investigation*. Give the other half one copy of Master 4.2b, *Data from Investigation*.**

   Alternatively, you can instruct students to proceed to *http://science.education.nih.gov/supplements/inquiry/student* and click on "Lesson 4—Pulling It All Together." Students should then click on either "Case Number 0439-a" or "Case number 0439-b" and review the data.

   Master 4.2a (case number 0439-a) contains data that relate to the probable cause of a disease outbreak at a local elementary school. Master 4.2b (case number 0439-b) contains data that relate to the protection offered by vaccination against chicken pox. The amount of data reviewed by each team is restricted so that you can more easily evaluate the students' abilities to ask appropriate testable questions and use evidence to propose explanations. In a later step, students will evaluate reports prepared by other students. The procedure used during this activity is designed to allow students to use their knowledge about scientific inquiry and to demonstrate critical-thinking skills in preparing and evaluating reports about scientific investigations.

NSES

Content Standard A: Mathematics is important in all aspects of scientific inquiry. Identify questions that can be answered through scientific investigations. Develop descriptions, explanations, predictions, and models using evidence.

NSES

Content Standard A: Use appropriate tools and techniques to gather, analyze, and interpret data. Think critically and logically to make the relationships between evidence and explanation. Recognize and analyze alternative explanations and procedures. Different kinds of questions suggest different kinds of scientific investigations.

Content Standard E: Science and technology are reciprocal.

Assessment: Collecting the report forms and evaluations provides a summative assessment of students' scientific inquiry skills.

4. **Give each student one copy of Master 4.3, *Report Form*. Explain that students are to**
   - **review the data on Master 4.2a or 4.2b, *Data from Investigation*,**
   - **discuss the data's meaning with their teammate, and**
   - **fill out the information requested on Master 4.3.**

   Give teams about 15 minutes to complete their task.

5. **Instruct each team to trade their Report Forms and their copy of the Data from Investigation master with a team that worked with the other data set.**

6. **Give each student one copy of Master 4.4, *Evaluation Form*. Instruct the teams to review the information on the other team's Data from Investigation and their Report Forms and then to answer the questions posed on the Evaluation Form.**

   Give teams about 15 minutes to complete their task. Remind the students that yes or no answers are unacceptable. Students should explain the reasoning behind each of their answers.

7. **After students have completed their tasks, collect all of the Report Forms and Evaluation Forms.**

Note to teachers: Students' responses on Masters 4.3, *Report Form*, and 4.4, *Evaluation Form*, give you opportunities for formal assessment. Answers to the questions posed on these forms should reflect students' understandings of the basic aspects of scientific inquiry addressed in this supplement. When assessing students' work, keep in mind the following:

Testable Questions

1. Testable questions ask about objects, organisms, and events in the natural world.
2. Testable questions can be answered through investigations that involve experiments, observations, or surveys.
3. Testable questions are answered by collecting and analyzing evidence that is measurable.
4. Testable questions relate to scientific ideas rather than personal preference or moral values.
5. Testable questions do not relate to the supernatural or to nonmeasurable phenomena.

Evidence

1. ***School absences:*** At the peak of the illness, 12.6 percent of students were absent from school. Two years ago, a similar percentage of students were absent because of the flu. There is no evidence, however, that the current illness is due to the flu.
2. ***Disease symptoms:*** Most of the symptoms of chicken pox were present in most children. Less than one-third of the ill children had blisters. This could be because blisters are only associated with a severe form of the disease or with a certain phase of the disease process.
3. ***Laboratory tests:*** Samples from only two children were sent for laboratory tests. One of them contained chicken pox virus. This means that just 3 percent (2 of 66) of the ill children were tested. It is possible that these results are not representative of the group of children who became ill. The finding of chicken pox virus in one sample, however, provides evidence that chicken pox is responsible for the illness in at least some of the children.
4. ***Infection rates of vaccinated compared with unvaccinated students:*** Children cannot get chicken pox more than once. This means that 75 percent (15 out of 20) of children who were not vaccinated and had not already had chicken pox became ill. In contrast, only about 11 percent (51 out of 445) of children who had been vaccinated and had not already had chicken pox became ill. The data show that vaccination provides substantial though not complete protection from infection. The fact that over 90 percent of parents report that they were vaccinated is not directly relevant to the cause of the children's illness.
5. ***Severity of the disease:*** The data show that most children who were vaccinated experienced a less severe form of the disease than did children who were not vaccinated. This means that vaccination not only provides protection against becoming infected, it also lessens the disease symptoms when an infection does occur.
6. ***Time of vaccination:*** Children who were vaccinated over four years ago were five times as likely to get chicken pox as were children vaccinated within the past four years. These data suggest that the protective effects of vaccination begin to wear off after about four years.

Explanation

1. The most likely explanation for the children's illness is that they were infected with the chicken pox virus. This explanation is consistent with the laboratory tests and doctors' examinations.
2. The most likely explanation for why some children who were vaccinated against chicken pox became infected is that the protective effects of the vaccine wear off after about four years. This explanation is consistent with time-of-vaccination data.

NSES

Content Standard C:
Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

Content Standard F:
The potential for accidents and the existence of hazards imposes the need for injury prevention. Important personal and social decisions are made based on perceptions of benefits and risks. Risk analysis considers the type of hazard and estimates the number of people who might be exposed and the number likely to suffer consequences.

Content Standard G:
Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

NSES

Content Standard G: Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skills, and creativity.

Next Steps

1. Conduct additional lab tests to confirm the chicken pox diagnosis.
2. Survey the medical literature to see whether any other diseases share the same symptoms as chicken pox.
3. Survey the medical literature to see whether similar outbreaks of children vaccinated against chicken pox have been reported.
4. Some of your students may suggest performing experiments on children, such as deliberately infecting them with virus and monitoring infection rates. Be sure to point out that any such experiments are prohibited on legal and ethical grounds!

Lesson 4 Organizer

What the Teacher Does	Procedure Reference
Activity 1: *Pulling It All Together*	
Explain to the students that they will continue in their roles as members of the community health department investigative team. • This time they will analyze data collected by others and prepare a report.	Page 91 Step 1
Display a transparency of Master 4.1, *Memo from Director*. Read the memo aloud. Alternatively, have students access the Web site and read the memo there.	Page 91 Step 2 T
Divide the class into teams of two. • Give half of the teams one copy of Master 4.2a, *Data from Investigation*. • Give half of the teams one copy of Master 4.2b, *Data from Investigation*. Alternatively, have students access the Web site and review the data there.	Page 91 Step 3 M
Give each student one copy of Master 4.3, *Report Form*. Explain that they are to • review the data on Data from Investigation, • discuss its meaning with their teammate, and • fill out the information requested on Master 4.3.	Page 92 Step 4 M
After teams have completed their task, instruct them to trade their Report Forms and Data from Investigation with a team that worked with the other data set.	Page 92 Step 5
Give each student one copy of Master 4.4, *Evaluation Form*. Instruct teams to • review the information on the Report Forms and • answer the questions posed on the Evaluation Form.	Page 92 Step 6 M
After students have completed their tasks, collect all of the Report Forms and Evaluation Forms.	Page 92 Step 7

T = Involves making a transparency. M = Involves copying a master.

