# Rare Diseases and Scientific Inquiry

developed under a contract from the
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Office of Rare Diseases Research


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

# Contents

# Foreword

*Rare Diseases and Scientific Inquiry* is the most recent addition to the National Institutes of Health (NIH) Curriculum Supplement Series. This series brings the latest medical science and research discoveries from NIH into the K–12 classroom. 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 is dedicated to promoting scientific literacy and the knowledge and skills we need to secure a healthy future for all.

*Rare Diseases and Scientific Inquiry* gives students an opportunity to grapple with some of the most challenging and engaging medical issues that confront our society. We designed *Rare Diseases and Scientific Inquiry* to complement existing life science curricula and to be consistent with *National Science Education Standards*. Middle school science teachers, medical experts, education specialists, scientists, representatives from the NIH Office of Rare Diseases Research (ORDR), and curriculum-design experts from Biological Sciences Curriculum Study (BSCS) created the activities. The collaborative development process includes geographically dispersed field tests by teachers and students.

The curriculum supplements enable teachers to facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements emphasize key biology concepts and analytic methods, cutting-edge science content, and built-in assessment tools. Activities promote active and collaborative learning to help students develop problem-solving strategies and critical-thinking skills.

Each of our curriculum supplements comes with a complete set of printed materials for teachers, including extensive background and resource information, detailed lesson plans, and masters for student worksheets. The Web site accompanying *Rare Diseases and Scientific Inquiry* has interactive materials to support the lessons. The supplements are distributed for free to educators across the United States upon request. They may be copied for classroom use and educational purposes but may not be sold.

We welcome your feedback. For a complete list of curriculum supplements and ordering information, or to submit feedback, visit http://science.education.nih.gov or write to

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We appreciate the valuable contributions from the talented staff at BSCS. We are also grateful to the NIH scientists, advisors, 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
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# About the National Institutes of Health

Founded in 1887, NIH is the federal focal point for health research in the United States. Today, it is one of the agencies in the Department of Health and Human Services. Its 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. NIH works toward meeting the mission by providing leadership, direction, and grant support to programs designed to improve the health of the nation through research.

NIH's education programs contribute to ensuring the continued supply of well-trained basic research and clinical investigators, as well as the myriad professionals in 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 education effort. It is a collaboration among the Office of Rare Diseases Research, the NIH Office of Science Education, and Biological Sciences Curriculum Study.

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

# About the Office of Rare Diseases Research

The Office of Rare Diseases (ORD) was established in 1993 at the National Institutes of Health. Later, the ORD's focus on research prompted a name change to the Office of Rare Diseases Research (ORDR). The ORDR provides information on rare diseases and rare disease research; supports scientific conferences; cosponsors, with the National Human Genome Research Institute, the Genetic and Rare Diseases Information Center; and coordinates and supports research on the diagnosis and treatment of rare diseases both intramurally and extramurally. The Office also funds the Rare Diseases Clinical Research Network (RDCRN), a group of clinical research sites in the United States and several foreign countries working on about 100 different rare diseases, and is working to harmonize community efforts on patient registries and biospecimen repositories. A rare disease (also called an "orphan disease") is a condition affecting fewer than 200,000 people in the United States (about 1 in 1,500) or one affecting more people but "for which no reasonable expectation exists that the costs of developing or distributing a drug can be recovered from the sale of the drug in the United States" (Orphan Drug Act of 1983).

For more about the ORDR, visit http://rarediseases.info.nih.gov.

# About Biological Sciences Curriculum Study

Headquartered in Colorado Springs, Colorado, BSCS was founded in 1958 as a curriculum study committed to an evidence- and inquiry-based approach to science education. BSCS instructional materials and professional development services are based on current research about teaching and learning for all science classrooms, kindergarten through college.

BSCS's materials are extensively field-tested in diverse settings across the country and evaluated for proven effectiveness. The BSCS 5E Instructional Model and inquiry are hallmarks of its materials, placing students at the center of their learning.

The BSCS mission is to transform science teaching and learning through research and development that strengthens learning environments and inspires a global community of scientifically literate citizens. BSCS is a 501(c)(3) nonprofit organization.

For more information, please visit http://www.bscs.org.

