Hydroville, USA

CONTENTS

ACKNOWLEDGMENTS

PESTICIDE SPILL SCENARIO

Hydroville Curriculum Project

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The overall goal of the Environmental Health Sciences (EHS) Center Community Outreach and Education Program (COEP) is to increase the public's ability to understand and to make informed decisions on issues relevant to the role of environmental factors in human health and disease. The COEP also strives to develop an understanding among the public about environmental health science research and its importance in assessing risks to human health, as well as to translate the research of the Center into knowledge applied to public health. Through community outreach and education, the Center seeks to increase the publics' awareness of the resources of the NIEHS in general and the EHS Center, specifically. To achieve these goals, the COEP enlists expertise of EHS Center investigators and actively collaborates with existing outreach programs, university affiliates, community organizations, and other NIEHS Center COEPs.

Disclaimer

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HYDROVILLE
PROJECT OVERVIEW

HYDROVILLE PROJECT OVERVIEW

Background

In September 2000, the National Institute of Environmental Health Sciences (NIEHS) awarded a 7-year grant to the Environmental Health Sciences Center at Oregon State University. This grant, titled “Learning Through Environmental Health Scenarios,” was used to create the Hydroville Curriculum Project. The Hydroville Curriculum Project seeks to improve high school students’ academic performance and stimulate interest in problem-solving, environmental health science, decision-making, team work, and social responsibility. The curricula use environmental health topics to enhance connections between science, language arts, math, social studies, health, and technology.

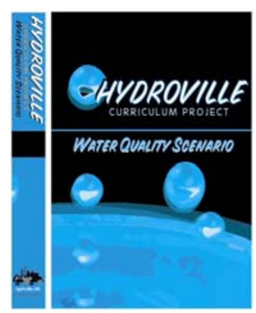
Introduction

The project has developed three curricula, each dealing with a real-life problem using real-life data. The town of Hydroville, which could be a town anywhere in America, is experiencing one of three environmental health problems: a pesticide spill, an indoor air quality problem, and a water quality problem.

Pesticide Spill

Indoor Air Quality

Water Quality



Students participate in a series of background activities to develop specific concepts and skills. Students then assume the roles of experts on a team brought in to solve the environmental health problem. As a team, they must develop and formally present a solution based on data collected through laboratory experiments, interviews, research, and interaction with experts. The curricula are structured to help students understand the complexity of environmental health issues and to emphasize that many real-world issues have many acceptable answers.

Meeting National Educational Standards

The Hydroville Curricula integrate environmental health science themes of toxicology, risk, and decision analysis with concepts in science, language arts, social studies, mathematics, technology, and health. Emphasized skills common for all these disciplines are problem solving, reading, evaluating, analyzing, calculating, writing, graphing, communicating, and teamwork. The principal standard that is covered in depth by these curricula is the science standard Science as Inquiry.

Science as Inquiry Standard

The Hydroville Curricula use real-life problems to help students master the seven abilities necessary to do science inquiry (Table 1). Research results have shown that through their immersion in the Hydroville problems, students begin to think more like scientists. They formulate hypotheses, use data from investigations to support or modify those hypotheses, and develop skills in communicating their findings to diverse audiences. Students take more responsibility for their own learning and have used these inquiry skills to design and continue research on local problems related to the Hydroville topic. Teachers using the curricula repeatedly site the development of inquiry skills as one of the major strengths and advantages of teaching the quarter-long Hydroville Curricula.

Table 1. Abilities Necessary to Do Scientific Research[1]

Identify questions and concepts that guide scientific investigations
Design and conduct scientific investigations
Use technology and mathematics to improve investigations and communications
Formulate and revise scientific explanations and models using logic and evidence
Recognize and analyze alternative explanations and models
Communicate and defend a scientific argument
Understandings about scientific inquiry

[1]*National Science Education Standards*. National Academy of Science. 1996.

Hydroville Curriculum Framework

The Hydroville Curricula have been developed around a carefully designed learning framework that reflects how scientists and experts solve real-world problems. This framework models the scientific method and widely used problem-based learning models (Table 2).

1. **Define the problem**: Students are introduced to an environmental health problem in Hydroville by watching a video that provides facts and background information.
2. **Collect data**: Students complete background activities to learn the concepts necessary to understand the problem and develop skills that environmental health experts use in the real world.
3. **Analyze data**: Students form teams of experts to investigate the problem, test, analyze data, and propose and test hypotheses.
4. **Synthesize data and generate solutions**: Student experts share data, revise their hypotheses, and develop an action plan to address the problem.
5. **Present solutions**: Student teams develop presentations within the context of the scenario and present their findings to the problem's stakeholders.

Table 2. Comparison of the Hydroville Curriculum Framework with Other Problem-based Learning Models

Steps	HCP Curriculum Framework	Problem-Based Learning Model[1]	Scientific Method[2]
1	• Define the problem	• Meet the problem	• Define problem
2	• Collect data • Develop hypothesis(es)	• KNK (know, need to know) • Define problem statement	• Derive hypothesis(es) • Review the literature
3	• Collect and analyze data to test hypothesis(es)	• Gather and share information	• Test hypothesis • Decide on a procedure • Develop methodology • Data collection and analysis
4	• Synthesize data • Generate solutions • Develop action plan	• Generate possible solutions • Evaluate fit of solutions	• Derive conclusion • Interpret results
5	• Present solutions	• Present findings	• Disseminate findings

[1] Problem-based learning model. Center for Problem-Based Learning, Illinois Mathematics and Science Academy, 1998–2001. http//www.imsa.edu/team/cpbl/whatis/model.html
[2] Scientific method. http//www.selu.edu/Academics/Education/EDF 600/mod3/sld003htm

Strengths of Hydroville Curricula

Research results from quantitative and qualitative data collected during field testing show that Hydroville Curricula:

- teach inquiry as a process rather than a subject to be learned, resulting in students that think more like scientists when approaching a problem
- develop higher-order and critical thinking skills
- teach group process and team-building skills as an integral part of every activity
- stress written and oral communication
- create an environment where students take responsibility and become self-directed learners

Embedded in the Hydroville curricular framework are content knowledge and skill development that create enduring understandings that students translate to other courses and their personal lives (Figure 1).

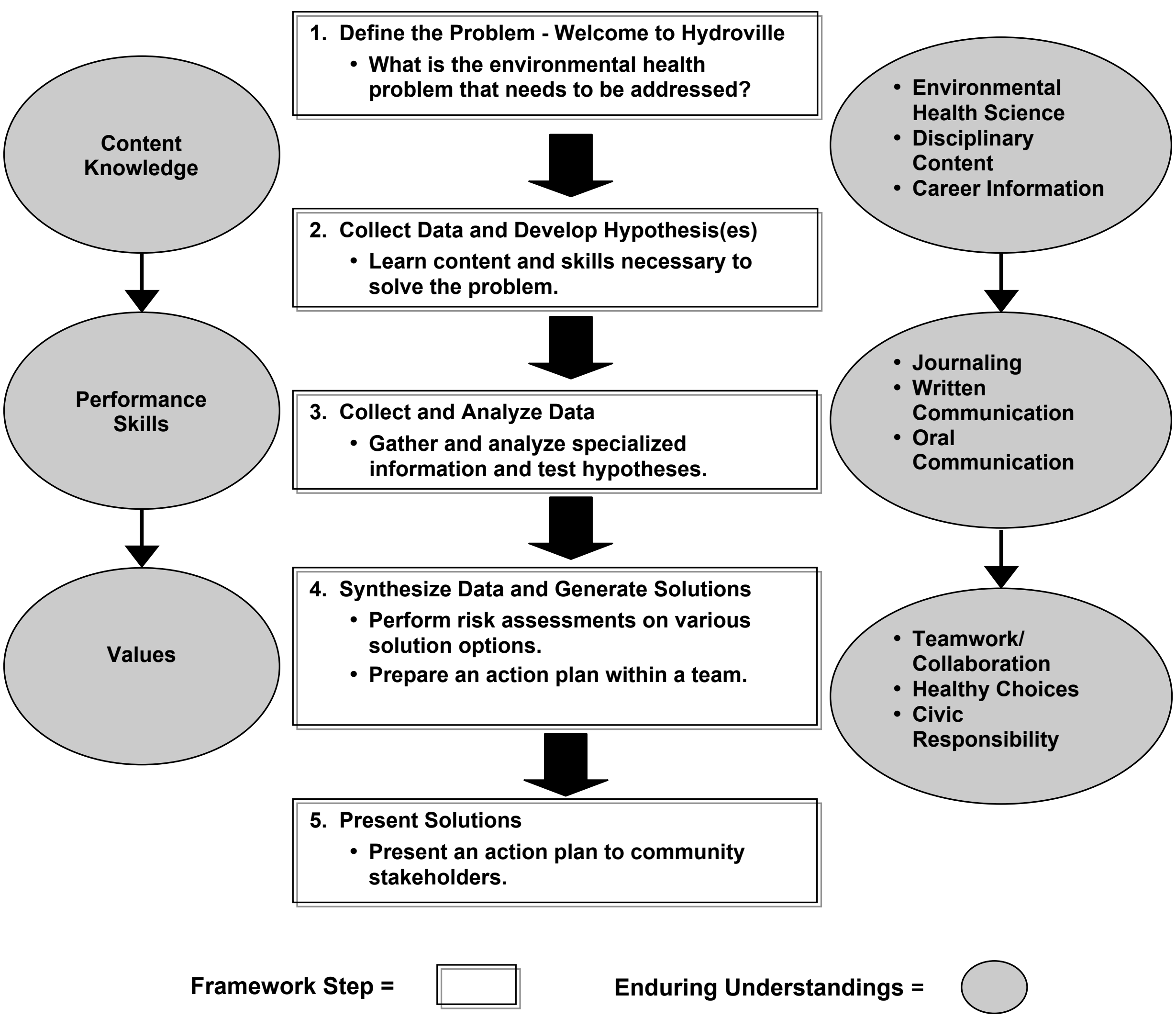


Figure 1. Hydroville Curriculum Framework and Enduring Understandings

Curricula Logistics

Grade Levels

The Hydroville Curricula are designed primarily for students in the 9th and 10th grades. They are also appropriate for use in alternative or charter schools; for 11th- and 12th-grade electives in biology, chemistry, and environmental science; or in programs for at-risk or gifted students. Additionally, many of the activities can be modified for advanced middle-school students. The Pesticide Spill and Water Quality scenarios are recommended for 9th-grade integrated or physical science classes. The Indoor Air Quality Scenario is recommended for 10th-grade biology.

Teaching Teams

Ideally, these curricula should be taught collaboratively by a team of teachers in science, language arts, social studies, math, and health who are interested in integrating across disciplines. Working in teams allows teachers to share in the preparation and implementation. However, a science teacher can use the Hydroville Curricula independently.

Time Requirements

The Hydroville Curricula were developed on the belief that students cannot be successful if they are thrust into a problem-based learning situation without sufficient preparation. Therefore, they require 9 weeks to complete. Specific time requirements are given in the Scope and Sequence section of each curriculum. The background activities can be used alone or integrated into existing lesson plans or state-mandated curricula.

The Hydroville curricula allow students to learn and develop enduring understandings of processes and skills necessary for success in all areas of their academic studies and their lives: problem solving, analysis and synthesis, group process, and written and oral communication.

SCOPE AND SEQUENCE

SCOPE AND SEQUENCE

Pesticide Spill Scenario

A tanker truck containing 20,000 gallons of chemical pesticide is traveling down a highway near Hydroville at 5:30 a.m. on a Tuesday in February. The truck hits a patch of black ice on a curve one-half mile south of Hydroville and overturns. Although shaken, the driver is not hurt and makes an emergency call to 911. In reporting the accident, he notes that pesticide is rapidly leaking onto the highway and into the adjoining drainage ditch. Local police and fire department HazMat (Hazardous Materials) teams are on the scene in 10 minutes. They quickly block off the area and reroute traffic.

The truck's manifest and placard identifies the liquid as *metam sodium*, a fumigant pesticide. Because this chemical is volatile and toxic, the HazMat team immediately dons protective clothing and tanked air. The drainage ditch is located close to Beaver Creek, one source of Hydroville's drinking water. Also, the wind is blowing from the east at 5 miles per hour. Should the wind shift, some of Hydroville's residential neighborhoods also may have to be evacuated. The insurance company for the trucking firm immediately calls a consulting company, Southerville EnviroClean, a team of experts specializing in hazardous materials removal.

Students involved in the Hydroville Pesticide Spill Scenario act as scientists and engineers that are the experts on the Southerville EnviroClean team. Their task is to remove the pesticide, evaluate the risk posed to the citizens of Hydroville, develop a remediation plan to clean up the site, and make a presentation about their proposal to an open meeting of the Hydroville Town Council.