Masters

Lesson 1, *Inquiring Minds*

Master 1.1, *The Mystery Cube Template* . . . . team copies
Master 1.2, *The Biological Box Template* . . . . team copies
Master 1.3, *Thinking about Inquiry* . . . . student copies

Lesson 2, *Working with Questions*

Master 2.1, *Working with Questions*. student copies and transparency
Master 2.2, *Letters to the Editor* . . . . student copies
Master 2.3, *Question and Investigation Form* . . . . student copies

Lesson 3, *Conducting a Scientific Investigation*

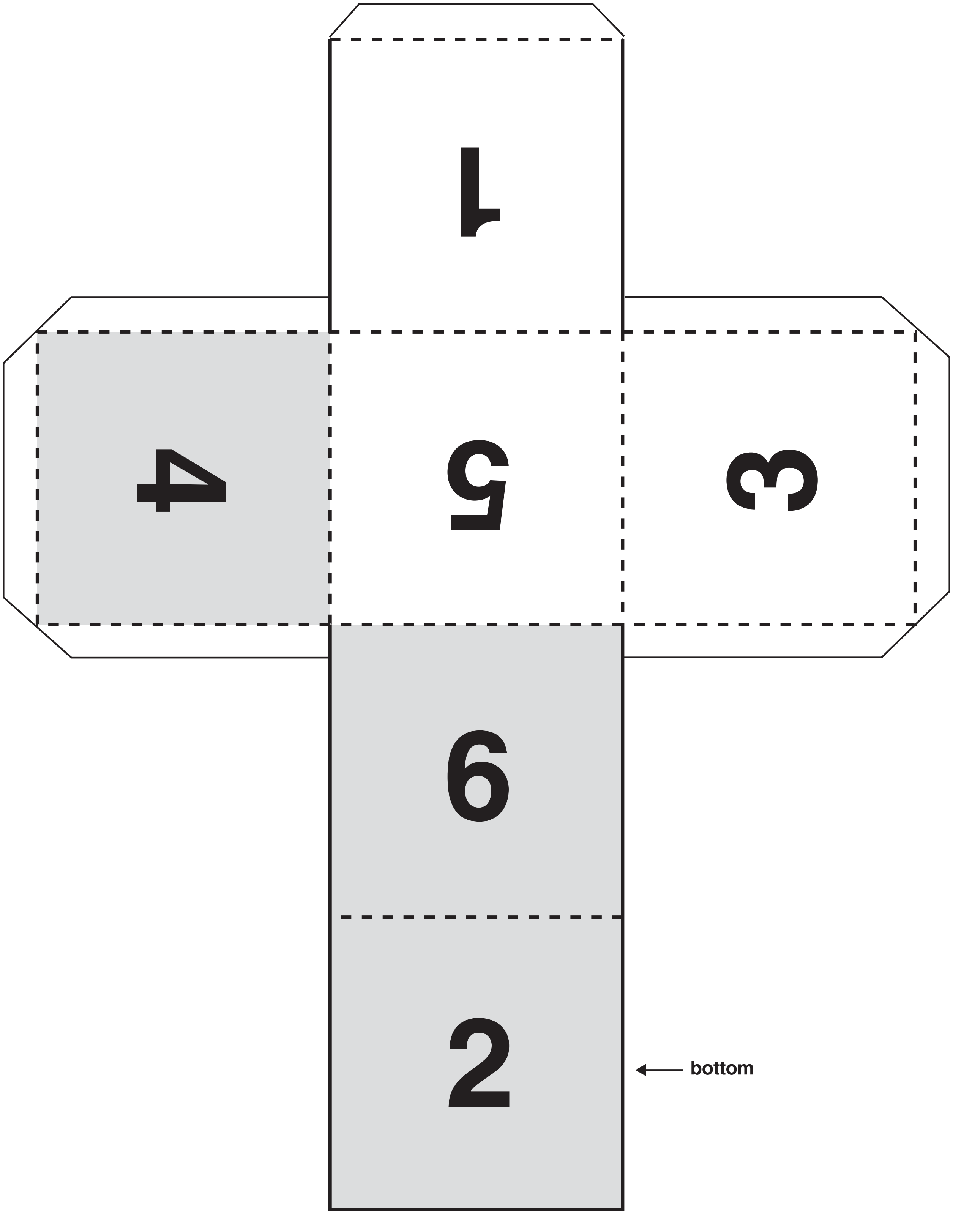
Master 3.1, *Investigative Report Form** . . . . student copies
Master 3.2, *Letter from Principal*. . . . . transparency
Master 3.3, *First Memo from Director* . . . . transparency
Masters 3.4a, b, c, *Attendance Data*. team copies
Master 3.5, *Second Memo from Director* . . . . transparency
Master 3.6, *Interview Summary* . . . . team copies
Masters 3.7a, b, *Quotes from Interviews*. . . . . team copies
Masters 3.8a, b, c, d, *School Calendars* . . . . team copies
Master 3.9, *Third Memo from Director*. . . . . transparency
Masters 3.10a, b, *Activity Tables* . . . . team copies
Masters 3.11a, b, *Activity Maps* . . . . team copies
Master 3.12, *Analyzing Evidence** . . . . student copies

Lesson 4, *Pulling It All Together*

Master 4.1, *Memo from Director* . . . . transparency
Master 4.2a, *Data from Investigation* . . . . for half of teams
Master 4.2b, *Data from Investigation* . . . . for other half of teams
Master 4.3, *Report Form** . . . . student copies
Master 4.4, *Evaluation Form** . . . . student copies