# Introduction to *Rare Diseases and Scientific Inquiry*

Calling a disease "rare" raises questions. What does it mean to say that a disease is rare? Why should rare diseases be singled out for special attention? In the United States, a disease is considered rare if it affects fewer than 200,000 people. Approximately 7,000 rare diseases are recognized, and researchers continue to describe new ones. Taken together, rare diseases represent a significant health concern affecting over 25 million Americans. Like more-common diseases, rare diseases may be caused by gene mutations, infection from pathogens, and exposure to harmful substances in the environment.

Because rare diseases affect fewer people than common diseases do, they have traditionally been allocated fewer research resources. This has made it more difficult for people with rare diseases to obtain accurate diagnoses of their conditions. Even with an accurate diagnosis, patients may find that there are no existing medications or other treatments to help them. People with rare diseases may feel isolated and even stigmatized. Fortunately, during the past 25 years, increased attention has been devoted to the study of rare diseases, and new treatments are being developed to help patients.

## What Are the Objectives of the Supplement?

*Rare Diseases and Scientific Inquiry* has two main objectives: to help students in grades 6–8 understand

1. that studying rare diseases is not only important to the people affected by the diseases, but it also contributes to understandings that researchers can apply to other, more-common diseases or, more generally, to how the body works and
2. the process of scientific inquiry through studying rare diseases.

The lessons in this supplement help students sharpen their skills in observation, critical thinking, experimental design, and data analysis. They also make connections to other disciplines such as English, mathematics, and social science.

As the supplement achieves its objectives, it helps convey to students the purpose of scientific research. Students experience how science provides evidence that can be used to understand and treat human disease. Ongoing research affects how we understand the world around us and gives us the foundation for improving choices about our personal health and the health of our community.

The lessons in this supplement 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 supplement is to encourage students to think in terms of these relationships now and as they grow older.

## Why Teach the Supplement?

Middle school life science classes offer an ideal setting for integrating many areas of student interest. In this supplement, students participate in activities that integrate inquiry, science, human health, mathematics, and

science-technology-society relationships. The real-life context of the supplement's classroom lessons is engaging for students, and they can immediately apply what they learn to their lives.

## What's in It for the Teacher?

*Rare Diseases and Scientific Inquiry* meets many of the needs of teachers in modern classrooms:

- The supplement meets science content, teaching, and assessment standards in the *National Science Education Standards* (National Research Council (NRC), 1996). It pays particular attention to the standards on scientific inquiry.
- It is integrated with other subjects, drawing most heavily from science, social science, mathematics, and health.
- It has a Web-based technology component that includes interactive activities and simulations.
- Finally, the supplement includes built-in assessment tools, which we note with an assessment icon in each lesson.

### Table 1. Correlation of *Rare Diseases and Scientific Inquiry* to Middle School Biology Topics

| Topics | Lesson 1 | Lesson 2 | Lesson 3 | Lesson 4 | Lesson 5 |
|---|---|---|---|---|---|
| Important levels of biological organization include cells, organs, tissues, organ systems, whole organisms, and ecosystems. | | ✓ | ✓ | ✓ | |
| Specialized cells carry out specialized functions. | ✓ | ✓ | ✓ | ✓ | ✓ |
| Humans have various body systems including those for digestion, reproduction, circulation, excretion, movement, control and coordination, and protection from disease. | ✓ | ✓ | ✓ | ✓ | ✓ |
| Body systems interact with each other. | | | ✓ | ✓ | ✓ |
| Every organism requires a set of instructions for specifying traits. Heredity is the passage of these instructions from one generation to another. | | ✓ | ✓ | ✓ | ✓ |
| Hereditary information is contained in genes. An inherited trait of an individual can be determined by one or by many genes. A single gene can influence more than one trait. | | | ✓ | ✓ | ✓ |
| The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited, and others result from interactions with the environment. | | | ✓ | ✓ | ✓ |
| Natural environments may contain substances and microbes that are harmful to human beings. | ✓ | ✓ | ✓ | ✓ | ✓ |

In addition, the supplement provides a means for professional development. Teachers can engage in new and different teaching practices like those described in this supplement without completely overhauling their entire program. In *Designing Professional Development for Teachers of Science and Mathematics*, S. Loucks-Horsley and coauthors (1998) write that supplements such as *Rare Diseases and Scientific Inquiry* can "offer a window through which teachers can get a glimpse of what new teaching strategies look like in action." By experiencing a short-term supplement like this one, 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 supplemental material like *Rare Diseases and Scientific Inquiry* can encourage reflection and discussion and stimulate teachers to improve their practices by focusing on student learning through inquiry.

