Chemicals, the Environment, and You: Explorations in Science and Human Health

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BSCS
A SCIENCE EDUCATION CURRICULUM STUDY

5415 Mark Dabling Boulevard
Colorado Springs, CO 80918

BSCS Development Team
Nancy M. Landes, Principal Investigator
Anne L. Westbrook, Project Director
Debra A. Hannigan, Curriculum Developer
Ann C. Lanari, Research Assistant
Carol Vallee, Project Assistant
Karen Bertollini, Project Assistant
Mary Crist, Project Assistant
Carrie Hamm, Project Assistant
Raphaela Conner, Project Assistant
Barbara Resch, Editor
Ric Bascobert, Editor
Diane Gionfriddo, Photo Research
Lisa Chilberg, Graphic Designer
Sandra Matthews, Evaluator

Videodiscovery, Inc. Development Team
Shaun Taylor, Vice President for Product Development
Michael Bade, Multimedia Producer, Project Director, Videographer
Greg Humes, Assistant Multimedia Producer
Cathy Saum, Graphic Designer
Lucy Flynn Zuccotti, Photo Research
Michele Moore, Assistant to Project Director
Jennifer Hunt, Costumes and Makeup
Mike Commins, Gaffer (Lighting)
Chet McKnight, Sound
Lee Strucker, Script Writer

Advisory Committee
Allen Dearry, National Institute of Environmental Health Sciences, Research Triangle Park, NC
David Eaton, University of Washington, Seattle, WA
Juliane Hill, University of Washington, Seattle, WA
Larry Johnson, Texas A & M University, College Station, TX
Greg Nichols, New Options Middle School, Seattle, WA
Josina Romero O'Connell, Challenger Middle School, Colorado Springs, CO
Jan Ryan, Brandeis Hillel Day School, San Francisco, CA
Karen Steinmetz, SUGEN, Inc., South San Francisco, CA
Susan Wooley, American School Health Association, Kent, OH

Writing Team
Juliane Hill, University of Washington, Seattle, WA
Charlene A. McQueen, University of Arizona, Tucson, AZ
Josina Romero O'Connell, Challenger Middle School, Colorado Springs, CO
Shaun Taylor, Videodiscovery, Seattle, WA
Mike Trush, Johns Hopkins University Bloomberg School of Public Health, Baltimore, MD

Artists
Susan Bartel
Lisa Chilberg

Cover Design
Martha Blalock, Medical Arts and Photography Branch, National Institutes of Health

Design and Layout
Angela Greenwalt, Finer Points Productions
Kyle McKibbin, Graphic Prints, Inc. (2012 edition)

Photo Credits
Michael Bade
Carlye Calvin

BSCS Administrative Staff
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Janet Carlson Powell, Associate Director, Chief Science Education Officer
Larry Satkowiak, Associate Director, Chief Operating Officer

Videodiscovery, Inc. Administrative Staff
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Shaun Taylor, Vice President for Product Development

National Institutes of Health
Allen Dearry, National Institute of Environmental Health Sciences (NIEHS)
Bruce Fuchs, Office of Science Education (OSE)
William Mowczko, OSE
Liam O'Fallon, NIEHS
Gloria Seelman, OSE
Frederick Tyson, NIEHS

Field-test Teachers
Bernard Bastick, Beckley-Stratton Junior High School, Beckley, WV
Joey Beckett, Beckley-Stratton Junior High School, Beckley, WV
Louisa Bliss, Gilman Middle School, Gilman, VT
Alice Cook, Moundsville Junior High School, Moundsville, WV
Cassie Cox, Moundsville Junior High School, Moundsville, WV
Rose DiCenso, Sabin Middle School, Colorado Springs, CO
Anthony DiSipio, Jr., Octorara Middle School, Atglen, PA
Claireen Espinoza, Taos Day School, Taos, NM
Anna Kong, Stone Academy, Chicago, IL
Susan Long, Frankfort Middle School, Ridgeley, WV
Greg Nichols, New Options Middle School, Seattle, WA
Josina Romero O'Connell, Challenger Middle School, Colorado Springs, CO
Barrington Ross, Shepard Magnet Middle School, Durham, NC
Jan Ryan, Brandeis Hillel Day School, San Francisco, CA
Mehar Safvi, Shepard Magnet Middle School, Durham, NC
Gina Ward, North Layton Junior High School, Layton, UT

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Please contact NIH with questions about this supplement at *supplements@science.education.nih.gov*.