Suggested Timing for the Pesticide Curriculum

This curriculum can be done in 6 weeks, but scheduling it in a 9-week quarter will give time for extensions and for the other normal school interruptions. It is an excellent culminating activity for the last quarter of the year after the required testing is finished.

Section	Number of 50-minute periods
Welcome to Hydroville	2
BACKGROUND ACTIVITIES	
1: Reading Household Labels	2
2: Toxicity Testing – Dose Makes the Poison	3
3: Pump It Up! Part I	2
4: Pump it Up! Part I	2–3
5: Constructing and Analyzing Graphs	1
6: Using Paper Chromatography	2
7: Soil Texture	1–2
8: Soil Permeability	1–2
9: Decision Analysis	1
10: Siting Yoretown's Landfill	2
PESTICIDE SPILL SCENARIO	
Data Collection	3–4
Data Analysis: Expert Groups	3
Data Synthesis	5
Solution Presentation	2–3
TOTAL	32–36

Alternative Sequence of Activities for the Single Science Teacher

Teachers who do not want to jigsaw the student teams into the Expert Groups and have four different activities going on in their classroom at the same time may want to reorder the activities. In this sequence of activities, the expert group activity follows right after the Background Activities that prepare the students for that expert group. All students in the class will do all the expert activities. What is lost with this arrangement is having one student in a group be the expert in a specific area and have the responsibility of providing her/his team with those parts of the solution. Students are empowered by being the only one on the team having specific information and must contribute to the team's success. That requirement (and often personal growth) is lost when everyone on the team participates in all the expert groups. But this order does simplify preparation and classroom management for the teacher and makes student absences less of an impact on the team.

Alternative Activity Order

	Activity	Pages
I.	Welcome to Hydroville	53–60
II	Data Collection	287–325
III	Data Analysis	
	Environmental Toxicologists Background Activity 1: Reading Household Product Labels Background Activity 2: Toxicity Testing Expert Group: Environmental Toxicologists	 63–85 89–115 335–358
	Mechanical Engineers Background Activity 3: Pump It Up!: Part I Background Activity 4: Pump It Up!: Part II Expert Group: Mechanical Engineers	 119–133 137–151 361–376
	Analytical Chemists Background Activity 5: Constructing and Analyzing Graphs Background Activity 6: Using Paper Chromatography Expert Group: Analytical Chemists	 155–171 175–194 379–429
	Soil Scientists Background Activity 7: Soil Texture Background Activity 8: Soil Permeability Expert Group: Soil Scientists	 197–220 223–239 433–460
IV	Data Synthesis Background Activity 9: Decision Analysis Background Activity 10: Siting Yoretown's Landfill Data Synthesis Activity	 243–257 261–283 463–485
V	Solution Presentation	489–499

Experts Enrich the Curriculum for Your Students

Inviting professional experts to work with your students can be rewarding for your students and for the experts. Professionals enjoy sharing their careers and their knowledge with students. Experts such as a soil scientist, engineer, chemist, toxicologist, or someone from a state or national environmental protection agency will enhance the learning for the students. They also help facilitate your job in guiding students to develop their remediation plan. In order to prepare the volunteer expert, supply him or her with the Scenario Fact Sheet, the fact sheet for their expert area, and the lesson plans for that expert group. Having professionals in your classroom can lead to long-term relationships with those professionals and their employers that may provide independent projects for your students or classes, and sources of funding for student and classroom projects.

Materials and Supplies

Required materials are listed at the beginning of each activity. Information for ordering all materials can be found in Appendix B. Hydroville Curricula have been designed to minimize the recurring cost for using the curriculum.

Background Activity Essential Skills

Each Background Activity has been developed to convey to students an essential skill or concept. There are often other common laboratory experiments with which the teacher is more familiar that teach the same essential skills. As the instructor, feel free to substitute activities that you commonly do with your classes for the Background Activities in the Pesticide Spill Scenario. Table 1 and each activity list the essential skills covered in that activity.

Table 1. Background Activities Essential Skills and Concepts

Background Activity	Essential Skill/Concept
1 Reading Household Product Labels	Recognizing signal words, routes of exposure, and understanding what makes a chemical hazardous
2 Toxicity Testing	Plotting and understanding dose-response curves
3 Pump It Up! Part I	How a piston pump works
4 Pump It Up! Part II	Applying principles of Boyle's law and piston pump mechanics to build a Supersoaker-type piston pump
5 Constructing and Analyzing Graphs	How standard graphs are derived, line of best fit, and applying standards to unknowns
6 Using Paper Chromatography	How molecules can be separated by their solubility in a solvent
7 Soil Texture	How to use the soil texture triangle to make a specific type of soil
8 Soil Permeability	How different soil mixtures differ in permeability
9 Decision Analysis	Developing a decision chart to analyze various elements of a decision
10 Siting Yoretown's Landfill	Using a decision chart for siting a city landfill

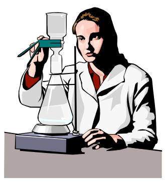
Pesticide Spill Concept Map

A concept map has been developed for each Hydroville Curriculum Project Scenario (see the *Pesticide Spill Concept Map* on the next page). The map is a very useful tool to share with students. It helps them see where they are in the process of working on the scenario. Every student should have a copy of the Cencept Map. Make a poster of the Concept Map and use it as you move through the five parts of the curriculum framework. Students see how the background activities relate directly to the expert work and the solution to the problem in Hydroville.

Pesticide Spill Scenario Concept Map

I. Problem Definition
- Hydroville Science Journal
- Teamwork Skills
- Welcome to Hydroville
- Background Activities

II. Data Collection
- 3-D model of spill site
- Hydroville Update
- Careers



ENVIRONMENTAL TOXICOLOGIST
Assess risk from pesticide

1. Reading Household Product Labels
2. Toxicity Testing

MECHANICAL ENGINEER
Design an effective pump

3. Pump It Up! *Part I*
4. Pump It Up! *Part II*

III. Data Analysis

Southerville EnviroClean

ANALYTICAL CHEMIST
Determine pesticide contamination

5. Constructing and Analyzing Graphs
6. Using Paper Chromatography

SOIL SCIENTIST
Determine soil permeability

7. Soil Texture
8. Soil Permeability

IV. Data Synthesis
Develop a Remediation Plan

9. Decision Analysis
10. Siting Yoretown's Landfill

V. Solution Presentation

Organization of Background Activities

Table 2: *Organization Structure for Background Activities* lists the organizational sections found in each Background Activity. All of the sections are in the same order for easy reference and use. The first part of each activity contains the *Teacher Section*. The Teacher Section begins with an overview of the activity: description, rationale, purpose/goals, prerequisites, time estimate, materials, etc. The pages that follow provide the teacher with background information, a suggested lesson plan, suggested assessment and extensions, and resources. The second half of each activity contains the *Student Section*, including student background information, instructions, and worksheets.

Table 2. Organization Structure for Background Activities

Teacher Section	
Description	A short description of the activity and of the essential skills and concepts developed in the activity
Rationale	An explanation of how the background activity develops the skills and content necessary to successfully complete the scenario
Purpose/Goals	A description of what students should be able to do when they finish the activity
Prerequisites	Student skills or previous activities required for the activity
Time Estimate	Time estimates for both teacher prep time and the actual student activity
Materials	A list of all the materials required for the activity; often listed for individual students or groups of three to four
Pages to Photocopy	All student pages that should be photocopied for use during the activity
Teamwork Skills	Recommended teamwork skills emphasized in each activity from the teamwork skills section of the curriculum
Terminology	List of key vocabulary terms introduced in the activity. Each term listed is defined in the glossary in Appendix C
Background Information	Resource and content information for teachers
Suggested Lesson Plan	The suggested lesson plan has three sections: *Getting Started*, *Doing the Activity*, and *Wrap-up*
Assessment	Examples of possible assessment questions or activities

Table 2 continued. Organization Structure for Background Activities

Teacher Section (continued)	
Extensions	Possible additional activities for science, math, language arts, and social studies
Resources	A list of sources for additional information from books, articles, videos, and the Web
Teacher Keys	Answer keys for student worksheets
Transparency	Transparencies for teacher's use
Student Section	
Instructions Readings	Student pages follow the teacher section; these pages include lab protocols, and background information
Worksheets	Student products used for assessment and stored in the Hydroville Science Journal

Appendices

Appendix A: Correlation of Activities to National Standards

This appendix contains tables showing the details for the correlations of each activity to the National Standards in science, mathematics, social studies, and language arts.

Appendix B: Materials List

Materials required are listed at the beginning of each activity. The complete list of materials and supplies is found in this appendix. Ordering information is provided for those items not readily available in several locations. Hydroville Curricula have been designed to minimize the recurring cost for using the curriculum.

Appendix C: Glossary

The Glossary contains definitions for all of the words found in the *Terminology* section of each activity.

Appendix D: Scoring Guide

A selection of scoring guides that can be used to evaluate student and team products. The list of scoring guides is found on the first page of the appendix.

Correlation of Background Activities with National Science Education Standards

1. Reading Household Product Labels

- Unifying concepts and processes: Systems, order, and organization
  Students should understand that household products are categorized according to degree of toxicity and ability to cause harm.
- Science in personal and social perspective: Personal and community health
  Students should recognize that they and members of their household make decisions that directly impact their health and potential for exposure to toxic products.
- Science in personal and social perspective: Natural and human-induced hazards
  Students should understand that both natural and man-made products can cause hazardous health effects.

2. Toxicity Testing – Dose Makes the Poison

- Science as inquiry: Abilities necessary to do scientific inquiry
  Students should recognize that charts, graphs, and measurements are important components of scientific inquiry.
- Science in personal and social perspective: Natural and human-induced hazards
  Students should understand that the use of chemicals presents the need to assess potential danger and risk through experiments assessing the dose-response.
- History and nature of science: Nature of scientific knowledge
  Students should realize that scientific knowledge is subject to change as new evidence becomes available.

3. Pump it Up! Part I – Analyzing Pumps

- Unifying concepts and processes: Evidence, models, and explanation
  Students should give evidence for their ideas about the function of each part of a piston pump.
- Unifying concepts and processes: Form and function
  Students should relate how the form of each part of the piston pump supports its function.
- Physical science: Motions and forces
  Students should understand that pressure is a force applied over a certain area. This force moves the water or air.

4. Pump it Up! Part II – Designing a Supersoaker

- Unifying concepts and processes: Evidence, models, and explanation
  Students should be able to use observations from operating the Supersoaker to develop a model of how a Supersoaker works.
- Unifying concepts and processes: Form and function
  Students should be able to identify how the form of the parts of their model contributes to the function of the model.
- Unifying concepts and processes: Systems, order, and organization
  Students should recognize that the Supersoaker is a system made up of various components that act together to make that system function.

5. Constructing and Analyzing Graphs— Circumference and Diameter

- Unifying concepts and processes: Change, constancy, and measurement
  Students should realize that although the objects are different sizes, the ratio of the circumference to the diameter of each object is a constant, known as pi, and that pi is a standard.
- Science as inquiry: Abilities necessary to do scientific inquiry
  Students should recognize that charts, graphs, and measurements are important components of scientific inquiry.

6. Using Paper Chromatography

- Unifying concepts and processes: Evidence, models, and explanation
  Students should use evidence gathered from the chromatograms to support their conclusions about which suspects can be excluded from suspicion based on evidence.
- Physical science: Structure and properties of matter
  Students should understand that the separation of dye molecules in chromatography is a physical property of the dye and movement of the dye is unique for each different dye molecule.
- Abilities necessary to do scientific inquiry: Communicate and defend a scientific argument
  Students should defend their conclusions about the dyes that were analyzed based on the evidence that they gathered.

7. Soil Texture

- Unifying concepts and processes: Evidence, models, and explanation
  Students should recognize that the test for soil texture is one way of collecting evidence about soils that can be used to explain how soils interact with things like water, air, and contaminants.

- Unifying concepts and processes: Systems, order, and organization
  Students should realize that the soil textural triangle is one way to organize soils that helps us understand the properties of soils.
- Physical sciences: Structure and properties of matter
  Students should recognize that the texture of the soil is a result of the physical properties of the clay and minerals in the soil.

8. Soil Permeability

- Physical science: Structure and properties of matter
  Students should understand that the permeability of the soil is a property that depends on the physical and chemical properties of the components of the soil.

9. Decision Analysis

- Science in personal and social perspectives: Personal and community health
  Students should realize that personal choices concerning fitness and health involve a variety of factors that may include scientific evidence.
- History and nature of science: Science as a human endeavor
  Students should realize that scientists are influenced by society and personal beliefs that in turn influence the questions scientists try to answer and how they answer those questions.
- History and nature of science: Nature of scientific knowledge
  Students should realize that scientific knowledge is subject to change as new evidence becomes available.