A correlation of the supplement's major concepts with the biology and scientific inquiry topics often included in the middle school life science curricula follows (Tables 1 and 2). We hope this information helps teachers make decisions about incorporating this material into the curriculum.

**Table 2. Correlation of *Rare Diseases and Scientific Inquiry* to Middle School Scientific Inquiry Topics**

| Topics | Lesson 1 | Lesson 2 | Lesson 3 | Lesson 4 | Lesson 5 |
|---|---|---|---|---|---|
| Testable questions can be answered through scientific investigations. | | ✓ | ✓ | ✓ | ✓ |
| Scientific investigations use appropriate tools to gather, analyze, and interpret data. | | ✓ | ✓ | ✓ | ✓ |
| Evidence is used to develop explanations and make predictions. | | ✓ | ✓ | ✓ | ✓ |
| Critical thinking is used to relate evidence to explanations. | ✓ | ✓ | ✓ | ✓ | ✓ |
| Alternative explanations are recognized and analyzed. | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mathematics is important to scientific inquiry. | | ✓ | ✓ | ✓ | ✓ |

# Implementing the Supplement

We designed the five lessons in this supplement to be taught in sequence for approximately 10 days, assuming class periods of about 50 minutes. The following pages offer general suggestions about using these materials in the classroom; you will find specific suggestions in the procedures of each lesson.

## What Are the Goals of the Supplement?

*Rare Diseases and Scientific Inquiry* is designed to help students attain these major goals associated with scientific literacy:

- to understand a set of basic scientific principles related to the study of rare diseases and the relationships of rare diseases to common diseases and human health,
- to experience the process of scientific inquiry and develop an enhanced understanding of the nature and methods of science, and
- to recognize the role of science in society and the relationship between basic research 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 start with what they already know about disease and scientific inquiry, some of which may be incorrect. They then gain a scientific perspective on rare diseases and the importance of these diseases to medicine and to their lives.

Students begin by considering their initial thoughts about disease, its causes, what makes a disease rare, and what it might be like to cope with a rare disease (Lesson 1). Students then explore the three major causes of disease (genetics, environmental exposure, and infectious agents). They focus on the case of an infectious bacterium that can cause both a common and a rare disease (Lesson 2). We use a case study to explain how a rare disease is identified and to illustrate the sometimes difficult problem of obtaining an accurate diagnosis (Lesson 3). In Lesson 4, students investigate how medical research and clinical trials have affected the treatment of a rare disease.

Lesson 5, the final lesson, gives students an opportunity to consider what they have learned in the previous lessons. The creation of an informational poster has students reconsider what they learned about rare diseases: how the diseases are investigated, how medical research can affect their treatment, and what it is like to cope with one. The following chart (Table 3) illustrates the science content and conceptual flow of the classroom lessons and activities.

### Table 3. Science Content and Conceptual Flow of the Lessons

| Lesson | Learning Focus, from BSCS 5E Instructional Model | Major Concepts |
|---|---|---|
| Lesson 1—What Is a Rare Disease? | Engage | Students may have different ideas about the definition of "disease." They may also have naïve preconceptions about what makes a disease rare and how rare diseases are treated, and they may have attitudes about people with rare diseases. |
| Lesson 2—What Causes Rare Diseases? | Explore | Diseases have three main causes: genetics, environmental exposure, and infectious agents. These three influences sometimes interact with each other. An infectious agent may be able to cause a common disease in one case and a rare disease in another case. Doctors must ask testable questions and collect evidence to answer such questions when coming to a diagnosis. |
| Lesson 3—The Difficulty of Diagnosis | Explain | Some rare diseases are inherited. A rare disease may affect multiple body systems. Rare diseases sometimes share symptoms with more-common diseases, which can make getting a proper diagnosis difficult. People with a rare disease must sometimes cope with a stigma associated with being different from others. |
| Lesson 4—The Importance of Medical Research | Elaborate | A karyotype can provide evidence that a disease has a genetic cause. Some genetic diseases are inherited, while others are not. Much medical information is available online, but not all of it is useful or reliable. Clinical trials are an application of the scientific method to medicine. They have helped improve treatments for many rare diseases. |
| Lesson 5—Communicating about Rare Diseases | Evaluate | Patient support groups, government agencies, and other organizations exist to provide reliable information about rare diseases to the public. Knowledge about rare diseases and their impacts on people's lives may reduce the stigma sometimes associated with having a rare disease. |