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Foreword

This curriculum supplement, from *The NIH Curriculum Supplement Series*, brings cutting-edge medical science and basic research discoveries from the laboratories of 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. NIH's Office of Science Education (OSE) is dedicated to promoting scientific literacy and the knowledge and skills we need to secure a healthy future for all.

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* (released by the National Academy of Sciences in 1996). It was developed and tested by a team of teachers, scientists, medical experts, and other professionals with relevant subject-area expertise from institutes and medical schools across the country, representatives from the National Institute of Environmental Health Sciences, and curriculum design experts from Biological Sciences Curriculum Study (BSCS) and Videodiscovery, Inc. The authors incorporated real scientific data and actual case studies into classroom activities. A three-year development process included geographically dispersed field tests by teachers and students. For the 2012 edition, key sections of the supplement were updated, but the Student Lessons remain basically the same.

The curriculum supplements enable teachers to facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements include a conceptual flow of lessons based on the BSCS 5E Instructional Model, 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 of our curriculum supplements comes with a complete set of materials for teachers and students, including extensive background and resource information, detailed lesson plans, masters for student worksheets, and a Web site with videos, interactive activities, updates, and corrections (as needed). The supplements are distributed at no cost to educators across the United States upon request. They may be copied for classroom use but may not be sold.

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

We appreciate the valuable contributions of the talented staff at BSCS and Videodiscovery, Inc. 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 materials are both engaging and effective.

I hope you find our series a valuable addition to your classroom and wish you a productive school year.

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

About the National Institutes of Health

Founded in 1887, NIH is the federal focal point for health research in the United States. Today, NIH is one of the agencies within 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 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 was one such education effort. It is a collaboration among the National Institute of Environmental Health Sciences, the NIH Office of Science Education, Biological Sciences Curriculum Study, and Videodiscovery, Inc.

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

About the National Institute of Environmental Health Sciences

The National Institute of Environmental Health Sciences (NIEHS) is one of 27 institutes and centers of the National Institutes of Health (NIH). The mission of NIEHS is to reduce the burden of human illness and disability by understanding how the environment influences the development and progression of human disease. Headquartered in Research Triangle Park, North Carolina, NIEHS supports environmental health research at universities, independent laboratories, and centers throughout the United States.

NIEHS is unique within NIH because its primary focus is on the public health impact of environmental exposures, rather than on one or two specific organs such as the heart or liver and finding ways to treat illnesses people already have. Promoting public health and preventing disease is one of the most important services the government can provide to its citizens. Protecting people from avoidable illness and death spares suffering, saves money, and improves the quality of life for society as a whole.

NIEHS provides the sound scientific foundation for defining the health effects of a broad array of environmental agents. Translating these findings into effective public health and prevention strategies requires that NIEHS communicate its discoveries to federal regulatory agencies such as the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA), as well as to public health agencies such as the Centers for Disease Control and Prevention (CDC). These organizations, in turn, use this information to calculate new standards to protect health and communicate public health messages to the public. This information is also the scientific basis for many laws passed by Congress to protect the nation's health.

The most effective way to promote public health and prevent disease and disability is to understand the cause of an illness and change the conditions that allow it to occur. NIEHS takes a holistic approach to health, viewing it as an integrated response of all organ systems of the body to the environment. A key strategy for preventing many diseases or minimizing their effects is to eliminate or reduce exposures to chemicals and other toxic agents in our environment, especially our food, water, and air. To help reduce exposure to these agents, NIEHS supports environmental public health activities that increase public awareness about the nature of the chemicals and how they may affect our health and that empower communities to take action to manage environmental health issues.

Environmental public health is defined as the science of conducting and translating research into action to address environmental exposures and health risks of concern to the public. NIEHS recognizes the importance of working in partnership with community groups to address their environmental health concerns. The institute supports programs that build the capacity of community groups and researchers to work together, advance environmental health literacy, increase awareness of environmental health concepts, and engage community residents as partners in the research process.

NIEHS supports environmental public health activities through

- Grants to support university-community partnerships that address local environmental health issues.
- Outreach activities NIEHS requires of academic research institutes it supports.
- Communication tools such as the science journal *Environmental Health Perspectives*.

Research areas of special interest to NIEHS are environmentally related diseases and disorders such as cancer, asthma, Alzheimer's disease, autism, and the potential effects on human health of endocrine disruptors, metals, pesticides,

nanotechnology, and climate change. To fully understand these diseases and conditions, environmental health research must examine the interface of exposure, genetic susceptibility, and time and duration of exposure.