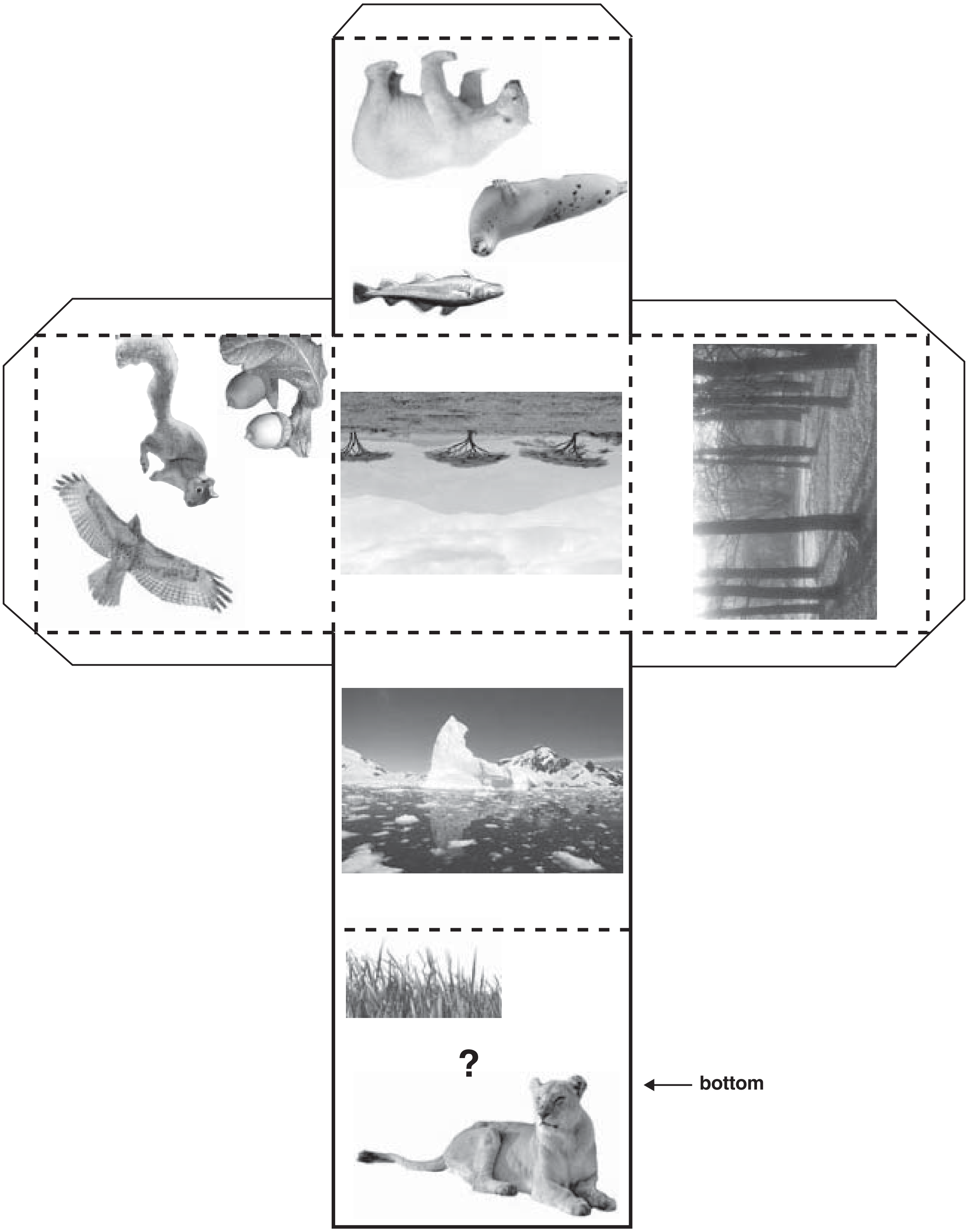
* Masters needed for Web version. Print version uses all the masters.

The Mystery Cube Template



Master 1.1

The Biological Box Template



Master 1.2

Thinking about Inquiry

Name: ______________________ Date: _________________

The following table lists parts of the process you went through to investigate the cube and box. Think back to your work with the Mystery Cube and the Biological Box. On the right side of the table under the heading "Biological Box Activity," provide an example of what you did in that activity that models the process of learning about the natural world.

Process	Biological Box Activity
Ask a testable question	
Gather evidence by making observations, recognizing patterns, and collecting data	
Share information	
Perform experiments	
Provide an evidence-based explanation	

Working with Questions

Name:______________________ Date: ______________

1. How is bug blood different from human blood?

2. Why do your fingers wrinkle after you take a bath?

3. Is rock music better than hip-hop music?

4. Why does bright light cause some people to sneeze?

5. Do smells affect people's moods?

6. Is vegetarianism better than eating meat?

Letters to the Editor

The Daily Bugle Newspaper

Letters to the Editor

Readers Sound Off about Proposed Quick and Tasty Restaurant:

Fast Food and Cancer?
When are Americans going to wake up to the dangers of restaurants like Quick and Tasty? The food they serve contains many chemicals known to cause cancer. It is no coincidence that as more people eat at these restaurants, more cases of cancer are being reported. Americans need to learn that organic foods are better than processed foods.

Signed, A Health-Conscious Reader

Healthy Diet? It's Up to You!
I for one will welcome Quick and Tasty to our neighborhood. Their food tastes great, is reasonably priced, and is good for you. People who say otherwise just eat too much or pick the wrong items. Their salads are just as good as those served at fancy restaurants but are much less expensive. I regularly eat at the Quick and Tasty near my business, and I'm in great shape.

Signed, Marathon Man

Weight a Minute!
Quick and Tasty is the last thing our community needs. The nation is in the midst of an epidemic of obesity, and fast-food restaurants are the biggest reason why. The food they serve has too many calories, and their portions are way too large. Society must be protected from companies like Quick and Tasty. They are more interested in making money than in the health of their customers.

Signed, Lean and Mean

Question and Investigation Form

Name: ________________________ Date: ____________________

Select one of the letters from Master 2.2, *Letters to the Editor*. Develop two scientific questions related to the letter. Then describe an investigation and the evidence you could gather to answer each question.

Letter you chose: _____________________________

Question 1   **Investigation**
Question 2   **Investigation**

Investigative Report Form

Investigator: ______________________

Date: ______________________

Testable Question

Evidence Collected

Analysis and Explanation of Evidence

Next Questions

Letter from Principal

Truman Middle School

Where Knowledge Is Good

Director
Community Health Department

Dear Director:

I want to alert you to a possible health problem affecting students at the Truman Middle School. I just had a discussion with the director of our student band. He told me that in his class on Wednesday, May 20, fully one-third of his students were absent.

This situation reminds me of last year when we had a widespread outbreak of the flu. Can you help us determine if we should be concerned? If there is a problem, can you suggest measures we might take to prevent or contain the disease?

Thank you for your attention to this matter.

Sincerely,

Samantha Perez

Samantha Perez
Principal, Truman Middle School

First Memo from Director

MEMO

To: **Members of the Health Department Investigative Staff**

From: **Director of the Community Health Department**

About: **School Absences**

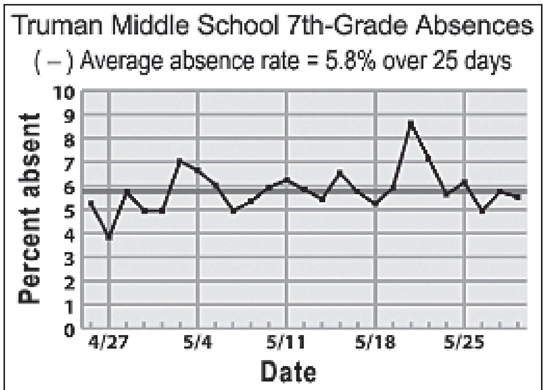
Principal Perez at Truman Middle School has alerted me to a possible health problem among her students (see accompanying letter). I need your staff to investigate the situation and determine if a health problem exists in our community. To get you started, I have arranged to give you access to the attendance data for each of our community's four middle schools.

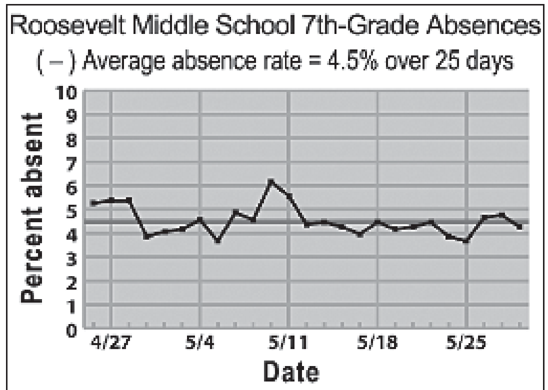
Please remember to take notes about your investigation. Each day, you should write your notes on a separate *Investigative Report Form*. The headings for our new *Investigative Report Forms* are