## How Does the Supplement Correlate to the *National Science Education Standards*?

*Rare Diseases and Scientific Inquiry* supports teachers in their efforts to reform science education in the spirit of the National Research Council's 1996 *National Science Education Standards* (*NSES*). The content of the supplement is explicitly standards based. The following chart (Table 4) lists the specific content standards that this supplement addresses.

## Table 4. Alignment of *Rare Diseases and Scientific Inquiry* Lessons with *National Science Education Standards* for Content, Grades 5–8

### *Table 4a.* NSES *Standard A, Science as Inquiry*

| As a result of activities in grades 5–8, all students should develop | Correlation to *Rare Diseases and Scientific Inquiry* Lessons |
|---|---|
| **Abilities necessary to do scientific inquiry** | 1, 2, 3, 4 |
| • Identify questions that can be answered through scientific investigations. | 1, 2, 3, 4 |
| • Design and conduct a scientific investigation. Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables. | 4 |
| • Use appropriate tools and techniques to gather, analyze, and interpret data. | 2, 3, 4 |
| • Develop descriptions, explanations, predictions, and models using evidence. Students should base their explanations on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument. | 1, 2, 3, 4 |
| • Think critically and logically to make the relationships between evidence and explanations. | 2, 3, 4 |
| • Recognize and analyze alternative explanations and predictions. | 2, 3, 4 |
| • Communicate scientific procedures and explanations. | 2, 3, 4 |
| • Use mathematics in all aspects of scientific inquiry. | 3, 4 |
| **Understandings about scientific inquiry** | 2, 3, 4, 5 |
| • 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 phenomena; and some involve making models. | 2, 3, 4 |
| • Mathematics is important in all aspects of scientific inquiry. | 3, 4 |
| • Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. | 2, 3, 4, 5 |
| • … Asking questions and querying other scientists' explanations is part of scientific inquiry. | 2, 3, 4, 5 |

### *Table 4b.* NSES *Standards C, F, and G, Life Science, Science in Personal and Social Perspectives, and History and Nature of Science*

| As a result of activities in grades 5–8, all students should develop understanding of | Correlation to *Rare Diseases and Scientific Inquiry* Lessons |
|---|---|
| **Standard C. Structure and Function in Living Systems** | All |
| • … Different tissues are … grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole. | 2, 3, 4 |
| • The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination, and for protection from disease. These systems interact with each other. | 2, 3, 4 |
| • Disease is a breakdown in structures or functions of an organism. | All |
| **Standard C. Reproduction and Heredity** | 2, 3, 4 |
| • Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another. | 2, 3, 4 |
| • The characteristics of an organism can be described in terms of a combination of traits. Some are inherited, and others result from interactions with the environment. | 3, 4 |
| • Hereditary information is contained in genes, located in the **chromosomes** of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes. | 4 |
| **Standard F. Personal Health** | 1, 2, 4 |
| • Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. | 1, 2, 4 |
| **Standard F. Risks and Benefits** | 1, 2, 3, 4 |
| • Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and personal hazards (smoking, dieting, and drinking). | 1, 2, 4 |
| • Individuals can use a systematic approach to thinking critically about risks and benefits. | 3, 4 |
| **Standard G. Nature of Science** | |
| • Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. | 2, 3, 4 |
| • It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. | 2, 3, 4, 5 |

### *Teaching Standards*

The suggested teaching strategies in all the lessons support educators as they work to meet the teaching standards outlined in the *National Science Education Standards* (NRC, 1996). This supplement helps science teachers plan an inquiry-based program by providing short-term objectives for students. It also includes planning tools such as the Science Content and Conceptual Flow of the Lessons chart (Table 3) and a suggested timeline for teaching the supplement (page 18). Teachers can use the supplement to update their curriculum in response to their students' interest in this topic. The focus on active, collaborative, and inquiry-based learning helps teachers support the development of student understandings and nurture a community of science learners.