NIEHS has a vested interest in developing and training the next generation of diverse environmental health scientists who will be needed to solve the complex problems mentioned above. The *Chemicals, the Environment, and You* curriculum is just one example of NIEHS's efforts to improve science education and literacy, increase the nation's understanding of the role of the environment in disease, empower teachers and other communicators to translate science, and provide the most current and credible information on environmental health science.

For more information see

NIEHS Science Education:
http://www.niehs.nih.gov/health/scied/index.cfm

***Environmental Health Perspectives* Science Education:**
http://ehp03.niehs.nih.gov/static/scied.action

Summers of Discovery:
http://www.niehs.nih.gov/careers/research/summers/index.cfm

NIEHS Web site:
http://*www.niehs.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 *Chemicals, the Environment, and You*

What Are the Objectives of the Module?

Chemicals, the Environment, and You has several objectives. The first is to help students understand major concepts that describe the relationship between chemicals in the environment and human health. By focusing on the science of toxicology, the module seeks to introduce students to the ways scientists learn about and measure how chemicals can both help and harm human health.

The second objective is to convey to students the ever-changing nature of our understanding of the influence of chemicals on the health of living organisms. For example, with each introduction of a new synthetic chemical, researchers must learn at what dose and by what route of exposure the chemical might be hazardous to human health. New data have informed people of the dangers of lead in paint and the disease implications of breathing secondhand smoke. Our increasing knowledge about the effects chemicals can have on the human body enables us to make choices to limit our exposure to some chemicals while using other chemicals in ways that improve the quality of our lives.

Science plays an important role in assisting individuals as they make choices about enhancing personal and public welfare. In this module, students see that science provides evidence that can be used to support ways of understanding and treating human disease. Because the mission of the National Institute of Environmental Health Sciences is to reduce human illness from environmental causes, the institute believes that education provides one context in which it can fulfill its mission. The lessons in this module encourage students to think about the relationships among knowledge, choice, behavior, and enhanced human health in this way:

Knowledge (what is known and not known)
+ Choice = Power
Power + Behavior = Enhanced Human Health
(that is, personal and public health)

An additional 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 science classes offer the perfect opportunity to integrate many areas of student interest. In this module, students participate in activities that integrate inquiry science, environmental studies, human health, history, decision-making concepts, and mathematics. The real-life context of the module's lessons is engaging for students, and the knowledge gained by participating in the module can be applied immediately to students' lives.

"The activities provided actual real-life occurrences that students could relate to."
—Field-test Teacher

"The lab made me think about medicines and what dose I should take."
—Field-test Student

What's in It for the Teacher?

Chemicals, the Environment, and You meets many of the criteria used to assess teachers and their programs.

- 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.**
- As described above, it is an **integrated** module, drawing most heavily from the subjects of science, history, mathematics, and health.
- The module has an online **technology component** that includes mini-documentaries, laboratory information and data tables, and interactive activities.
- Finally, the module includes built-in **assessment** tools indicated by an assessment icon in each lesson.

In addition, the module provides a means for **professional development**. Teachers can engage in new and different teaching practices like those described in this module without completely overhauling their entire yearlong program. In *Designing Professional Development for Teachers of Science and Mathematics (1)*, Susan Loucks-Horsley *et al.* write that replacement modules such as *Chemicals, the Environment, and You* 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 unit 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 a replacement unit like this one can encourage reflection and discussion and stimulate teachers to improve their practices by focusing on student learning through inquiry.

Table 1 correlates topics often included in the middle school curriculum with the lessons in this module. This information is presented to help teachers make decisions about incorporating this material into the curriculum.

Table 1. Correlation of *Chemicals, the Environment, and You* to middle school topics.

Topics	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6
Chemical composition of all matter	•					
Chemicals in the environment	•	•			•	•
Human health and medicine	•			•	•	•
Individual variation/susceptibility			•	•	•	•
Risk assessment and management		•			•	•
Scientific methods		•	•	•		

Implementing the Module

The six lessons in this module are designed to be taught either in sequence for two or more weeks (as a replacement for a part of the standard curriculum) or as individual lessons that support or enhance your treatment of specific concepts in middle school science. The following pages offer 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?

Chemicals, the Environment, and You is designed to help students develop the following major goals associated with scientific literacy:

- to understand a set of basic scientific principles related to chemicals, human health, and the study of toxicology;
- 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 science and human health.

What Are the Science Concepts and How Are They Connected?