10. Siting Yoretown's Landfill

- Unifying concepts and processes: Evidence, models, and explanation
  Students should use evidence gathered from the maps to support their conclusions about siting the landfill.
- Science in personal and social perspectives: Environmental quality
  Students should analyze the effects on environmental quality of the siting decisions that are made.
- Science in personal and social perspective: Natural and human-induced hazards
  Students should study the effects of the natural geology and human-made structures of a landfill on human health.
- Science in personal and social perspective: Science and technology in local, national, and global challenges
  Students should understand that science and technology could be used to reduce the environmental effects of a hazard such as a landfill.

HYDROVILLE SCIENCE JOURNAL

HYDROVILLE SCIENCE JOURNAL

HYDROVILLE SCIENCE JOURNAL

Description:

The Hydroville Science Journal is central to the Hydroville Curriculum Project.

As team members and experts-in-training, students will write in the Hydroville Science Journal to track specific threads of the material and facilitate their own learning as they encounter new skills, new terms, and new challenges. Each background activity helps students develop skills and knowledge for the scenario. Therefore, students will be writing, documenting, and synthesizing materials that will prepare them to act as expert decision makers. The Hydroville Science Journal gives each student a place to record responses to journal prompts and questions, definitions of terminology, notes to reflect on teamwork skills, and to apply, reflect, analyze, and evaluate information. In other words, the Hydroville Science Journal prepares students for solving the problem, launching them into action as expert decision makers.

Experts such as scientists, engineers, and others in technological fields must learn to analyze and synthesize information, grasp new concepts, be able to apply them, and communicate effectively. The Hydroville Science Journal provides a place for students to assemble and order key pieces of information, store their notes, answer guided questions, and explore their own thinking.

Purpose/Goals:

Students will be able to:

- organize a notebook to record information and save worksheets completed during the Background Activities, Expert Groups, etc.
- use the information in the science journal to analyze and synthesize data, construct hypotheses, and organize materials for the presentation of their team's solution presentation

Prerequisites:

None

Time Estimate:

This activity is designed to accompany *Welcome to Hydroville*.

Prep: If you plan to provide the class with sets of notebooks, there is a one-time expenditure of about 2 hours to organize and label notebooks.

Activity: One half of a 50-minute class period for students to organize notebooks that you provide, or you may have the students create their Hydroville Science Journals as a homework assignment.

Materials:

Each Student:

- ☐ Three-ring binder with six dividers
- ☐ Notebook paper

Pages to Photocopy:

One 3-hole punched copy per student:

- Worksheet: *Checklist for Hydroville Science Journal*

Background Information:

Writing in the Hydroville Science Journal Supports Learning

Writing in the Hydroville Science Journal provides a place for students to test their understanding, and to question and challenge their own assumptions. It is the *raw material* of thought – their record of data, events, information, and reflection.

As a teacher, feel free to structure the Hydroville Science Journal and the writing to the academic needs and styles of your students. The more regularly students write in their journals, the more effective the process will be. Student writing mimics scientific journaling, with students keeping a daily record of observations, measurements, hypotheses, and conclusions.

Journal writing is a useful means of pre-assessing students' knowledge of a particular subject or concept. Giving students a writing prompt at the beginning of the class period is a particularly useful time to pre-assess students. Likewise, concluding class with a prompt allows students to reflect upon what they have learned, what they are still unclear about, and to generate questions for further inquiry.

Through the close integration of skill-building, reading, recording, writing, and thinking, students will become more aware of their own writing and thinking processes. The Hydroville Science Journal promotes critical thinking skills, preparing students for their roles as experts and decision makers.

Source:

Bloom, B.S. (Ed.) (1956) *Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain*. New York; Toronto: Longmans, Green.

Suggested Lesson Plan:

Getting Started

1. If you are providing notebooks:
   - Put the *Checklist for Hydroville Science Journal* in the front.
   - Insert six dividers labeled: Journal Prompts, Background Activities, Data Collection and Analysis, Data Synthesis and Solution Presentation, Teamwork Skills, and Glossary.
   - Number the spine of the notebooks with period and notebook number.
   - Designate a bookshelf or cupboard in your classroom to store notebooks.
   - **Note**: An inexpensive science journal can be made by folding 8.5 x 11-inch pieces of paper in half and stapling down the fold. The downside of this journal is that it cannot store handouts and worksheets
2. Have the students create their Hydroville Science Journals either as a homework assignment or at the beginning of the unit.
3. There are three options for handling the Hydroville Science Journal pages:
   - You have the option of handing out the student worksheets one activity at a time. Students can use notebook paper for their Journal Prompts and Glossary entries.
   - To organize the Pesticide Spill unit at the beginning, you can print out the entire Hydroville Science Journal from the file on the Teacher Resource CD. Photocopy the number you need for each class and place the pages in file folders for distribution by activity.
   - You can photocopy the Hydroville Science Journal pages as a whole from the Teacher Resource CD and give students all the pages for their notebooks at the beginning of the unit. Then students fill the pages in as required.

4. Teachers using the Hydroville Curriculum often begin each day with a journal prompt. Students enter class, pick up their journals, and work on the prompt that is on the board or an overhead, allowing the teacher to take roll, deal with individual students, etc.

Doing the Activity

1. On the first day of "Welcome to Hydroville," students set up and organize their journals.
2. Class can begin by students picking up their journals and writing their answers to daily journal prompts as the teacher takes care of beginning-of-class duties.

Wrap-up

At the conclusion of this curriculum unit, the student's journal will represent an individual's experience, observations, information, and perspectives. It functions as a resource for numerous social studies and language arts assignments. It stands as the student's portfolio for the project: a record of the event, and a site for further inquiry and assessment.

Assessment

The primary means of assessment for the Hydroville Science Journal should be formative. Formative assessment is an informal means of assessment conducted as a part of the instructional process. Assessing students' writing formatively does not involve giving students a final grade; therefore, the students' writing in the Hydroville Science Journal should *not* be thought of as a final measure of what was learned.

A sample grading checklist for the Hydroville Science Journal can be used by students to help organize their journals and by teachers for grading of the journal when submitted by students as their portfolios for the curriculum. See Worksheet: *Checklist for Hydroville Science Journal.*

A formative assessment method that provides students the feedback they need, and which allows teachers a means of assessment that is efficient, is the check/check-plus/check-minus system:

Grade/Mark	Level of Thinking
✔– (check-minus)	• Consistently inadequate responses to writing prompts • Thinking does not reflect attempts to draw connections
✔ (check)	• Consistently adequate responses to writing prompts • Thinking is oftentimes more than superficial and reflects genuine attempt to write coherently about the subject at hand
✔+ (check-plus)	• Writing quality and quantity is above average • Continually attempts to draw connections and to extend and apply their written thoughts to more than just the topic at hand

Assessment Example:

Journal Prompt: What is the definition of *environmental health science*? Why is it important to study this topic? Why should people who make laws understand about this science?

Assessment	Student Answer
✔– (check-minus)	The health of the environment is important for understanding diseases.
✔ (check)	Environmental health science is the study of how the environment affects our health and it is important to study it to understand how air, water, and food can cause diseases.
✔+ (check-plus)	Environmental health science is the study of how the environment affects human health. It is important to study this topic to understand how the food, water and air around us can cause disease. Lawmakers need to understand environmental health science to set appropriate limits on what is in our water, air and food.

Checklist for Hydroville Science Journal

Journal Section	Document Name	Grade
Divider 1 – Journal Prompts		
Record journal prompts by background activity and date.		
Divider 2 – Background Activities		
Welcome to Hydroville	*Map of Hydroville*	
	Pesticide Spill Concept Map	
1. Reading Household Product Labels	R: *What Makes a Product Hazardous?*	
	W1: *Reading Hazardous Household Product Labels*	
	W2: *Hazardous Household Products Inventory*	
	W3: *Writing a Memo: Results of a Hazardous Household Product Inventory* (optional)	
2. Toxicity Testing – Dose Makes the Poison	R: *Toxicology – The Dose Makes the Poison*	
	I1: *Chemical Dilution Setup*	
	I2: *Toxicity Testing on Seeds*	
	W1: *Toxicity Testing on Seeds Lab Report*	
	W2: *Student Assessment*	
3. Pump It Up! – I. Analyzing Pumps	W1: *A Squirt Gun Dissection*	
	W1a: *A Hand Pump Dissection*	
	W2: *How Does a Squirt Gun Work?*	
4. Pump It Up!- II. Designing a Super Soaker	W: *Designing a Super Soaker Model*	
5. Constructing and Analyzing Graphs	W1: *Constructing and Analyzing Graphs*	
	W2: *Scored Classroom Assignment: Mathematics* (optional)	
6. Using Paper Chromatography	I: *Using Paper Chromatography*	
	W1: *Paper Chromatograms*	
	W2: *Paper Chromatography Analysis*	
7. Soil Texture	WI: *Soil Texture*	
	Soil Texture Triangle and Soil Texture Flowchart	
8. Soil Permeability	I: *Soil Permeability*	
	W: *Soil Permeability*	
9. Decision Analysis	W1: *Decision Chart*	
	R: *Cost/Benefit Analysis and Ethical Considerations* (optional)	
	W2: *What's the Big Idea?* (optional)	
10. Siting Yoretown's Landfill	I: *Siting Yoretown's Landfill*	
	W1: *Site Evaluation*	
	W2: *Landfill Site Comparison*	
	W3: *Decision Chart for Landfill Site*	

Checklist for Hydroville Science Journal (continued)

Journal Section	Document Name	Grade
Divider 3 – Data Collection and Data Analysis		
Building a 3-D Model of the Spill Site	R: *Topographic Maps*	
	W1: *Reading for Understanding Questions*	
	I: *Building a 3-D Model of the Spill Site*	
	Topographic Map of Spill Site	
	W2: *Conclusion Questions*	
Hydroville Update	*Copy of Truck Manifest*	
	HTV Newsflash & Toxic Pesticide Spill Near Hydroville	
Career Information	R: *Getting Factual Information from the Web*	
	R: *Protocol for Conducting Interviews* (optional)	
	W3: *Career Information*	
Expert Group	Readings, Instructions, and Worksheets	
	Expert Group Report	
Divider 4 – Data Synthesis and Solution Presentation		
Data Synthesis	I: *Data Synthesis*	
	W1: *Decision Chart*	
	W2 or W2a: *Presentation Planning Task List or Southerville EnviroClean Project Planning Task List* (filled in or blank)	
	R: *Components to Consider When Preparing a Presentation*	
	W3: *Designing a 12–15 Minute Team Presentation*	
	W4: *Team Presentation Planning Checklist*	
Solution Presentation	I: *Reflection on Pesticide Spill Scenario*	
Divider 5 – Teamwork Skills		
	W1: *Teamwork Skills Analysis (T-chart)*	
	W2: *Teamwork Skills Practice Guide*	
	I: *Toxic Popcorn*	
	Include other T-charts for skills practiced in class	
Divider 6 – Glossary		
Record new terminology and definitions on loose-leaf notebook paper.		

I: Instructions R: Reading W: Worksheet

TEAMWORK SKILLS

Hydroville, USA

TEAMWORK SKILLS

Description:

The Hydroville activities require students to emulate real-life situations by working in teams. Working together and communicating effectively will play an important role for the success in each of the background activities, Expert Groups, and final team presentation. This section offers tools and activities to facilitate teamwork practice and skill development with your students.

Purpose/Goals:

Students will be able to:

- identify the relationship between specific teamwork skills and team success
- distinguish verbal and non-verbal behaviors that contribute toward teamwork
- participate in a team-building activity

Prerequisites:

None

Time Estimate:

This activity is designed to accompany *Welcome to Hydroville*.

Prep: 20 minutes

Activity: One 50-minute period

Materials:

Each Student:

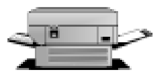
- ☐ Hydroville Science Journal

Each Group of Four Students:

Team-building Activity: Toxic Popcorn

- ☐ A 10-foot-diameter circle drawn on floor with tape
- ☐ Two coffee cans, one half- filled with popcorn
- ☐ Three pieces of rope (7 feet long each)
- ☐ One bicycle inner tube

Pages to Photocopy:



Transparencies:

- Transparency 1: *Teamwork Skills*
- Transparency 2: *Teamwork Skills Analysis (T-chart)*
- Transparency 3: *Teamwork Skills Practice Guide*
- Transparency 4: *Toxic Popcorn*

One 3-hole-punched copy/student for the Hydroville Science Journal:

- *Teamwork Skills Emphasized in Hydroville Challenge Problems*
- Worksheet 1: *Teamwork Skills Analysis (T-chart)*
- Worksheet 2: *Teamwork Skills Practice Guide*
- Instructions: *Toxic Popcorn*

Background Information:

An individual working alone rarely solves problems in communities, businesses, academic research, or other social structures. Teams of colleagues, often with very different values and points of view, must work together to develop and complete plans of action. The success of individuals is often determined by their ability to work well with others. The skills necessary for team success are not innate and often must be taught, even to adults.