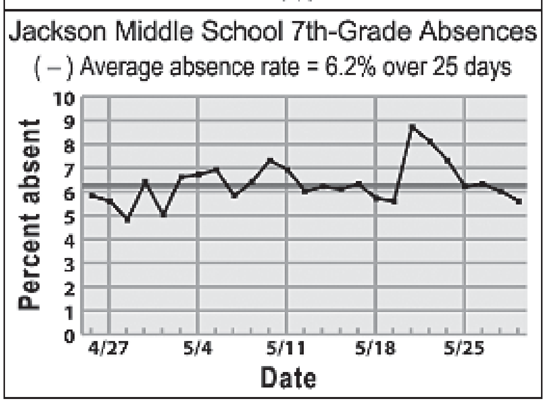
1. Testable Question
2. Evidence Collected
3. Analysis and Explanation of Evidence
4. Next Questions

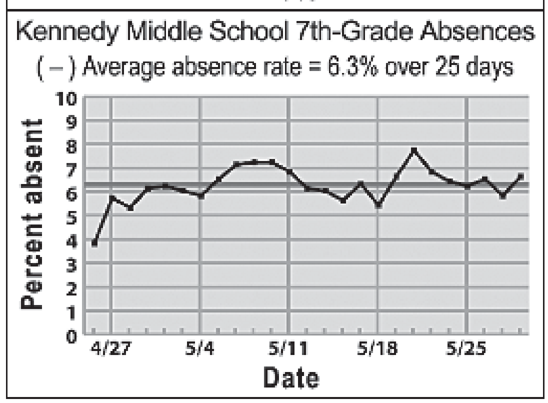
For your first investigation to determine if a health problem exists, you will need to ask a testable question that can be answered by analyzing school attendance data.