We have organized the lessons to form a conceptual whole that moves students from an introduction to chemicals and toxicology (*Chemicals, Chemicals, Everywhere*), to an investigation of the effect of various doses of chemicals on seed germination (*The Dose Makes the Poison*), to a discussion of the relationship between dose and response that can be represented by a dose-response curve (*Dose-Response Relationships*). Once students have experienced the process of toxicology testing, they discuss how individual responses to chemicals can vary (*Individual Responses Can Be Different*), and how knowledge about chemicals can be used to assess and manage risk from chemical exposure (*What Is the Risk?*). Finally, students consider how their understanding of how chemicals can affect human health can help them make decisions related to personal and public health (*Environmental Hazards*).

Table 2 summarizes the sequence of major concepts addressed by the six lessons.

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

Chemicals, the Environment, and You 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 module 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. Table 3 lists the specific content standards this module addresses (page 5).

Teaching Standards

The suggested teaching strategies in all the lessons support teachers as they work to meet the teaching standards outlined in the *National Science Education Standards*. The 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 *Conceptual Flow of the Lessons* (Table 2) and the *Suggested Timeline* (Table 8) for teaching the module. Teachers can use this module to update their curriculum in response to their students' interest in this topic. The focus on active, collaborative, and inquiry-based learning in the lessons helps teachers support the development of student understanding and nurture a community of science learners.

The structure of the lessons in this module 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. The use of the 5E Instructional Model combined with active, collaborative learning allows teachers to respond effectively to the diversity of student backgrounds and learning styles. The module is fully annotated, with suggestions for how teachers

Table 2. Conceptual flow of the lessons.

Lesson	Learning Focus	Major Concept
Lesson 1 *Chemicals, Chemicals, Everywhere*	Engage: Students express prior knowledge and become engaged in the study of toxicology.	Everything in the environment is made of chemicals. Both naturally occurring and synthetic substances are chemical in nature. People are exposed to chemicals by eating or swallowing them, breathing them, or absorbing them through the skin or mucosa, and they can protect themselves from harmful chemicals by blocking these routes of exposure.
Lesson 2 *The Dose Makes the Poison*	Explore: Students explore the response seeds have to different doses of chemicals. The Explore phase gives students a common set of experiences upon which to begin building conceptual understanding.	The total amount of chemical that is administered to, or taken by, an organism is called a dose, and the effect a chemical has on a living organism is called the response. The effect a chemical has on a living organism is related to dose and the resultant concentration of the chemical in the organism. Toxicity tests enable toxicologists to learn about responses of living organisms to doses of chemicals.
Lesson 3 *Dose-Response Relationships*	Explain: Students express their conceptual understanding of the laboratory investigation in their own words and using graphs.	Dose and response are related and can be represented by a dose-response curve. Data from toxicology testing can be represented by a dose-response curve, from which scientists can describe the threshold and potency of chemicals.
Lesson 4 *Individual Responses Can Be Different*	Explain/Elaborate: Students broaden their conceptual understanding and apply what they have learned in a new context.	The variety of responses among organisms that get the same dose of chemical is due to individual susceptibility. Dose and individual susceptibility play roles in all situations involving chemicals, including those involving medicines and caffeine.
Lesson 5 *What Is the Risk?*	Elaborate: Students extend the module's concepts in a different activity to help them apply scientific terms and concepts in appropriate ways.	People can make some choices about chemical exposure; however, some exposure is controlled at a level other than an individual one. Collective groups of people, such as communities and governments, seek to control chemical exposure on a community or global level.
Lesson 6 *Environmental Hazards*	Evaluate: Students demonstrate their understanding of concepts and performance of skills.	People can use their understanding of the science of toxicology to identify potential sources of harm to human health from chemicals in the environment. They can use their knowledge to propose possible means to eliminate or reduce exposure to environmental toxic agents.

Table 3. Content Standards: Grades 5–8.