Several cooperative skills have been selected for emphasis in the Background Activities (Table 1, next page). Each Background Activity has a *Teamwork Skills* section that recommends the skill emphasized in that activity. The models presented are adaptations from the cooperative skills research of David W. Johnson, Roger T. Johnson, and Edythe Johnson Holubec (*The New Circles of Learning: Cooperation in the Classroom and School*, 1994, published by the Association for Supervision and Curriculum Development).

Table 1. Teamwork Skills Emphasized in Hydroville Curricula

Teamwork Skills	Problem-solving Skills
1. Everyone contributes and helps.	1. Criticize ideas without criticizing people.
2. Everyone listens to others with care.	2. Identify where there is disagreement within the group.
3. Encourage others in the group to participate.	3. Integrate a number of different ideas into a single position.
4. Praise helpful actions or good ideas.	4. Ask for justification for team member's conclusion or answer.
5. Ask teammates for help if you need it.	
6. Check to make sure that everyone understands.	
7. Stay on task with your group.	

When a student first practices a new skill, she or he experiences an awkward, self-conscious stage. Students may feel a degree of phoniness as they try to do or say phrases on purpose. These are natural steps from mechanical to a finally automatic, routine use of the skill. The students will often laugh at how they try the new skills. But when a teacher listens in on a group, watches for cooperative skill usage, tallies students' use of the skill, and encourages the students, the students will keep trying.

Occasionally, only one or two teams need help with specific cooperative skills. In these cases, teachers act as a coach, helping students identify a useful skill and its importance, and the verbal and non-verbal behaviors that portray that skill. Often, teamwork is improved when the teacher or activity designates defined roles (such as starter, summarizer, recorder, technician, etc.). The teacher may devise methods for selecting which team members get specific roles (such as alphabetical order by first names) or allow the teams to determine what role each member receives. This can be an opportunity for students with special talents, organizational skills, or learning styles to be recognized for their value to teams.

Although each background activity emphasizes certain teamwork skills, there may not be enough time to work on a T-chart for each skill. You may also have been working on these skills during the year so that all you need to do is reference a specific skill that you know students need to practice.

Suggested Lesson Plan:

Getting Started

1. This activity should be done before or after *Welcome to Hydroville*. Emphasize that students will be working in teams and these skills are critical to the success of their team in solving the problem.

2. Time constraints may prevent you from creating a T-chart for each skill listed. You may just want to reference the poster of skills when doing the background activities. If you observe one specific skill that the class or a group is having trouble with, you might then take the time to create a T-chart for that skill and use the practice guide to evaluate student performance.

3. **Journal Prompt:** Think about your or your parents' work environment. Do people work alone or in a group or team? Are laws or regulations that govern individuals or a community made by one person or a group of people? How do you know how to work in a group? Are you born with this skill?
   Emphasize that today a person working alone rarely solves problems in communities, businesses, academic research, and most other social structures. Teams of colleagues, often with very different values and points of view, must work together to agree on and complete plans of action. Your success in a job will often be determined by how well you work with others.

   The skills necessary for team success must be learned. Since teamwork is critical to be successful in almost any job, we will be practicing these skills throughout our time in Hydroville.

Doing the Activity

1. Show Transparency 1 (or poster): *Teamwork Skills.*
   This is the list of teamwork and problem-solving skills that you will need to successfully complete this Hydroville unit. You will be working in all sorts of teams. You will be graded on your ability to work together to solve a problem.

   Stress the importance of each of these skills to the success of the teams in solving the pesticide spill problem. This chart can be enlarged and posted in the classroom as a reference and reminder for the students throughout the curriculum.

2. Put up Transparency 2: *Teamwork Skills Analysis (T-chart).*
   For each skill, we will develop a T-chart that you will keep in your Hydroville Science Journal and will use for team evaluation and scoring.

   Explain that students will fill in the T-chart when they are introduced to a skill for the first time. Each T-chart is kept in their

3. Using the T-chart transparency, practice one skill together as a group. Hand out Worksheet 1: *Teamwork Skills Analysis (T-chart)*. Have each student fill out Worksheet 1 and file it in the teamwork section of their Hydroville Science Journal.

   The following example will assist you with the students in filling in their T-chart as you go through the steps:

   a. Name the skill to be analyzed.

      ***Skill**: Everyone listens to others with care.*

   b. Have the students analyze and list ways the skill is important to the success of the team. This list could be divided into two sections: one listing how the skill can lead to a successful product for the team, and the other listing how the skill is important to the feelings the team members develop about each other and themselves.

      Importance to team success:

      ***Product:** In a team, everyone's ideas are important to the success of the team. Successful solutions often happen when you build on the ideas of others.*

      ***Feelings:** When everyone listens carefully to your ideas, you feel like a valuable member of the team and are more willing to work hard and participate.*

   c. Have students brainstorm and list on each half of the T-chart specific verbal and non-verbal (body language) behaviors that they can use to practice this skill (Table 2). It is important that they devise short descriptions or phrases to describe the behavior.

Table 2. T-chart Listing Verbal and Non-verbal Behaviors

Verbal (Sounds Like)	**Non-verbal (Looks Like)**
• Only one person is talking • Other members ask questions of the person speaking	• Members are looking at the person speaking • Members aren't talking with others in other groups • Members are taking notes

4. Prior to assigning the team-building activity, show Transparency 3: *Teamwork Skills Practice Guide*. Go over the guide and give students their copy for their Science Journals.

   This is the scoring guide that will be used by an observer to evaluate how a team is doing on a specific skill.

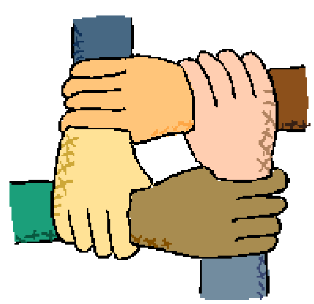
5. Show Transparency 4 to introduce the team-building activity, “Toxic Popcorn.”
6. During the team-building activity, teachers can simply note examples of skill usage using Transparency 3 as they observe the various groups throughout the activity. Then, during the wrap-up of the activity, these examples can be shared. It is interesting to observe how all groups tend to take ownership of the positive skill usage.
7. At other times, one member of the team can use the Worksheet 2: *Teamwork Skills Practice Guide*, to observe, tally, and then share the other members’ skill usage. The following directions can be used when a team member uses the *Teamwork Skill Practice Guide*.
    - *A member of your team should serve as an observer. The observer should watch and listen to the other team members as they work on tasks and discuss ideas. While they are listening, the observer does not participate in the team tasks, as they must analyze what you are doing, and record the teamwork behaviors on the Practice Guide. Use a T-chart of the skill to help with the analysis. Your team may want to select an alternate observer to record behaviors during the second half of the activity.*
    - *Before the end of the classs period, or when the task is completed, the observers should review their results with the team members. Only point out examples of positive use of the skill—**no putdowns**!!*
    - *Then, each team member should complete the “rating” row on the guide. Together, discuss how the skill helped the team and write a teamwork skill goal for the future.*

Wrap-up

1. Students share the results of the *Teamwork Skills Practice Guide*.
2. Debrief using the T-chart and classroom observations. If the mastery of cooperative skills is truly an important aspect of a lesson, it must be assessed along with the lesson content during the wrap-up of the activity. If this piece is omitted, the students do not believe that the team skills are a valid part of the learning and will not continue to practice them.
3. Share with the class your observation of their success with the teamwork skill. Recognize and reinforce positive verbal and non-verbal behaviors rather than negative.
4. Have students demonstrate their plan for preventing the disaster of the toxic popcorn. *Remember to send participants to the hospital if they cross the line.*
5. **Journal Prompt:** Allow the students to comment and reflect on their experiences working together as a team.

Teamwork Skills

Teamwork Skills	Problem-solving Skills
1. Everyone contributes and helps.	1. Criticize ideas without criticizing people.
2. Everyone listens to others with care.	2. Identify where there is disagreement within the group.
3. Encourage others in the group to participate.	3. Integrate a number of different ideas into a single position.
4. Praise helpful actions or good ideas.	4. Ask for justification for team member's conclusion or answer.
5. Ask teammates for help if you need it.	
6. Check to make sure that everyone understands.	
7. Stay on task with your group.	



Together
Everyone
Achieves
More

Transparency 2

Teamwork Skills Analysis (T-chart)

1. Skill:

2. Importance to team success:

a. Product:

b. Feelings:

VERBAL (Sounds like)	NON-VERBAL (Looks like)

Transparency 3

Teamwork Skills Practice Guide

Observer(s): ______________________________ Date:____________

Skill: ____

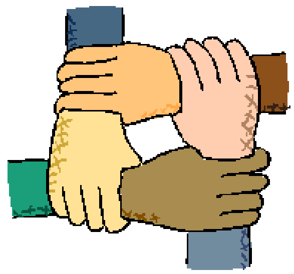
Importance to team success: ___________________________________

Team Members

	Name:	Name:	Name:	Name:	Name:
Demonstrates Skill: Tally each time a team member is observed using the skill.					
Notes: List one or two verbal or non-verbal behaviors each team member demonstrates.					
Rating: Each team member should consider her or his tallies, notes, and experiences. Then check all ratings that apply to their use of the skill.	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill

Transparency 4

Toxic Popcorn



Together
Everyone
Achieves
More

Objective:

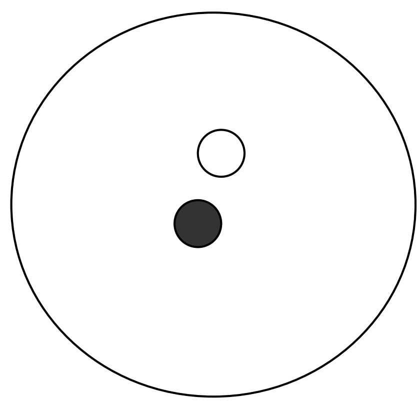
Transfer the toxic popcorn from the UNSAFE can to the SAFE can, using only the materials provided.

Inside the circle you will find two cans. One can is UNSAFE and is half full of the toxic popcorn, which represents hazardous waste. The other can is SAFE and is available for decontamination.

Diameter of circle = 10 feet

Safe can ○

Unsafe can ●



Materials:

- ☐ Three pieces of rope
- ☐ Inner tube

Student Pages for

TEAMWORK SKILLS

Follow this Page

Worksheet 1

Name_______________________________

Date__________________ Period_______

Teamwork Skills Analysis (T-chart)

1. Skill:

2. Importance to team success:
   a. Product:

   b. Feelings:

VERBAL (Sounds like)	NON-VERBAL (Looks like)

Worksheet 2

Name________________________________

Date__________________ Period______

Teamwork Skills Practice Guide

Directions

1. Before you begin the Background Activity, **work together** to write on the *Practice Guide* (page 2) the teamwork skill you will practice today. Write the name of the skill *and* a brief definition. *Also* write a sentence that describes how the use of this skill can benefit your team members and the accomplishment of your tasks. Briefly examine the T-chart for this skill to refresh your understanding of verbal and non-verbal behaviors that demonstrate the skill you are practicing.
2. A member of your team should serve as an *observer*. The observer should watch and listen to the other team members as they work on tasks and discuss ideas. While they are listening, the observer does not participate in the team tasks, as they must analyze what you are doing, and record the teamwork behaviors on the *Practice Guide*. Use a T-chart of the skill to help with the analysis. Your team may want to select an alternate observer to record behaviors during the second half of the activity.
3. Before the end of the class period, or when the task is completed, the observers should review their results with the team members. Only point out examples of positive use of the skill—**no putdowns**!!!
4. Then, each team member should complete the "rating" row on the bottom of the *Practice Guide*.
5. Together, discuss how the skill helped the team and write a teamwork skill goal for the future.