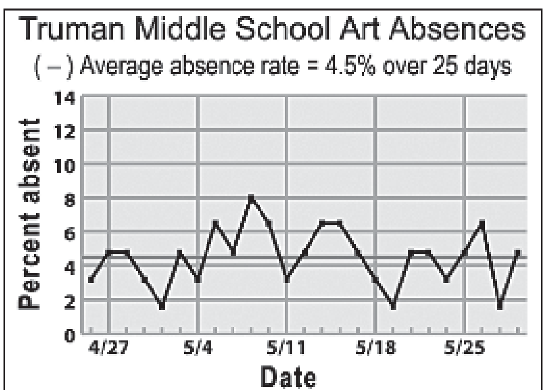
Attendance Data

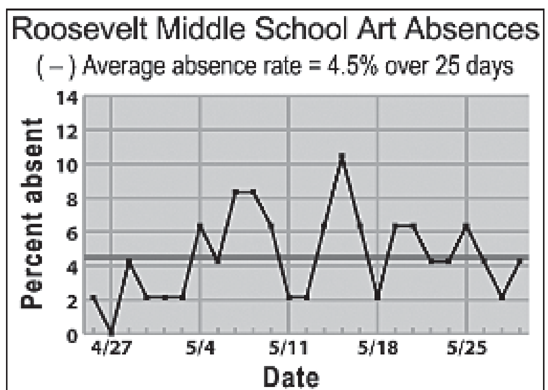


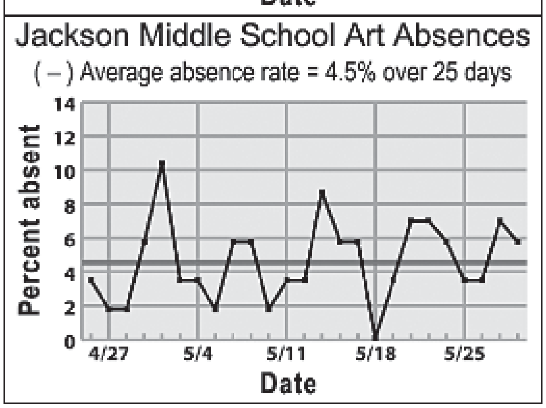


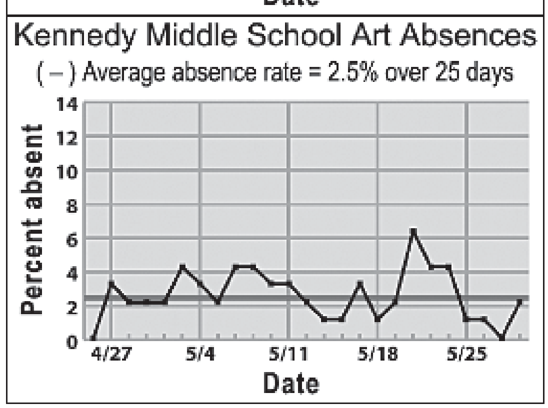




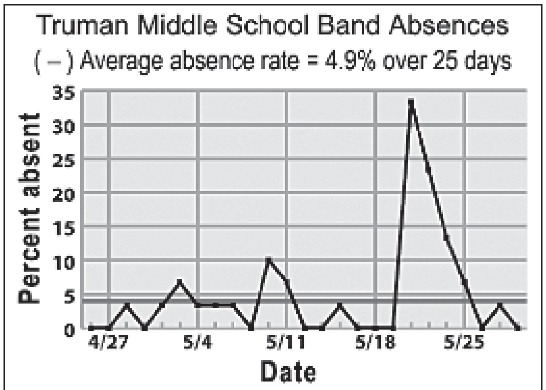


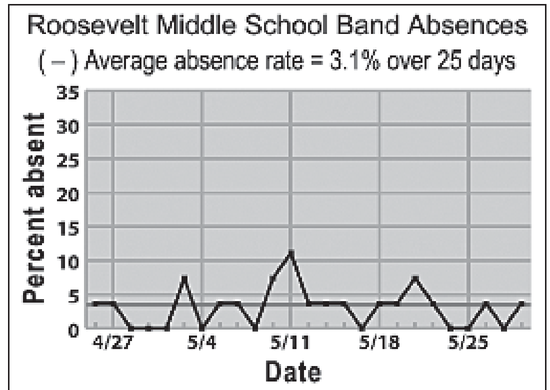


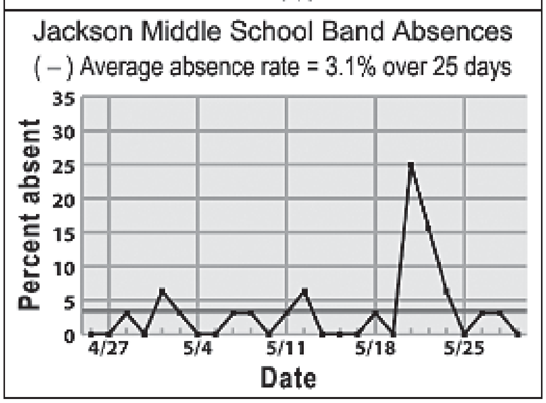


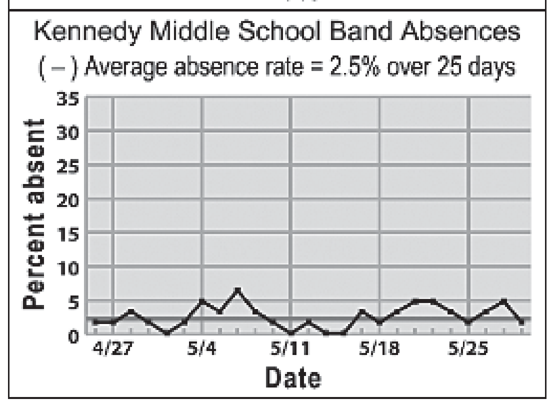


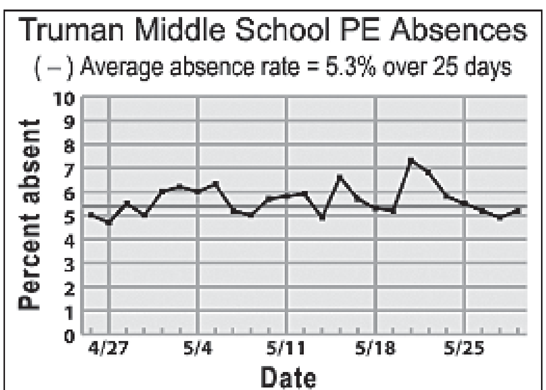
Attendance Data

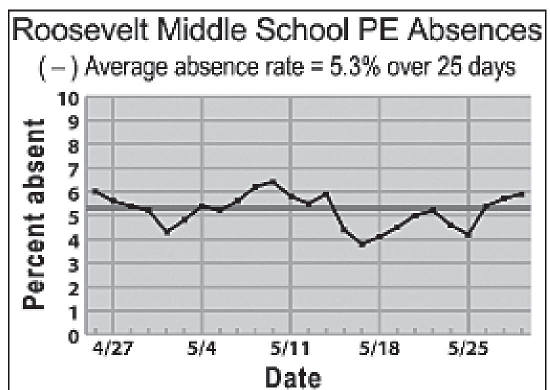


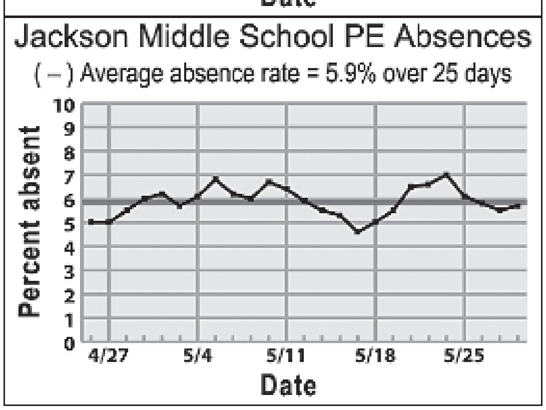


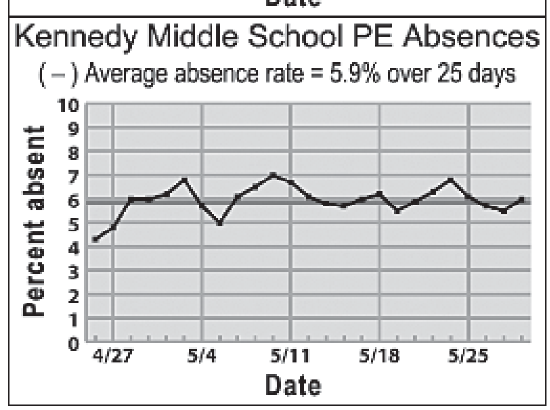












Attendance Data: Percent Absent

Date	4/24	4/27	4/28	4/29	4/30	5/1	5/4	5/5	5/6	5/7	5/8	5/11	5/12	5/13	5/14	5/15	5/18	5/19	5/20	5/21	5/22	5/25	5/26	5/27	5/28
Truman Middle School																									
7th grade (450 students)	5.2	3.8	5.7	4.9	4.9	7.0	6.6	6.0	4.9	5.3	5.9	6.2	5.8	5.4	6.5	5.7	5.2	5.9	8.6	7.1	5.6	6.1	4.9	5.7	5.5
PE classes (225 students)	5.0	4.7	5.5	5.0	6.0	6.2	6.0	6.3	5.2	5.0	5.7	5.8	5.9	4.9	6.6	5.7	5.3	5.2	7.3	6.8	5.8	5.5	5.2	4.9	5.2
Band class (30 students)	0.0	0.0	3.3	0.0	3.3	6.7	3.3	3.3	3.3	0.0	10.0	6.7	0.0	0.0	3.3	0.0	0.0	0.0	33.3	23.3	13.3	6.7	0.0	3.3	0.0
Art classes (62 students)	3.2	4.8	4.8	3.2	1.6	4.8	3.2	6.5	4.8	8.0	6.5	3.2	4.8	6.5	6.5	4.8	3.2	1.6	4.8	4.8	3.2	4.8	6.5	1.6	4.8
Roosevelt Middle School																									
7th grade (378 students)	5.2	5.3	5.3	3.8	4.0	4.1	4.5	3.6	4.8	4.5	6.1	5.5	4.3	4.4	4.2	3.9	4.4	4.1	4.2	4.4	3.8	3.6	4.6	4.7	4.2
PE classes (200 students)	6.1	5.7	5.5	5.3	4.4	4.9	5.5	5.3	5.7	6.3	6.5	5.9	5.6	6.0	4.5	3.9	4.2	4.6	5.1	5.3	4.7	4.3	5.5	5.8	6.0
Band classes (27 students)	3.7	3.7	0.0	0.0	0.0	7.4	0.0	3.7	3.7	0.0	7.4	11.1	3.7	3.7	3.7	0.0	3.7	3.7	7.4	3.7	0.0	0.0	3.7	0.0	3.7
Art classes (48 students)	2.1	0.0	4.2	2.1	2.1	2.1	6.3	4.2	8.3	8.3	6.3	2.1	2.1	6.3	10.4	6.3	2.1	6.3	6.3	4.2	4.2	6.3	4.2	2.1	4.2
Jackson Middle School																									
7th grade (505 students)	5.7	5.5	4.7	6.3	4.9	6.5	6.6	6.8	5.7	6.3	7.2	6.8	5.9	6.1	6.0	6.2	5.6	5.5	8.6	8.0	7.2	6.1	6.2	5.9	5.5
PE classes (235 students)	5.0	5.0	5.5	6.0	6.2	5.7	6.1	6.8	6.2	6.0	6.7	6.4	5.9	5.5	5.3	4.6	5.0	5.5	6.5	6.6	7.0	6.1	5.8	5.5	5.7
Band class (32 students)	0.0	0.0	3.1	0.0	6.3	3.1	0.0	0.0	3.1	3.1	0.0	3.1	6.3	0.0	0.0	0.0	3.1	0.0	25.0	15.6	6.3	0.0	3.1	3.1	0.0
Art classes (58 students)	3.4	1.7	1.7	5.7	10.3	3.4	3.4	1.7	5.7	5.7	1.7	3.4	3.4	8.6	5.7	5.7	0.0	3.4	6.9	6.9	5.7	3.4	3.4	6.9	5.7
Kennedy Middle School																									
7th grade (680 students)	3.9	5.8	5.4	6.2	6.3	6.1	5.9	6.6	7.2	7.3	7.3	6.9	6.2	6.1	5.7	6.4	5.5	6.7	7.8	6.9	6.5	6.3	6.6	5.9	6.7
PE classes (350 students)	4.3	4.8	6.0	6.0	6.2	6.8	5.7	5.0	6.1	6.5	7.0	6.7	6.1	5.8	5.7	6.0	6.2	5.5	5.9	6.3	6.8	6.1	5.7	5.5	6.0
Band classes (64 students)	1.6	1.6	3.2	1.6	0.0	1.6	4.7	3.2	6.3	3.2	1.6	0.0	1.6	0.0	0.0	3.2	1.6	3.2	4.7	4.7	3.2	1.6	3.2	4.7	1.6
Art classes (95 students)	0.0	3.2	2.1	2.1	2.1	4.2	3.2	2.1	4.2	4.2	3.2	3.2	2.1	1.1	1.1	3.2	1.1	2.1	6.3	4.2	4.2	1.1	1.1	0.0	2.1

Second Memo from Director

MEMO

To: **Members of the Health Department Investigative Staff**

From: **Director of the Community Health Department**

About: **Band Student Absences at Truman and Jackson Middle Schools**

Thank you for your hard work. You have established that a potential health problem exists at Truman and Jackson middle schools. I have informed the principal at each school that you will continue your investigation and keep them informed of your progress.