The structure of the lessons enables teachers 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. Using the BSCS 5E Instructional Model, combined with active, collaborative learning, allows teachers to respond effectively to the diversity of student backgrounds and learning styles. The supplement is fully annotated, with suggestions for how teachers can encourage and model the skills of scientific inquiry, as well as foster the curiosity, skepticism, and openness to new ideas and data that characterize the successful study of science.

### *Assessment Standards*

Teachers can engage in ongoing assessment of their teaching and of student learning by using the assessment components embedded in each lesson. The assessment tasks are authentic; they are similar in form to tasks that students will engage in outside the classroom or that scientists do. Annotations guide teachers to these opportunities for assessment and provide answers to questions that can help teachers analyze students' feedback.

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

The lessons in this supplement use a research-based pedagogical approach called the BSCS 5E Instructional Model, or the BSCS 5Es. The BSCS 5Es are based on a **constructivist** theory of learning. A key premise of this theory is that students are active thinkers who build (or construct) their own understanding of concepts out of interactions with phenomena, the environment, and other individuals. A constructivist view of science 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.

The three key findings related to student learning identified in *How People Learn* (Bransford et al., 2000), a comprehensive review of research on learning, support the pedagogical strategies promoted by implementing the BSCS 5Es:

- Students enter class with a variety of preconceptions that may later significantly interfere with learning if those preconceptions are not engaged and addressed.
- To develop competence in a given subject, students must build a strong foundation of factual knowledge within the context of a coherent conceptual framework.
- Students benefit from a metacognitive approach to learning that emphasizes goal setting and self-monitoring.

The BSCS 5Es sequence the learning experiences so that students can construct their own understanding of a science concept

over time. The model leads students through five phases of active learning that are easily described using five words that begin with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate. Rather than just listening and reading, students are also analyzing and evaluating evidence, experiencing, and talking with their peers in ways that promote the development and understanding of key science concepts. These inquiry-based experiences include both direct experimentation and development of explanations through critical and logical thinking. Students often use technology to gather evidence, and mathematics to develop models or explanations.

The BSCS 5Es emphasize student-centered teaching practices. Students participate in their learning in ways that are different from those seen in a traditional classroom. The following charts exemplify what teachers do (Table 5) and what students do (Table 6) in the BSCS 5E Instructional Model.

The following paragraphs illustrate how we implemented the BSCS 5Es in *Rare Diseases and Scientific Inquiry*.

### Engage

Students come to learning situations with prior knowledge. The Engage lesson gives you the chance to find out what students already know or think they know about the topic and concepts to be developed.

The Engage phase of this supplement (in Lesson 1) is designed to

- pique students' curiosity and generate interest;
- determine students' current understandings about disease, the scientific study of disease, and their attitudes toward disease;
- encourage students to compare their ideas with those of others; and
- give you a chance to hear or read students' current conceptions, which you can address in the later lessons.

### Explore

In the Explore phase of the supplement (Lesson 2), students investigate a variety of medical problems and consider possible causes for each. Students interact with medical reports, assess which problems pose the biggest risks, and act accordingly. The lesson allows students to express their developing understanding of rare diseases and scientific inquiry through analyzing and comparing data, analyzing hypothetical situations, and answering questions.

### Explain

The Explain phase provides opportunities for students to connect their previous experiences and begin to make conceptual sense of the main ideas of the supplement. It also allows you to introduce formal language, scientific terms, and content information that might make students' previous experiences easier to describe and explain.

In the Explain phase (Lesson 3), students investigate a case study dealing with **Marfan syndrome**. Students

- explain, in their own words, concepts and ideas about the causes of rare diseases;
- listen to and compare others' explanations of the results with their own;
- become involved in student-to-student discourse in which they explain their thinking to others and debate their ideas;
- record their ideas and current understandings; and
- revise their ideas.

### Elaborate

In the Elaborate lesson (Lesson 4), students make conceptual connections between new and previous experiences. They draw on their knowledge about rare diseases and scientific inquiry to investigate how medical research can help doctors diagnose and improve treatments for a rare disease. In this lesson, students

- connect ideas and apply their understandings of rare diseases and scientific inquiry to the treatment of childhood **leukemia**,

## Table 5. Understanding the BSCS 5E Instructional Model: What the Teacher Does

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