Worksheet 2, Page 2

Name ______________________________

Date __________________ Period _______

Teamwork Skills Practice Guide

Observer(s): __________________________________ Date: _____________

Skill: ____

Importance to team success: ____

Team Members

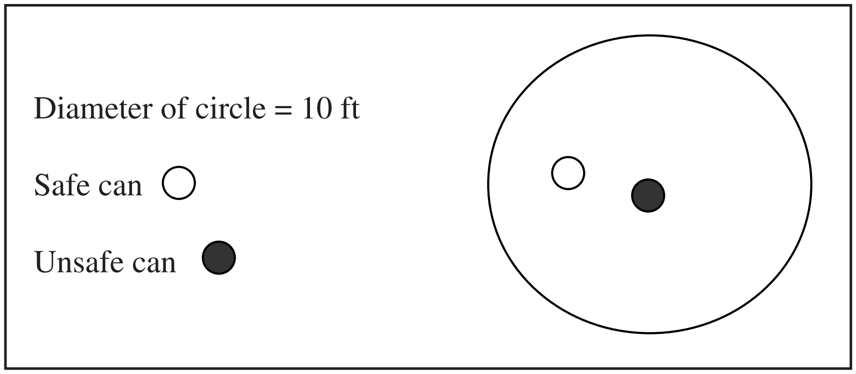
	Name:	**Name:**	**Name:**	**Name:**	**Name:**
Demonstrates Skill: Tally each time a team member is observed using the skill.					
Notes: List one or two verbal or non-verbal behaviors each team member demonstrates.					
Rating: Each team member should consider her or his tallies, notes, and experiences. Then check all ratings that apply to their use of the skill.	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill	__I need more practice __I am improving __I am pretty good at this __I show excellent use of the skill

Toxic Popcorn

Background

A can of highly toxic popcorn has contaminated a circle approximately 10 feet in diameter. The toxic area makes a cylinder that extends to the ceiling. If the poisonous popcorn is not transferred to a safe container for decontamination, the toxic popcorn will contaminate and destroy the population of the entire city. You do not have time to contact authorities and evacuate the city. The lives of thousands of people are in your hands, and you must act immediately.

Inside the circle you will find two cans. The unsafe can is about half full of the toxic popcorn. The safe can is available for decontamination.



Objective

In 30 minutes or less, transfer the toxic popcorn from the unsafe can to the safe can, using only the materials provided.

Materials

Per group of four:

- ☐ Three pieces of rope (7 feet long each)
- ☐ One bicycle inner tube

Rules

1. No participant may cross the plane of the circle with any part of the body. If this occurs, the person must be taken to the hospital immediately (removed from play) and may not participate in any form from then on. One member (the EMT) of the group is responsible for the safety of all members and watches to make certain no one enters the circle. If a member crosses the line, the EMT has the member sit down and no longer participate.
2. No participant may sacrifice himself or herself to aid in the transfer of popcorn.
3. No spills are allowed, or the popcorn will explode.
4. Participants may use only the materials provided. However, they can be used in any way desired.
5. The popcorn will not spread its toxicity to the safe can, the ropes, or the tube. The participants have no protection inside the imaginary cylinder created by the 10-foot-diameter circle.
6. The safe can may move anywhere in or outside of the circle. The unsafe can must stay inside the circle, and not be moved more than 1 foot from its center.

Remember, the popcorn must be transferred within 30 minutes, or there will be a tremendous disaster.

PROBLEM DEFINITION

WELCOME TO HYDROVILLE

Description:

The Hydroville Pesticide Spill Scenario is presented to the students through a 10-minute video. It is important that the students understand why they are involved with Hydroville before beginning the background activities. They learn how the background activities will prepare them to be part of the environmental clean-up team that has been hired to remove the pesticide, develop a remediation plan for the site, and present their findings.

Purpose/Goals:

Students will be able to:

- create and use a Hydroville Science Journal
- understand the importance of teamwork in solving the problem
- describe the initial facts about the Pesticide Spill Scenario

Prerequisites:

None

Time Estimate:

Prep: 15 minutes

Activity: Two 50-minute periods

Materials:

- ☐ Pesticide Spill Scenario Video – 11 minutes (ordering information at www.hydroville.org)
- ☐ TV and VCR or DVD player
- ☐ Poster board or paper
- ☐ Post-it® Notes
- ☐ Markers

Pages to Photocopy:

One copy/student:

- *Map of Hydroville*
- *Pesticide Spill Concept Map*

Teamwork Skill:

- Everyone listens to others with care.

Terminology:

Active compound
Closed system
DEQ
Fumes
HazMat Team
Level B personal protection
Manifest
Metam sodium
MITC (methyl isocyanate)
Reservoir
Stakeholders
Vapors
Water intakes
Water soluble

Suggested Lesson Plan:

Doing the Activity

1. Begin *Welcome to Hydroville* by creating the students' Hydroville Science Journals. See the lesson plans in the *Hydroville Science Journal* section of this curriculum.
2. **Journal Prompt:**
   a. Give three examples of how humans impact the environment.
   b. Give three examples of how the environment impacts humans.
   c. What do you think the study of environmental health science covers?
3. As a class, discuss students' answers to the journal prompt. Introduce the students to the field of environmental health science. Be certain that students understand that environmental health science deals with the effects of our environment (air, water, food, etc.) on our personal health.
4. Divide your class into teams of four to six students. Follow the lesson plans in the *Teamwork Skills* section of this curriculum. Students will create T-charts and have one team member use the *Teamwork Skills Practice Guide* to evaluate their team's use of the teamwork skill while performing the Toxic Popcorn Challenge.
5. Show the Pesticide Spill Scenario video to the class. Hand out a copy of the *Map of Hydroville* to each student to put into their Hydroville Journal. They should become familiar with the town geography as they discuss the video.

6. Have the class reassemble into the teams from the teamwork skill practice. Provide each group with Post-it® Notes and poster-sized paper.
7. Teams should divide the paper into two columns and label them "What we know" and "What we want to know."
8. Show the video a second time, have students write down facts from the video on the sticky notes. After the video, have students compile their facts on the poster board under "What we know."
9. Have groups brainstorm questions about what they would like to know. Have a group recorder put these questions on the notes and place them under the column: "What we want to know."
10. Collect the posters and create a class set of facts and questions and hang the poster in the class. Revisit the questions periodically and see if the class has come up with answers which can be moved to the "What we know" column.
11. In the video, students learn that the insurance company is bringing in a team of experts immediately to clean up the spill. Brainstorm the skills team members should have. What careers or professions have those skills? The students often can come up with the skill or knowledge needed but do not know of a profession that would have this knowledge. Help the students put together a list that has the following:
    - They would need to have information about the soil at the spill site and how fast the pesticide was moving through the soil. Therefore the team would need a *soil scientist*.
    - They would need to know something about the pesticide and how it affects plants, animals, and humans. *Environmental toxicologists* study these effects.
    - They would need to pump the pesticide out of the ditch. The knowledge of a *mechanical engineer* would be needed for this.
    - They would need to know what the pesticide has contaminated – the soil, Beaver Creek, the groundwater, or air. An *analytical chemist* would know how to measure the pesticide in these samples.
12. In pairs, have students brainstorm the following two questions:
    a. What would be the goals of their team cleanup?
    b. What actions should their team take to clean up the site?
13. Have students share their ideas. On a transparency, make a list of actions that the class thinks needs to be taken to clean up the spill. Include the initial actions taken in the video. Keep this class list. You will use it again in Background Activity 9,

Decision Analysis. Here are some example actions (this list is not complete!):

- Seal the tanker.
- Stop the flow of pesticide.
- Evacuate the area.
- Get the name of the pesticide and learn about its toxicity.
- Test the drinking water.
- Pump out the pesticide.
- Remove the contaminated soil.
- Stop fishing in the river until further notice.
- Have Hydroville residents drink bottled water until further notice.
- Shut down the water system for Hydroville.
- Develop press releases for TV and radio to inform the public what is going on.
- Alert hospitals and clinics of symptoms caused by the pesticide and what they can do for the patients.

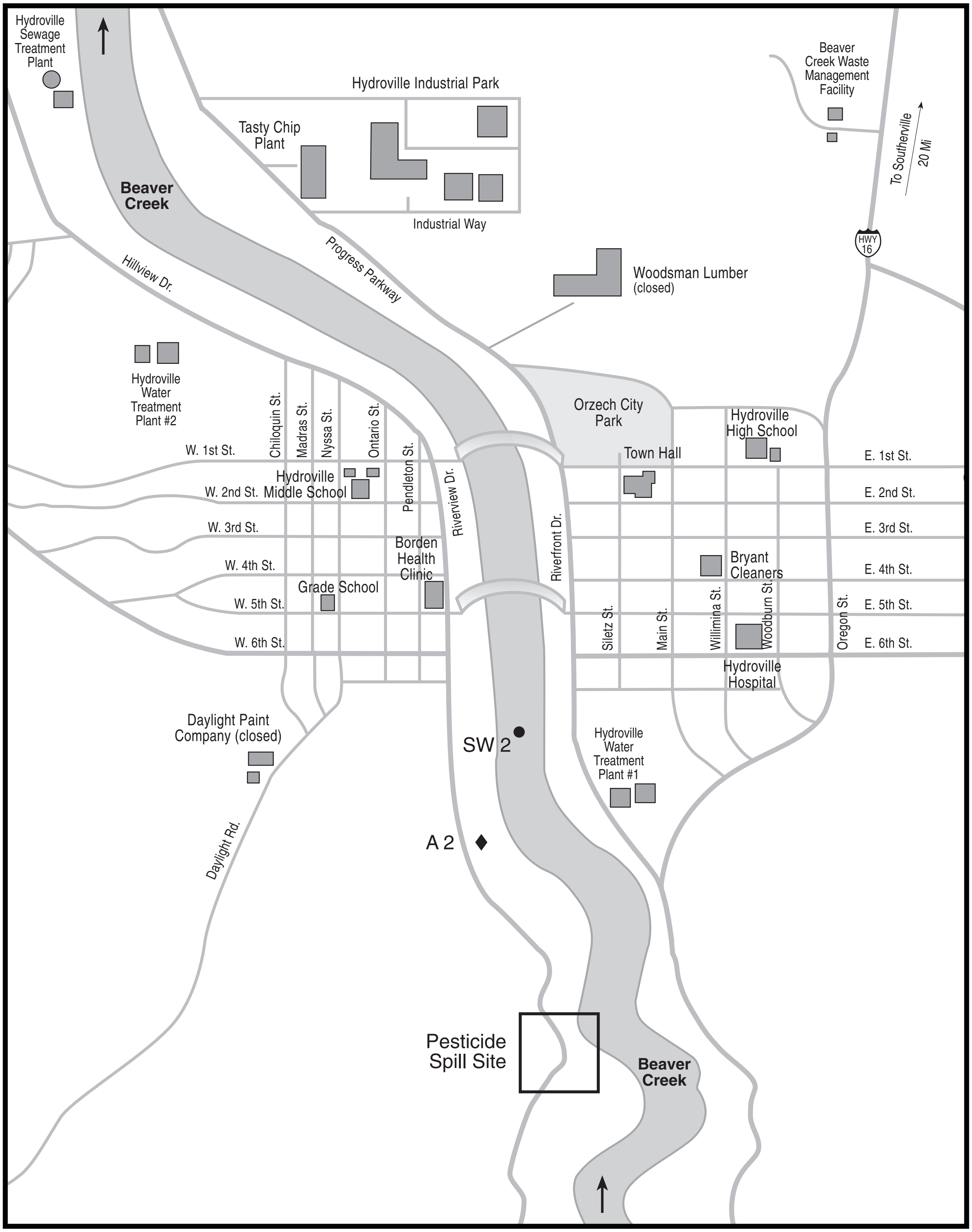
14. Hand out the *Pesticide Spill Concept Map* to each student. Explain that they will take on roles as experts on the cleanup team from Southerville EnviroClean. Show how each Background Activity develops the skills and concept knowledge to participate as an expert on the team and make the decisions necessary to develop a remediation plan for the site. This plan should meet the needs of the insurance company, the citizens of Hydroville, and government regulatory agencies.
15. Explain to the students that over the next few weeks they will be acquiring the vocabulary, concepts and skills of the experts on the team. Each team member will take on the role of one of the experts when Southerville EnviroClean begins the clean-up of the spill site.

Student Pages for

WELCOME TO HYDROVILLE

Follow this Page

Map of Hydroville



KEY	Sample Sites				
		SW	surface water	●	metam sodium
		A	air	♦	MITC

0 500 1000
1/2 inch = 500 ft
N

Pesticide Spill Scenario Concept Map

I. Problem Definition
- Hydroville Science Journal
- Teamwork Skills
- Welcome to Hydroville
- Background Activities

II. Data Collection
- 3-D model of spill site
- Hydroville Update
- Careers

ENVIRONMENTAL TOXICOLOGIST
Assess risk from pesticide

1. Reading Household Product Labels
2. Toxicity Testing

MECHANICAL ENGINEER
Design an effective pump

3. Pump It Up! *Part I*
4. Pump It Up! *Part II*

III. Data Analysis

Southerville EnviroClean

ANALYTICAL CHEMIST
Determine pesticide contamination

5. Constructing and Analyzing Graphs
6. Using Paper Chromatography

SOIL SCIENTIST
Determine soil permeability

7. Soil Texture
8. Soil Permeability

IV. Data Synthesis
Develop a Remediation Plan

9. Decision Analysis
10. Siting Yoretown's Landfill

V. Solution Presentation

BACKGROUND ACTIVITY 1

READING HOUSEHOLD PRODUCT LABELS

Description:

Students review labels from household products to recognize signal words and understand the basis for what makes these products hazardous. They take an inventory of hazardous household products in their home, garage, or utility area, and identify and chart the products. Then students write a brief report on their findings to an adult decision-maker in their household.