Staff members have interviewed the parents of the absent students. The results of their interviews are summarized in the accompanying tables (one for each middle school). The tables provide a reason for each student's absence. If a student is sick, the symptoms are reported in the table. You also can read quotes from the parent interviews that are available as of today.

The principals from Truman and Jackson middle schools have sent school calendars that provide information about the activities of band-class students over the past two months.

Keep up the good work. I look forward to learning the results of your investigation.

Interview Summary

Results of Interviews with Parents of Absent Students

Truman Middle School Band Class			
Student	**Reason for absence**	**Symptoms**	**Parent interview available?**
T1	Sick	Stomachache, headache, fever	No
T2	Sick	Stomachache, vomiting, fever	No
T3	Sick	Stomachache, headache, vomiting	No
T4	Sick	Stomachache, diarrhea	Yes
T5	Sick	Stomachache, diarrhea, fever	No
T6	Sick	Stomachache, vomiting, diarrhea	Yes
T7	Family vacation	None	No
T8	Sick	Stomachache, headache, diarrhea	No
T9	Sick	Stomachache, diarrhea, fever	No
T10	Sick	Stomachache, vomiting, diarrhea, fever	Yes

Jackson Middle School Band Class			
Student	**Reason for absence**	**Symptoms**	**Parent interview available?**
J1	Broken leg	Broken leg	No
J2	Sick	Stomachache, diarrhea, vomiting, fever	Yes
J3	Sick	Stomachache, headache, diarrhea, fever	No
J4	Sick	Stomachache, diarrhea, fever	No
J5	Sick	Stomachache, headache, diarrhea	No
J6	Sick	Stomachache, vomiting, diarrhea, fever, headache	Yes
J7	Sick	Stomachache, headache	No
J8	Sick	Stomachache, headache, diarrhea	No

Quotes from Interviews

Interview with Parent of Student T4

Health worker: I understand that your daughter missed school on May 20 and 21. Can you tell me why she was absent?

Parent: She woke up before her alarm clock went off and complained that she felt sick to her stomach. About an hour later she threw up and so I kept her home.

Health worker: I see. How is she doing now?

Parent: She is better. She missed two days of school, though, and is busy getting caught up.

Interview with Parent of Student T6

Health worker: Can you tell me why your son missed school on May 20 and 21?

Parent: Yes, he had the flu.

Health worker: Did you take him to the doctor?

Parent: No, but I'm pretty sure it was just the flu. He probably caught it from his friend who was also sick at the same time.

Health worker: Maybe. After being exposed to the flu, it generally takes three to five days for symptoms to show up.

Quotes from Interviews

Interview with Parent of Student T10

Health worker: Why was your son absent from school on May 20 and 21?

Parent: He came home from the band competition and complained that his stomach hurt. The next day he felt worse. I took his temperature and found that he had a fever, so I kept him home. I think he had food poisoning. You should check out the restaurant that they went to.

Health worker: I suppose it could be food poisoning. Symptoms of food poisoning usually appear in the next day or two after eating contaminated food.

Interview with Parent of Student J2

Health worker: Why did your son miss school on May 20 and 21?

Parent: He had a bad stomachache and diarrhea. I took his temperature and it was a little high. I was going to take him to the doctor, but he started getting better, so I canceled the appointment.

Health worker: Well, I'm glad he's doing better!

Interview with Parent of Student J6

Health worker: Can you tell me why your daughter missed school on May 20 and 21?

Parent: She woke up with a stomachache and spent the whole morning in the bathroom. Later, she developed a fever and a headache. Do you think it is anything serious?

Health worker: We're concerned that the absent students may all have the same illness. I'll be sure and let you know what our investigation turns up.

School Calendars

Truman Middle School Band Calendar

April						
Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
29	30	31	1	2 Parent Teacher Conferences	3 No School—Teacher Work Day	4
5	6 No School—Spring Break	7 No School—Spring Break	8 No School—Spring Break	9 No School—Spring Break	10 No School—Spring Break	11
12	13 Band practice	14	15 Band practice	16	17 Band practice	18 Band Concert
19	20 Band practice	21	22 Band practice	23	24 Band practice	25
26	27 Band practice	28	29 Band practice	30	1	2

School Calendars

Truman Middle School Band Calendar

May						
Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
26	27	28	29	30	**1** Band practice	2 Bake Sale Fundraiser
3	**4** Band practice	**5** May Day Parade with bands from Jackson and Roosevelt	**6** Band practice	**7**	**8** Band practice	9
10	**11** Band practice	**12**	**13** Band practice	**14**	**15** student planning meeting for battle of bands with Jackson	16
17	**18** Band practice	**19** Battle of the Bands with Jackson	**20** Band practice	**21**	**22** Band practice	23
24	**25**	**26**	**27** Band practice	**28**	**29** Band practice	30
31	1	2	3	4	5	6

School Calendars

Jackson Middle School Band Calendar

April						
Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
29	30	31	**1**	**2** Parent Teacher Conferences	**3** No School—Teacher Work Day	4
5	**6** No School—Spring Break	**7** No School—Spring Break	**8** No School—Spring Break	**9** No School—Spring Break	**10** No School—Spring Break	11
12	**13**	**14** Band practice	**15**	**16** Band practice	**17**	18
19	**20**	**21** Band practice	**22**	**23** Band practice	**24**	25
26	**27** Band Concert	**28** Band practice	**29**	**30** Band practice	1	2

School Calendars

Jackson Middle School Band Calendar

May						
Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
26	27	28	29	30	**1**	2
3	**4**	**5** May Day Parade with bands from Truman and Roosevelt	**6**	**7** Band practice	**8**	9
10	**11**	**12** Band practice	**13**	**14** Band practice	**15** student planning meeting for battle of bands with Truman	16
17	**18**	**19** Battle of the Bands with Truman	**20**	**21** Field Trip to Band Concert at State College	**22**	23
24	**25**	**26** Band practice	**27**	**28** Band practice	**29**	30
31	1	2	3	4	5	6

Third Memo from Director

MEMO

To: **Members of the Health Department Investigative Staff**

From: **Director of the Community Health Department**

About: **WATER ALERT**

I need to alert you to a new situation that may or may not relate to your investigation. A neighboring community has discovered a problem that may affect us and other communities in the region. Bacteria that cause stomach illness have been detected in its water supply. The health department in that community reports a sharp increase in illnesses that have symptoms similar to food poisoning and a stomach virus (stomachache, vomiting, nausea, and diarrhea). We're taking the necessary steps to watch for problems in our community.