Standard A: As a result of activities in grades 5–8, all students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry.	**Correlation to *Chemicals, the Environment, and You***
• Design and conduct a scientific investigation.	Lessons 2, 4
• Use appropriate tools and techniques to gather, analyze, and interpret data.	Lessons 2, 3, 4
• Develop descriptions, explanations, predictions, and models using evidence.	Lessons 2, 3, 4, 6
• Think critically and logically to make the relationships between evidence and explanations.	Lessons 3, 4, 6
• Communicate scientific procedures and explanations.	Lesson 3
• Use mathematics in all aspects of scientific inquiry.	Lessons 2, 3, 4
• Develop understandings about scientific inquiry.	Lessons 2, 4, 6
Standard B: As a result of their activities in grades 5–8, all students should develop an understanding of properties of matter.	**Correlation to module**
• There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances we encounter.	Lesson 1
Standard E: As a result of their activities in grades 5–8, all students should develop understandings about science and technology.	**Correlation to module**
• Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance.	Lessons 1, 5
• Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.	Lessons 1, 4, 5
Standard F: As a result of their activities in grades 5–8, all students should develop an understanding of	**Correlation to module**
• personal health	Lessons 4, 5, 6
• natural hazards	Lessons 1, 5, 6
• risks and benefits	Lessons 1, 5, 6
Standard G: As a result of their activities in grades 5–8, all students should develop an understanding of the history and nature of science.	**Correlation to module**
• Understand science as a human endeavor.	All lessons
• Understand the nature of science.	All lessons
• Understand the history of science.	Lesson 5

can encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.

Assessment Standards

Teachers can engage in ongoing assessment of their teaching and of student learning using the variety of assessment components embedded within the module's structure. The assessment tasks are authentic: They are similar in form to tasks in which students will engage in their lives outside the classroom or in which scientists participate. Annotations guide teachers to these opportunities for assessment and provide answers to questions that can help teachers analyze student feedback.

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

Because learning does not occur through a process 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 understandings. 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 they can when they work alone in a competitive environment. When all this active, collaborative learning is directed toward inquiry science, students succeed in making their own discoveries. They ask questions, observe, analyze, explain, draw conclusions, and ask new questions. These inquiry experiences include both those that involve students in direct experimentation and those in which students develop explanations through critical and logical thinking.

This view of students as active thinkers who construct their own understanding out of 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 model sequences the learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model takes students through five phases of learning that are easily described using five words that begin with the letter "E": Engage, Explore, Explain, Elaborate, and Evaluate. The following paragraphs illustrate how the 5Es 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 what they think they know about the topic and concepts to be developed.

The Engage lesson in this module, Lesson 1: *Chemicals, Chemicals, Everywhere*, is designed to

- pique students' curiosity and generate interest,
- determine students' current understanding of the concepts of chemicals and routes of exposure,
- invite students to raise their own questions about chemicals and human health,
- encourage students to compare their ideas with the ideas of others, and
- allow 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: *The Dose Make the Poison,* students explore the effect different doses of chemicals have on seed germination. This lesson provides a common set of experiences within which students can compare what they think about what they are observing and experiencing.

During the Explore lesson, students

- interact with materials and ideas during the seed investigation;
- consider different ways to solve a problem or answer a question;
- acquire a common set of experiences with their classmates so they can compare results and ideas;
- observe, describe, record, compare, and share their ideas and experiences; and
- express their developing understanding of the effects of chemicals on seed germination orally and by making graphs.

Explain

The Explain lesson provides opportunities for students to connect their previous experiences and to begin 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 and explain.

In the Explain lessons in this module, Lesson 3: *Dose-Response Relationships* and Lesson 4: *Individual Responses Can Be Different*, students

- explain concepts and ideas about their seed investigations in their own words;
- listen to and compare others' explanations of their results 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 to describe dose-response relationships;
- compare their current thinking with what they previously thought; and
- compare their ideas with what scientists know and understand about toxicology testing and the application of the results to human systems.

Elaborate

In Elaborate lessons, students apply or extend the concepts in new situations and relate their previous experiences to new ones.

In the Elaborate lessons in this module, part of Lesson 4: *Individual Responses Can Be Different* and Lesson 5: *What Is the Risk?*, students

- make conceptual connections between new and former experiences, particularly with respect to the dose of medicine they take and the effect of the caffeine they drink;
- use what they have learned to explain the acetaminophen mystery and the tragedy that happened in Minamata, Japan;
- connect ideas, solve problems, and apply their understanding in these new situations;
- use scientific terms and descriptions;
- draw reasonable conclusions from evidence and data;
- add depth to their understanding of concepts and processes; and
- communicate their understanding to others.

Evaluate

The Evaluate lesson 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 model, as described in the following section. Combined with the students' written work and performance of tasks throughout the module, however, the Evaluate lesson can serve as a summative assessment of what students know and can do.

The Evaluate lesson in this module, Lesson 6: *Environmental Hazards,* provides opportunities for students to

- demonstrate what they understand about the concepts of toxicology and how well they can