Rationale:

For the Pesticide Spill Scenario, students must have an understanding of toxicology concepts and terms. The Environmental Toxicologists also need to learn to communicate technical information to a non-technical audience.

Purpose/Goals:

Students will be able to:

- identify hazardous household products based on product signal words
- understand federal regulations and labeling requirements
- read product labels noting signal words, hazardous properties, and routes of exposure
- inventory hazardous household products in their homes and identify unsafe storage and use of products

Prerequisites:

None

Time Estimate:

Prep: 60 minutes

Activity: Two 50-minute periods

- Day 1: Reading Hazardous Household Product Labels
- Day 2: Hazardous Household Products Inventory (homework) Have students set up the experiment for BA 2.
- Day 3: Writing a Memo: Results of a Hazardous Household Product Inventory (optional)

Materials:

- ☐ Hydroville Science Journal
- ☐ 25–30 hazardous household products: oven/drain cleaners, pesticides, solvents, etc., along with a few non-hazardous/non-toxic products for comparison (shampoo, toothpaste, etc.)

Pages to Photocopy:

- Transparency 1: *Which of These Household Products Is Hazardous?*
- Transparency 2: *What Are Properties of Hazardous Substances?*
- Transparency 3: *How Do You Know If a Product Is Hazardous?*
- Transparency 4: *Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)*
- Transparency 5: *Routes of Exposure*

One copy/student:

- Reading: *What Makes a Product Hazardous?*
- Worksheet 1: *Reading Hazardous Household Product Labels*
- Worksheet 2: *Hazardous Household Products Inventory*
- Worksheet 3: *Writing a Memo: Results of a Hazardous Household Product Inventory*

Teamwork Skill:

- Everyone contributes and helps.

Terminology:

Absorption
Acute toxicity
Caution
Chronic toxicity
Corrosive
Danger Toxic
Environmental Protection Agency (EPA)
Flammable
Hazardous substance
Ingestion
Inhalation
Irritant
Lethal Dose50 (LD_{50})
Pesticides
Poison
Route of exposure
Signal words
Strong sensitizer
Warning

Background Information:

Refer to Reading: *What Makes a Product Hazardous?*

Suggested Lesson Plan:

Day 1. Reading Hazardous Household Product Labels

Getting Started

1. Assign Reading: *What Makes a Product Hazardous?* This reading provides students with background information on hazardous household product labeling requirements and definitions.

2. Gather 25–30 common household products from around your home, classroom, and school. Locate a variety of hazardous household products that have *Danger*, *Warning*, or *Caution* on the product label. Products should also vary in their hazardous properties: corrosive, irritant, strong sensitizer, flammable, and toxic.

   Examples: kitchen products (cleansers, drain cleaners); bathroom items (toothpaste, toilet bowl cleaner); household cleaners (detergents); lawn and garden supplies (fertilizers, pesticides); automotive and paint supplies, etc. Also include some non-hazardous products, e.g., shampoo, toothpaste, and other non-toxic substances, i.e., products that do not have signal words.

   NOTE: Include pesticides that are commonly used in the home or garden, e.g., ant killers, insect spray, and also cleaning products that advertise as "antibacterial," "disinfectant," and/or "kills mold."

3. Display the products in a visible area in the front of the classroom.

   SAFETY: Be sure that ALL product containers are safe for students to handle.

4. **Journal Prompt**:

   a. What do you think of when you hear the term "hazardous"? *Something is hazardous when it causes harm to a person or the environment.*

   b. What are properties of hazardous substances? *A hazardous substance is any product that is toxic, corrosive, flammable or combustible, an irritant, or a strong sensitizer. A hazardous household product requires labeling if the product may cause substantial personal injury or illness during handling or use, including ingestion by children.*

   c. How do you know if a product in your house is hazardous? *Read the product label to find out if a product is hazardous.*

Doing the Activity

1. **Demonstration: "Hazardous" vs. "Non-hazardous" Household Products**
   Using Transparency 1, have the students decide which of the

products displayed are hazardous and which are not, based on the definition for hazardous chemicals. Separate products into categories: "hazardous" and "non-hazardous."

2. Ask the students if they can suggest ways to separate the "hazardous" products into smaller classifications, e.g., signal words, location used, or other properties. Students should discuss the criteria they applied.
3. Use Transparencies 2–5 to discuss these key points:
   - Federal laws require companies that manufacture household products to warn consumers of their products' hazard to humans, animals, or the environment.
   - According to the federal government, there are six properties used to identify hazardous household products: corrosive, irritant, strong sensitizer, flammable, explosive/reactive, and toxic.
   - Law requires hazardous substances to be properly labeled with signal words – *Poison, Danger, Warning*, and *Caution* – to inform consumers of level of hazard. They are listed from most to least hazardous.
   - The Environmental Protection Agency (EPA) regulates pesticides. The signal words for pesticides are based on toxicity testing. Signal words are associated with the level of toxicity of the product, e.g., high toxicity, moderate toxicity, and low toxicity, based on toxicity testing.
   - Discuss different ways a person can be exposed to hazardous substances: inhalation, ingestion, and absorption (skin and eye contact).
4. Divide students into groups of three or four. Hand out Worksheet 1: *Reading Hazardous Household Product Labels* to every student.
5. Working in pairs, students read product labels of 10 household products displayed in the classroom. Students should refer to the Reading: *What Makes a Product Hazardous?* to identify hazardous properties and signal words.

Wrap-up

1. As a class, use an overhead to share data collected on Worksheet 1.
2. Discuss the Conclusion Questions on Worksheet 1.
3. **Homework Assignment**: Distribute Worksheet 2: *Hazardous Household Products Inventory* to the students and review assignment. Students should bring the completed data table and the answers to the *Conclusion Questions* the following class period.

   NOTE: Instead of assigning Worksheet 2 for homework, students could inventory hazardous products found in the school building, e.g., bathroom cleaners, office supplies, auto shop supplies, etc.

Day 2. Experiment Setup for Background Activity 2

Follow the lesson plan for Day 1 of Background Activity 2.

Day 3. Writing a Memo: Results of a Recent Household Hazardous Product Inventory (optional)

Getting Started

1. Review homework assignment Worksheet 2: *Hazardous Household Products Inventory*.
2. **Journal Prompt**:
    a. Since you have investigated and inventoried your household, do you see any patterns in signal words and their products? For instance, do products with *Caution* as a signal word typically represent certain kind of products?
    b. Have students share their responses to the Journal prompts. Focus on terminology and signal words.

Doing the Activity

1. Give each student a copy of the Instructions: *Writing a Memo: Results of a Recent Household Hazardous Product Inventory*. This 1-page example of a memo gives the students a suggested approach to communicating technical information with their parents or adults in their household. Based on their data table and their answers to the Conclusion Questions, students create memo recommending action or commending their readers.
2. Give students a copy of the *Writing a Memo – Scoring Guide* from Appendix D so they know how they will be graded.

Wrap-up

Journal Prompt:

a. Write a brief summary of what hazardous products you found in your house.

b. What would you say to your family regarding the household hazardous products you surveyed? Are they stored safely?

c. Are there any recommendations you would make to your family based on your findings? What are they? Be specific.

Assessment:

- Students turn in Worksheets 1 and 2.
- Use the *Writing a Memo – Scoring Guide* to evaluate the student memos.

Extensions:

- Students make bar graphs based on data collected in class based on categories of signal words or physical properties, e.g., "signal word vs. total number of products" or "physical property vs. total number of products."
- Create a poster, a brochure, video, or oral presentation designed to inform the public about FIFRA and FHSA labeling laws.
- Design a better product label, or look for label violations from outdated products.
- Translate information on labels into another language and/or provide product label information to families in the community.

Resources:

- National Pesticide Information Center. *Environmental and Molecular Toxicology*. For questions concerning pesticides and other hazardous household products, call NPIC @ 1-800-858-7378 (PEST). http://npic.orst.edu
- Please refer to the Pesticide Spill Curriculum Web resources page: http://www.hydroville.org/links/ps_resources.aspx

Teacher Key

Worksheet 1

NOTE: This data table includes examples of products that could be brought into the classroom.

Product	Hazardous Properties – List properties that make it hazardous	Signal Word	Route of Exposure (Ingestion, Inhalation, Absorption)
All-purpose cleaner	Irritant	Warning	Absorption: eye irritant, skin sensitivity
Sealant	Irritant Toxic	Caution	Inhalation, absorption: skin sensitivity
Oven cleaner	Flammable	Caution	Inhalation, absorption: skin sensitivity
Lubricant (WD-40)	Flammable Toxic	Danger	Inhalation, ingestion
Bleach	Irritant Toxic Corrosive	Danger	Absorption: eyes and skin irritant, ingestion
Toilet bowl cleaner	Toxic Corrosive	Danger	Inhalation, ingestion, absorption: eye and skin irritant
Cleanser	Irritant Strong sensitizer Corrosive	Caution	Absorption: eye and skin irritant, ingestion
Insecticide	Toxic	Caution	Absorption: eye and skin contact, inhalation, ingestion, skin sensitivity
Varnish remover	Flammable	Danger Poison	Ingestion, absorption: skin and eye irritant
Rat killer	Toxic	Caution	Ingestion, absorption: eyes and skin

Conclusion Questions

NOTE: Answers are based on examples from table above. Answers will vary if using actual products.

1. Which hazardous properties were most common? *Toxic and irritant*
2. Which signal word was most common? *Caution*
3. Which products are most toxic? How did you determine this? *Drain cleaners, bleach, lubricant, and toilet bowl cleaners. They are labeled Danger/Poison.*
4. What are the three routes of exposure? Which route was most common? *Ingestion, Inhalation, and Absorption: skin/eye contact. Dermal appears to be most common.*
5. Which product(s) have signal words based on toxicity testing? *Pesticides and "anti-microbial" cleaners, such as a toilet bowl cleaner.*
6. What did you learn from this activity? *Answers will vary.*

Teacher Key

Worksheet 2

Answers for Hazardous Household Products Inventory will vary.

Product	Signal Word	Route of Exposure	Directions for Use	Storage Location in Home

Conclusion Questions

1. Complete the following data table. Of the 10 products you identified in your home, how many are labeled Danger, Danger–Poison, Warning, and Caution? What percentage of the products inventoried are represented by each signal word?
   Answers are based on household hazards products listed on Worksheet 1.

Signal Words	Number	Percent (%)
Danger	*3*	*30*
Danger–Poison	*1*	*10*
Warning	*1*	*10*
Caution	*5*	*50*

2. How many of the products surveyed in your home are stored incorrectly according to the directions on the label? Describe examples of improper storage and how you can corrrect it.
   Answers will vary.

3. If a product label recommends that you "keep out of reach from children," where could you safely store this product?
   Examples include: in a locked cabinet or on a high shelf out of a small child's reach.

4. Based on the manufacturer's direction for use for a specific product, what would a misuse look like? (For example, how could you misuse an oven cleaner?)
   If you were using an oven cleaner, a misuse would be to not wear protective gloves or to spray surfaces other than the inside of the oven.

5. What can you do to reduce your risk of being exposed to these products?
   Answers will vary. Purchase alternative cleaning products that may be safer to use or less toxic. Use cleaners that have no signal words or that are labeled Caution. Avoid products that have the signal words Danger, Danger–Poison, or Warning. Read product labels, always follow directions, and wear protective equipment when advised.

Transparency 1

Which of These Household Products Is Hazardous?

Hazardous	Non-Hazardous

Transparency 2

What Are Properties of Hazardous Substances?

Symbol	Hazardous Properties
	**Corrosive** – can burn or destroy living tissue (skin, eyes) by contact.
	**Irritant** – (non-corrosive): can cause injury to skin, eyes, or lungs by contact.
	Strong Sensitizer – can cause an allergic reaction with repeated exposure.
	**Flammable** – easily set on fire and can burn rapidly.
	Explosive/reactive – can spontaneously ignite, create high pressure, or create poisonous vapors when mixed with other products.
	**Toxic** – poisonous when eaten, inhaled, or absorbed through the skin. May cause long-term illness (such as cancer).

Transparency 3

How Do You Know if a Product Is Hazardous?