By the way, I'm pleased to hear of the progress you are making with your investigation. As requested by your team supervisor, our staff has collected information about the activities that students participated in during the Battle of the Bands event. This information is available in a table and displayed as a series of maps.

Keep up the hard work. I look forward to learning the results of your investigations.

Activity Tables

Activities in which Students Participated

Truman Middle School[a, b]

Student	Biff's French Restaurant	Cheep Chicken Hut	Volleyball	Soccer	Swimming
T1		X			X
T2	X			X	
T3		X			X
T4		X			X
T5		X			X
T6		X			X
T8		X			X
T9		X			X
T10	X				X
T11	X				X
T12		X			X
T13	X		X		
T14	X			X	
T15		X			X
T16		X		X	
T17	X				X
T18	X		X		
T19	X		X		
T20	X			X	
T21	X			X	
T22	X		X		
T23		X		X	
T24	X			X	
T25		X		X	
T26	X		X		
T27	X			X	
T28		X			X
T29	X		X		
T30		X			X

[a]Student T7 was on vacation and did not attend the Battle of the Bands event.
[b]The shaded area indicates students who did not become sick.

Activity Tables

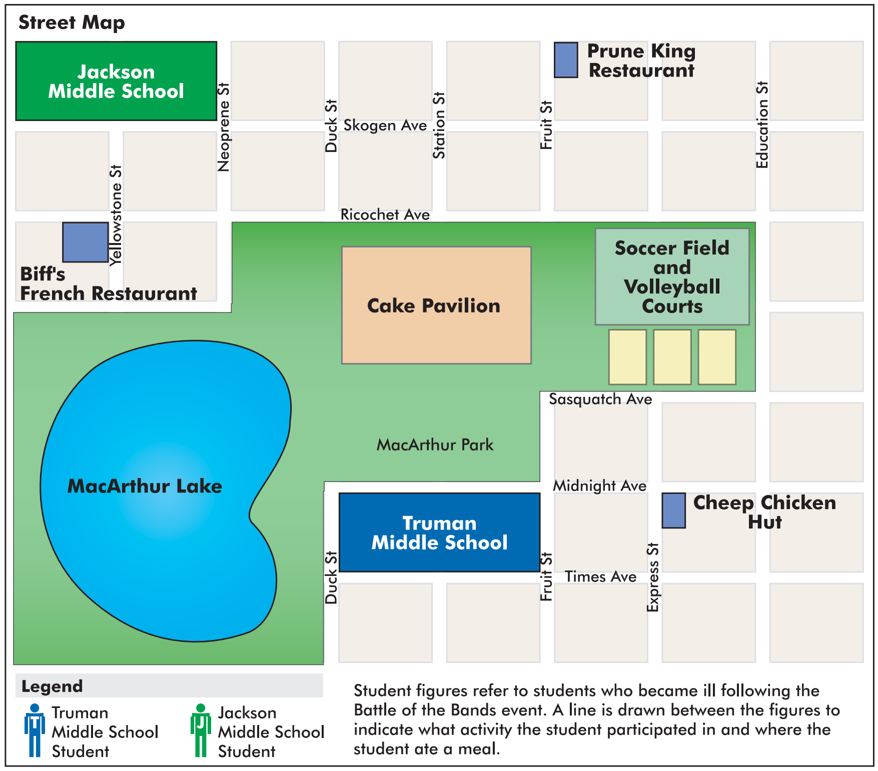
Activities in which Students Participated

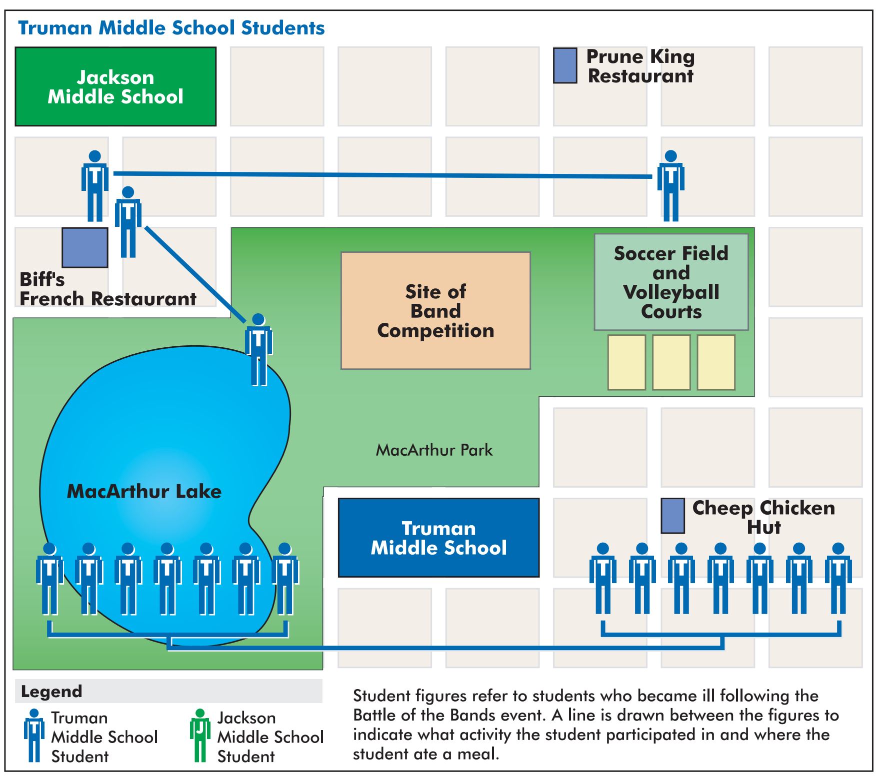
Jackson Middle School[a, b]

Student	Cheep Chicken Hut	Prune King Restaurant	Volleyball	Soccer	Swimming
J2	X				X
J3	X			X	
J4		X			X
J5	X		X		
J6	X				X
J7	X				X
J8	X				X
J9		X	X		
J10		X	X		
J11		X		X	
J12	X				X
J13		X			X
J14		X	X		
J15		X		X	
J16	X				X
J17		X		X	
J18	X			X	
J19		X	X		
J20		X			X
J21		X	X		
J22		X		X	
J23		X		X	
J24	X		X		
J25	X				X
J26		X		X	
J27		X		X	
J28		X	X		
J29		X		X	
J30	X			X	
J31		X			X
J32	X				X

[a] Student J1 has a broken leg and did not attend the Battle of the Bands event.
[b] The shaded area indicates students who did not become sick.

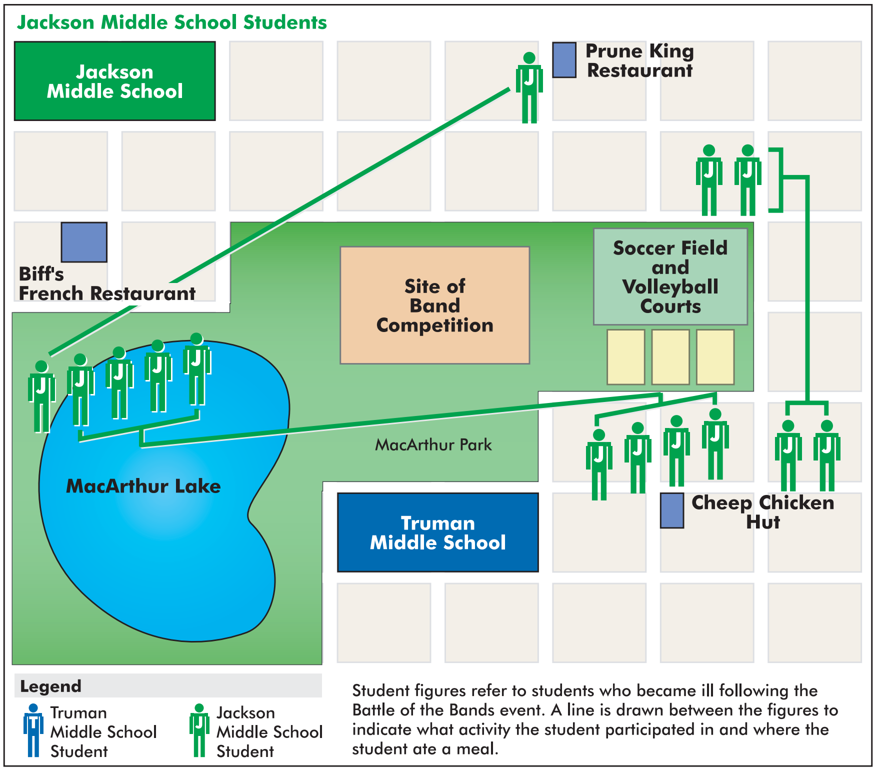
Activity Maps

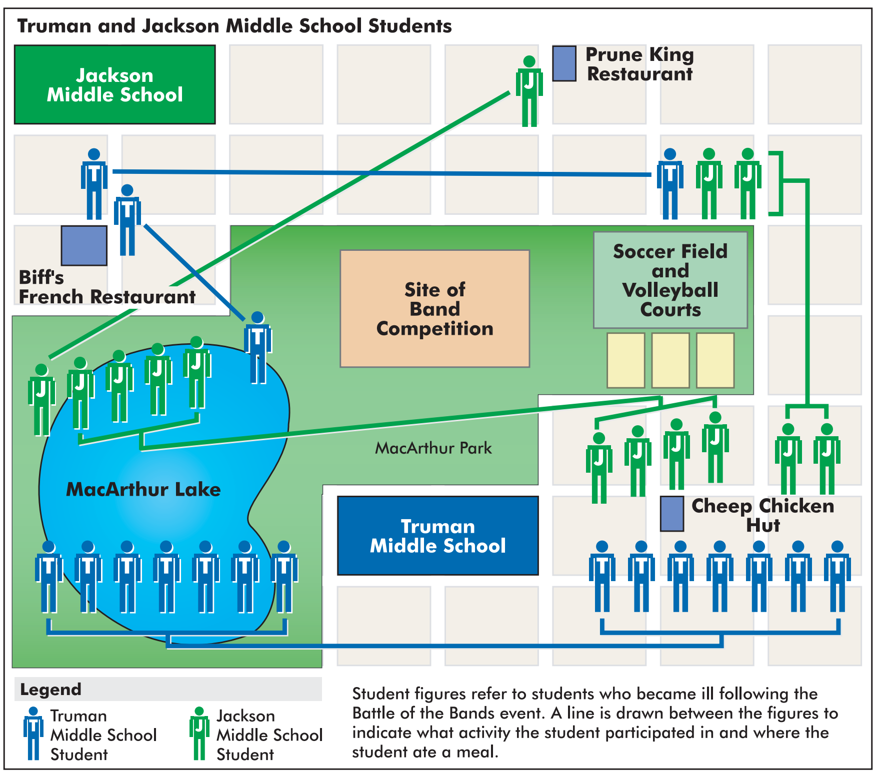




For each student, a line is drawn between two figures to indicate what activity the student participated in and where the student ate a meal on May 19.

Activity Maps





For each student, a line is drawn between two figures to indicate what activity the student participated in and where the student ate a meal on May 19.

Master 3.11b

Analyzing Evidence

Name: ___________________________ Date: __________________

For the evidence listed below, write down the information you learned from it and explain how it helped, or did not help, you answer a testable question.

1. Memos from the director of the community health department

2. Attendance data for seventh-grade students at four middle schools

3. Summaries of interviews from parents of absent students

4. Transcripts from interviews with parents of absent students

5. School calendars

6. Student activity tables

7. Activity maps

Memo from Director

MEMO

To: **Members of the Health Department Investigative Staff**

From: **Director of the Community Health Department**

About: **Disease Outbreak**

The director of our Disease Awareness unit has alerted me to a disease outbreak at one of our elementary schools. Her staff have completed an initial investigation into the outbreak and sent data to us for analysis.

I need you to review the data they have sent and prepare a brief report. You will complete a form based on our *Investigative Report Form*.

Data from Investigation

Community Health Department

Case Number 0439-a
Disease Outbreak at Lincoln Elementary School

Results from Initial Investigation

I. School absences
The school has 520 students. The illness occurred over a two-month period. At the peak of the outbreak, 66 students (12.6 percent) were absent from school. Two years ago, a similar percentage of students were absent from what turned out to be the flu.

II. Disease symptoms
I interviewed the doctor who treated the ill students. He concluded that 66 students had chicken pox, based have having the characteristic rash and at least two other symptoms. The following table shows how many of these students displayed symptoms of chicken pox.

Symptom of chicken pox	Number of students with symptom
Mild fever	66
Runny nose	60
Slight cough	56
Rash	66
Blisters	17
Headache	55
Sore throat	54

III. Laboratory tests
Samples taken from two of the ill students were sent away for lab analysis. One of the two samples was found to contain the chicken pox virus.

Data from Investigation

Community Health Department

Case Number 0439-b
Disease Outbreak at Lincoln Elementary School

Community Health Department

Results from Initial Investigation

I. Infection rates of vaccinated compared with unvaccinated students
Parents were interviewed to see if the children had been vaccinated. They were also asked if the children had already had and recovered from chicken pox. Children cannot get the disease a second time. Over 90 percent of parents reported having had chicken pox as children.

	Number of Students	
Student breakdown	**Vaccinated**	**Unvaccinated**
Total	470	50
With chicken pox now	51	15
Who had chicken pox before	25	30

II. Severity of the disease
Two doctors examined the sick children and classified each case as mild, moderate, or severe.

	Number of Students	
Student breakdown	**Vaccinated**	**Unvaccinated**
With mild disease	43	3
With moderate disease	7	9
With severe disease	1	3

III. Time of vaccination
Parents of children who were vaccinated were asked if their child was vaccinated within the past four years. Children who were vaccinated over four years ago were five times as likely to get chicken pox as were children vaccinated within the past four years.

Community Health Department

Report Form

Investigator name: ______________________

Date: ___________________

I have reviewed case number 0439-a / 0439-b (circle one).

I have identified the following testable question or questions:

The questions are based on the following evidence:

My analysis of the evidence and my conclusions are as follows:

I have identified the following questions that could be asked as next steps in the investigation:

Community Health Department

Evaluation Form

Investigator name: ______________________________

Date: __________________________

I have evaluated the report by team member ____, who studied case number 0439-a / 0439-b (circle one). My evaluation is presented below.

1. Was a testable question (or questions) identified?

2. Was the evidence collected appropriate for answering the questions?

3. Was there other evidence that should have been used by the investigator?

4. Were proposed explanations supported by the evidence collected?

5. Were there other explanations that should have been considered?