Signal Words for Household Products

Signal Word	Description	Examples
Poison	Highly toxic, can cause death in small amounts	Paint remover, antifreeze
Danger	Explosive, extremely flammable, corrosive or highly toxic certain solvents	Oven and drain cleaners, bleach, spray adhesive,
Warning	Flammable, moderately toxic, sensitizer	Paint, paint thinners, other solvents
Caution	Slightly toxic, irritant cleanser	Dishwasher soap,

If there is no signal word, it is not ***hazardous***.

Transparency 4

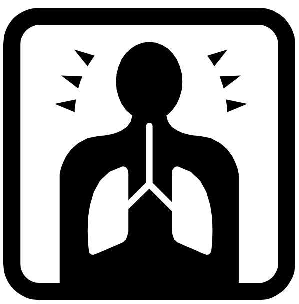
Signal Words for Pesticides

Hazard Rating	Signal Words	Toxicity
most	**DANGER**	High toxicity
↓	**WARNING**	Moderate toxicity
least	**CAUTION**	Low toxicity

Transparency 5

Routes of Exposure

Ingestion – eating or drinking hazardous substances or contaminated foods and water then absorbing these substances through your intestinal tract.



Inhalation – breathing in gases, vapors, and sprays that are absorbed through the lungs and enter the bloodstream.

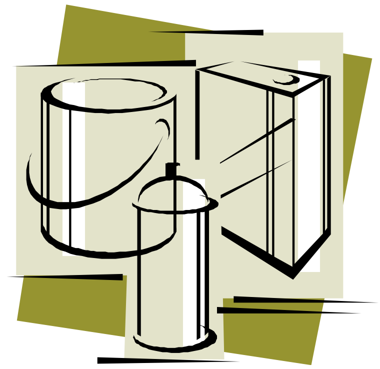
Absorption (skin or eye contact) – absorbing hazardous substances through the skin or your eyes, and into your tissues.

Student Pages for

READING HOUSEHOLD PRODUCT LABELS

Follow this Page

Hazardous Substances



Did you know that you can usually find 3–10 gallons of hazardous substances in the average home? Many of the products we use for cleaning, gardening, home improvement, or car repair are considered hazardous. When used or disposed of improperly, these products can be a danger to our health and can also pollute the environment.

What Makes a Product Hazardous?

According to the federal government, a hazardous product has at least one of the following properties:

Symbol	Hazardous Properties
	**Corrosive –** *can burn or destroy living tissue (skin, eyes) by contact.*
	**Irritant –** *(non-corrosive)***:** *can cause injury to skin, eyes, or lungs by contact.*
	Strong Sensitizer – *can cause an allergic reaction with repeated exposure.*
	**Flammable –** *easily set on fire and can burn rapidly.*
	Explosive/reactive – *can spontaneously ignite, create high pressure, or create poisonous vapors when mixed with other products.*
	**Toxic –** *poisonous when eaten, inhaled, or absorbed through the skin. May cause long-term illness (such as cancer).*

How Do I Know if a Product Is Hazardous?

The federal government requires proper labels on all hazardous products. The label must describe the type of injury or hazard that can be caused by the product and any safety precautions necessary for use or storage. Labels on hazardous products must also contain a **signal word** that quickly tells you how hazardous the product is. One of the following signal words will be found on all household products that are considered hazardous:

Signal Word	Description	Examples
Poison	Highly toxic, can cause death in small amounts	Paint remover, antifreeze
Danger	Explosive, extremely flammable, corrosive or highly toxic	Oven and drain cleaners, bleach, spray adhesive, certain solvents
Warning	Flammable, moderately toxic, sensitizer	Paint, paint thinners, other solvents
Caution	Slightly toxic, irritant	Dishwasher soap, cleanser

Reading, Page 2

What About Pesticides?

Pesticides are a unique type of hazardous product and are regulated by the U.S. Environmental Protection Agency (EPA). Although some people think the word "pesticide" means "bug killer," pesticides are actually a large category of products that are used to kill or control a variety of pests. Products typically include the name of the targeted pest rather than the general term "pesticide," as shown in the following table:

Pest	**Category**
Insects	Insecticide
Plants (weeds)	Herbicide
Mice or rats (rodents)	Rodenticide
Mold or mildew (fungi)	Fungicide
Bacteria or viruses (microorganisms)	Anti-microbial product*

**Hand sanitizers or other products used on your body are regulated by the Food and Drug Administration, not the EPA.*

The EPA uses its own set of signal words for pesticides. The words are similar to those used for other household hazardous products, but these signal words specifically tell you about the toxicity of the pesticide product. The more toxic the product is, the smaller the amount it will take to cause death or injury. As with other household hazardous products, all pesticide labels must contain a signal word.

Hazard Rating	**Signal Words**	**Toxicity**
most	**DANGER**	High toxicity
↓	**WARNING**	Moderate toxicity
least	**CAUTION**	Low toxicity

Read the Label First!

In addition to signal words, product labels contain much more important information. This includes:

- instructions for proper use
- storage information
- protective equipment requirements
- active ingredients, first aid information
- proper disposal information

Protect yourself, others, and the environment by carefully reading the label and following the listed instructions on the products you use!

Worksheet 1

Name________________________________

Date__________________ Period_______

Reading Hazardous Household Product Labels

There is a lot of information on product labels, but this activity focuses on identifying hazardous household products.

Procedure:

1. Read 10 product labels for the various household products on display. Find the Hazardous Properties, Signal Words, and Route of Exposure for each product.
2. Refer to Reading: *What Makes a Product Hazardous?* to help you complete the table below.

SAFETY: Be sure that ALL products are handled safely. DO NOT open any products.

Product	Hazardous Properties – List properties that make it hazardous	Signal Word	Route of Exposure (Ingestion, Inhalation, Absorption)

Worksheet 1, Page 2

Name________________________________

Date__________________ Period_______

Conclusion Questions:

1. Which hazardous properties were most common?

2. Which signal word was most common?

3. Which products are most toxic? How did you determine this?

4. What are the three routes of exposure? Which route was most common?

5. Which product(s) have signal words based on toxicity testing?

6. What did you learn from this activity?

Worksheet 2

Name______________________________

Date_________________ Period______

Hazardous Household Products Inventory

Procedure:

1. Take an inventory of 10 household products found in your home. Try to locate two or three hazardous products in each area of your house. Don't inventory all 10 products from one location. Randomly survey products from the following areas in your home:
   - Garage
   - Under your kitchen and bathroom sinks
   - Closet or shelf where household cleaning products are stored
   - Basement
2. Read both front and back labels. Fill in the chart using information on the label.

SAFETY: Use caution when handling all products.

Product	Signal Word	Route of Exposure	Directions for Use	Storage Location in Home

Worksheet 2, Page 2

Name______________________________

Date_________________ Period______

Conclusion Questions:

1. Complete the following data table. Of the 10 products you identified in your home, how many are labeled *Poison*, *Danger, Warning*, and *Caution*? What percentage of the products inventoried are represented by each signal word?

Signal Words	**Number**	**Percent (%)**
Poison		
Danger		
Warning		
Caution		

2. How many of the products surveyed in your home are stored incorrectly according to directions on the label? Describe examples of improper storage and how you can correct it.

3. If a product label recommends that you “Keep out of reach of children,” where could you safely store this product?

4. Based on the manufacturer’s direction for use for a specific product, what would a misuse look like? (For example, how could you misuse an oven cleaner?)

6. What can you do to reduce your risk of being exposed to hazardous products?

Worksheet 3

Writing a Memo: Results of a Hazardous Household Products Inventory

1. Based on what you learned from your Hazardous Household Products Inventory and the responses in your Science Journal, create a 1-page memo (to the adult decision-makers in your household) that recommends corrective action or recognizes good practices.
2. Write your memo in the following report/memo format. This is an example of a technical document that may help you communicate technical information with parents or adults.

Heading

Date: Today's date

To: Names of household adult decision-makers (parents, grandparents)

From: Your full name

Subject: This acts as a title, between seven and nine words – cap all main words (for example, **A Follow-up to My Survey of Our Hazardous Household Products**)

Introductory Paragraph

The memo style is used as method of internal communication. It is in the block style. Paragraphs are usually six to eight sentences long. The introductory paragraph gives a brief background and states the main point. In this case, it would mention the recent survey of 10 items and note two to three key observations. For example: "In analysis of the survey, I noted that most of our household hazardous products are stored safely; however, two items, both labeled with the signal word 'Danger,' are within reach of small children."

First Heading

Report the overall observations from your Hazardous Household Products Inventory.

Specific Information

In this paragraph, students introduce the signal words and review their findings. Example: "I am learning about the signal words on household hazardous labels." Students can introduce the three key terms and briefly define them. Then note: "Out of the 10 products I charted, 20% were labeled *Caution*, 20% *Warning*, and 60% *Danger*." Lead into the commendations and recommendations for actions based on these findings.

Second Heading

Include your step-by-step recommendations for action. *Key recommendations included*. Begin by commending the readers for good choices they made in safety and storage of household hazardous products. Then suggest in one, two, or three steps what needs to be accomplished to make the home a safe place for children.

Conclusion

Use brief, forward-looking language. This can be a brief closing with positive comments and a review of the recommended action.

BACKGROUND ACTIVITY 2

TOXICITY TESTING – DOSE MAKES THE POISON

(Adapted from Lesson 3: Dose Response Relationships, from *Chemicals, the Environment, and You: Explorations in Science and Human Health,* NIH Curriculum Supplement developed collaboratively by BSCS, Videodiscovery, and the National Institutes of Health, NIH Publication No. 00-4870, copyright 2000 by BSCS and Videodiscovery, Inc., used with permission of BSCS, Colorado Springs, CO.)

Description:

Students collect data on germination to draw a dose-response curve and determine the TC_{50} (Toxic Concentration 50) and NOEL (No Observable Effect Level) of a household chemical on radish seeds.

Rationale:

In the Hydroville Pesticide Spill Scenario, the Environmental Toxicologists gather information about the toxicity of the spilled pesticide and its effects on plants and animals.

Purpose/Goals:

Students will be able to:

- set up an experiment to test the effect of different doses of a chemical on seed germination
- graph their data and create dose-response curves for their data
- analyze class curves to determine TC_{50} for stopping radish seed germination for three chemicals
- explain the concept of "the dose makes the poison"

Prerequisites:

Background Activity 1: *Reading Household Product Labels*

Time Estimate:

Prep: 60 minutes (you may want to have a lab assistant make up the dilutions of the chemicals to be tested. This will save about 30 minutes of class time.)

Activity: Four 50-minute periods (you need 4 consecutive days for this activity)

- Day 1: Toxicity testing-laboratory experiment setup (before second day of BA 1)

- Day 2: Seed observation and complete BA 1 memo
- Day 3: Seed observation and discussion of toxicology and dose-response curves
- Day 4: Seed observation and graphing data and conclusion questions

Materials:

Each Student:

- ☐ Hydroville Science Journal

For Chemical Dilution Setup:

Safety issue: Do not use any chemicals with *Danger* on the label.

Chemicals to be tested:

- ☐ Water-soluble plant fertilizer
- ☐ Insect repellent
- ☐ Window cleaner
- ☐ All-purpose cleaner
- ☐ Vinegar
- ☐ Salt*
- ☐ Coffee*

*Make into a liquid solution

- ☐ 50 mL of chemical in a 100 mL beaker
- ☐ Six 50 mL beakers
- ☐ One 25 mL graduated cylinder
- ☐ One 10 mL graduated cylinder
- ☐ 100 mL distilled water in a beaker
- ☐ Eyedropper

Each Group of Three to Four Students:

- ☐ Six petri dishes or resealable plastic bags
- ☐ Six sheets of 2-ply paper towel
- ☐ Sixty radish seeds (1 tsp = 60 seeds)
- ☐ Permanent marker
- ☐ Masking tape
- ☐ Latex gloves
- ☐ Safety glasses

Pages to Photocopy:

Classroom Hints: You can copy laboratory protocols onto overheads to save paper, or make laminated class sets of the student worksheets and instructions.

- Graph paper

Transparencies:

- Transparency 1: *Dose-response Curve*
- Transparency 2: *Dose Responses for Toxicity Testing of "X"*
- Transparency 3: *Liver Damage Caused by Chemicals "X" and "Y"*

One copy/student:

- Reading: *Toxicology – The Dose Makes the Poison*
- Instructions 1: *Chemical Dilution Setup*
- Instructions 2: *Toxicity Testing on Seeds*
- Worksheet 1: *Toxicity Testing on Seeds Lab Report*
- Worksheet 2: *Student Assessment*

Teamwork Skill:

Check to make sure everyone understands.

Terminology:

Dose
Dose response
Dose-response curve
Duration
Frequency
Individual susceptibility
TC_{50} (Toxic Concentration 50)
LD_{50} (Lethal Dose 50)
NOEL (No Observed Effect Level)
mg/kg
Risk
Toxicity
Toxicology

Background Information:

For centuries, humans have observed that some chemicals found in nature were poisonous. Examples include snake and insect venoms, poisonous plants (hemlock, poison ivy), and minerals such as lead and arsenic. Poisonous chemicals produced by living organisms are called *toxins*. The 16th century physician Paracelsus recognized that the same chemical could have both therapeutic and toxic properties depending upon how much of it was used. He wrote, "All substances are poisons; there is none which is not a poison. The right dose differentiates a poison from a remedy."

The beneficial or harmful effects of a chemical are dependent upon the amount of the chemical that gets into an organism. That amount is called the *dose*. The *toxicity* or harmful effects from a chemical are also influenced by the exposure (route, frequency, and duration), individual susceptibility, properties of the chemical, and exposure of the organism to other substances.

Toxicology

Toxicology is the science that studies the ability of chemicals to cause harmful effects. Because studies with humans are not allowed, toxicologists use animal models to determine the toxic effects that a chemical can cause and the doses at which those effects occur. Mice and rats are the subjects used in the majority of toxicology studies. Since the only human toxicology data on pesticides and industrial chemicals come from accidents, suicides, or occupational exposures, the animal data are used to predict safe levels of exposure for humans to these chemicals. In most cases, chemicals are tested in cell cultures to determine the mechanisms by which chemicals cause toxicity.

When a substance, such as a drug, will be intentionally ingested by humans, studies in dogs, monkeys, and humans themselves may be required. In these studies, identical groups of subjects are exposed to different amounts of the chemical, and the effects produced are measured.

Toxicity of a chemical can be described in many different ways. Three common terms used are:

- **Lethal Dose 50 (LD_{50}) –** LD_{50} is the dose of a chemical that causes the death of 50% of an experimental group of animals. If the result of the exposure is not death but another effect, *toxic dose 50 (TD_{50})* is used.
- **Toxic Concentration 50 (TC_{50}) –** TC_{50} is the term used when observing the toxic effects of a solution of a chemical on experimental subjects (for example, fish, cells, or in this activity, radish seeds).
- **No Observed Effect Level (NOEL) –** NOEL is defined as the highest dose or concentration tested at which the toxic effect is zero. The value for the NOEL is extrapolated from a dose-response curve. (See Day 3 lesson plan.)

Suggested Lesson Plan:

Getting Started

1. This activity should be started on a Monday or Tuesday of a full week of school. The experiment is set up between Day 1 and Day 2 of Background Activity 1.
   a. Day 1: Experiment setup for toxicity testing (during Background Activity 1)
   b. Day 2: Seed observations

c. Day 3: Discussion of toxicology and dose response and seed observation

d. Day 4: Seed observation, graphing data, and lab report

Classroom Hints:

- You can mix solutions and dilutions for your classes. (See Instructions 1: Chemical Dilutions Setup.) This saves considerable class time but does not help students to understand dilutions and concentration.
- Heavy-duty plastic bags can be used instead of Petri dishes, but check to make certain the chemicals do not dissolve the bags.

2. Assign Reading: *Toxicology – The Dose Makes the Poison* and Reading for Understanding Questions.

3. **Journal Prompt**. Place the household products from BA 1 on a table in front of the room. (You can add signs to represent such things as rat poison, alcohol, tobacco, gasoline, etc.).

   a. Make the following six columns on a page in your Science Journal: Natural, Synthetic, Good, Bad, Toxic, Nontoxic.

   b. List the products found on the table down the left side of the page. Put a check in each column that applies to that product.

   c. Share your list with a partner. Do you agree? If not, explain to your partner why you made your choices on the ones where you differ.

Doing the Activity

Day 1. Setting up the Laboratory Experiment

1. Divide the class into groups of three or four.
2. Have students choose a household chemical (see suggested list in Materials) to test for toxicity. How will they be able to tell if a certain dose of the chemical is toxic to radish seeds?
3. Students should follow procedures on Instructions 1 (if students are preparing the dilutions) and Instructions 2.
4. If you have class time available, have student teams design their own experiment for determining the toxicity of a chemical on radish seed germination. Before beginning the experiment, have groups submit their experimental design, including purpose, materials, procedure, and data tables. Check for complete procedure steps, experimental controls, and control of variables in their experimental design.
5. Seeds should be stored in Petri dishes in a stack, lying flat with the seeds up, on a tray. Put the trays in a dark, warm place when students are not making observations.

Day 2. Seed Observation

Students should make three observations of the seeds, recording the number of seeds germinated and the number of seeds not germinated in Table 1 on Worksheet 1.

Day 3. Seed Observation and Discussion of Toxicology and Dose-Response Curves

1. Students should make three observations of the seeds, recording the number of seeds germinated and the number of seeds not germinated in Table 1 on Worksheet 1.
2. Use Transparencies 1–4 to present the concepts of *toxicology* and *dose-response curves*.
3. First have students share their understandings of the following terms and phrases from the reading they did for homework. Use the information in the teacher *Background Information* to frame your discussion.
   - "The right dose differentiates a poison from a remedy" (Paracelsus)
   - Toxic, toxicity, and toxicology
   - Dose
4. Show students Transparency 1. Use this graph to illustrate NOEL, LD_{50}, and dose-response curve.
   a. This graph is called a *Dose-response Curve*. It was made from data collected during an experiment on rats to test the lethal dose of a chemical. There were 10 rats given each dose. The dose given to the rats in milligrams/kilogram body weight (mg/kg) is plotted on the X-axis. The percent of rats that died in each dose group is plotted on the Y-axis.
   b. The LD_{50} is determined by extrapolating a line from 50% dead on the Y-axis to the curve and then down to the X-axis as shown by the dotted line on the graph. The LD_{50} for this chemical is 46 mg/kg.
   c. The NOEL (No Observed Effect Level) for this chemical is shown with the arrow and is 20 mg/kg.
5. Put up Transparency 2: *Dose Responses for Toxicity of "X,"* which shows data demonstrating the dose-response curves derived from a typical animal experiment.
   - In this study, groups of 20 rats were given increasing amounts (doses) of the substance X. Three different responses were measured – liver toxicity, immune system toxicity, and lethality (death).
   - The percentage of rats in each dose group showing the toxic effect is plotted on the graph.

- Based on this data, it is clear that liver toxicity occurs at the lowest dose of chemical. If "X" is a new drug, doctors who prescribe the drug might be instructed to watch for signs of liver toxicity in their patients.
- Have students determine the NOEL for liver damage for substance X.
  (100 mg/kg)
- Have students use the dotted line on the graph to calculate the TD_{50} for "X" to cause liver damage in rats. Then do the same for the TD_{50} to cause immune suppression and death.
  Draw a straight line over from the 50% responding on the Y-axis to each curve in the figure; then draw a vertical line to the X-axis and determine the dose at that point. The liver TD_{50} is 200 mg/kg. The immune suppression TD_{50} is 290 mg/kg. The TD_{50} for death is 350 mg/kg.

6. Transparency 3: Comparing toxicity of different chemicals. If the same response (e.g., liver toxicity) is measured in different toxicology experiments using different chemicals, then the toxicity of the chemicals can be directly compared as shown on Transparency 3, *Liver Damage Caused by Chemicals "X" and "Y."*
   - Ask your students: From the information shown on the graph, which drug would be considered most toxic to the liver of rats? Why?
     "X," because it causes liver damage at lower doses.
   - From the graph, determine the NOEL for each chemical.
     X = 20 mg/kg and Y = 160 mg/kg. Chemical X is eight times more toxic to the liver than chemical Y.
   - If X and Y represent two new drugs prescribed at a dose of 10 mg/kg to treat headaches, which drug would be safer to use? Why?
     Chemical Y. Answers will vary but what students should see from the graph is that with Chemical X you start to see liver damage at a dose much closer to the prescribed dose than with Chemical Y.
7. Transparency 4 shows the relative toxicity of some chemicals in terms that are more familiar to the average person. The data has been converted from LD_{50} data for rats.

Day 4. Seed Observations, Graphing Data, and Conclusion Questions

1. Have students make their last observations of their seeds and complete the data table.
2. On the graph paper, students create a dose-response curve for the chemical they tested. They plot the dosage (% concentration) on the horizontal axis vs. the response on the vertical axis (number of seeds not germinated), to create a dose-response curve for their

chemical. Have them plot a dose-response curve for two other chemicals tested by other teams.

3. In this experiment, students will determine a toxic concentration (TC) rather than toxic dose (mg/kg) for the chemical they tested. They use the same procedure as they have for LD_{50} or TD_{50}. From their graphs, have students determine a TC_{50} for radish seed germination for their chemical, and then compare the toxicity of their chemical to other chemicals tested.
4. Students answer the Conclusion Questions on Worksheet 1.

Wrap-up

Journal Prompts:

1. "What conclusions can you make, if any, about the safety or potential harm on humans of the chemicals that your class tested?"
2. "What are the advantages and disadvantages of using plants as a model system for toxicology testing?"

Assessment:

1. Collect lab report.
2. Hand out Student Assessment and a blank piece of graph paper. Read the first two paragraphs as a class. Read the questions and then have students complete the assignment.

Resources:

- *Calculated Risks*. Joseph V. Rodricks. Cambridge University Press, New York, 1992.
- *Toxicology.* Casarett & Doull. Curtis D. Klassen, Ed. McGraw-Hill, New York, 1996.
- *Introduction to Toxicology*. J.A. Timbress. Taylor & Francis, London, 1995.
- *The Dose Makes the Poison*. M. Alice Ottoboni. Vincente Books, Berkley, CA, 1984.
- *Toxic Substances in the Environment*. B. Magnus Francis. Wiley-Interscience Publication. John Wiley & Sons, Inc., New York, 1994.
- *Toxicology for the Citizen*. Alice E. Marczewski and Michael Kamrin. Institute for Environmental Toxicology, Michigan State University. Nov. 1991.
- Please refer to the Pesticide Spill Curriculum Web resources page: http://www.hydroville.org/links/ps_resources.aspx

Teacher Key:

Reading for Understanding Questions

1. In your own words, describe what is meant by the phrase "The dose makes the poison." Give an example.
   This statement means that toxicity of a substance is dependent upon the dose or amount of exposure. A chemical can be safe (even beneficial) in small doses and harmful in high doses. Examples will vary but some common examples are sugar, salt, water, vitamins, etc.

2. Define the following terms.

   a. Toxicity – *the harm a chemical can cause an organism*

   b. NOEL – *no observed effect level, the highest dose or concentration at which the toxic effect is zero*
   NOEL = 20 mg/kg

   c. Lethal Dose 50 – *the dose of a chemical that causes 50% of the tested individuals to die*
   In Table 1, which substance has the highest toxicity (lowest LD_{50}?) *Botulism toxin*

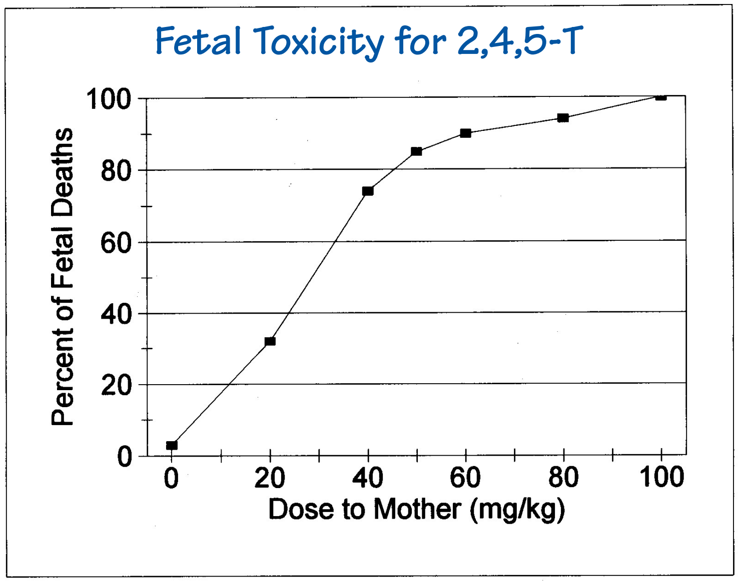
   d. Toxic Concentration 50 – *the concentration of a chemical that causes 50% of the tested individuals to show toxic effects*

3. Name the six factors that affect the toxicity of a chemical.
   a. Properties of individual substances
   b. Dose
   c. Frequency of exposure
   d. Duration of exposure
   e. Route of exposure
   f. Individual susceptibility

4. In your own words, describe how the concepts of toxicity and risk relate to each other. Give an example that includes the six factors listed in question 3.
   Answers will vary, but see the last paragraph of the reading for an example.

Worksheet 1: *Answers will vary.*

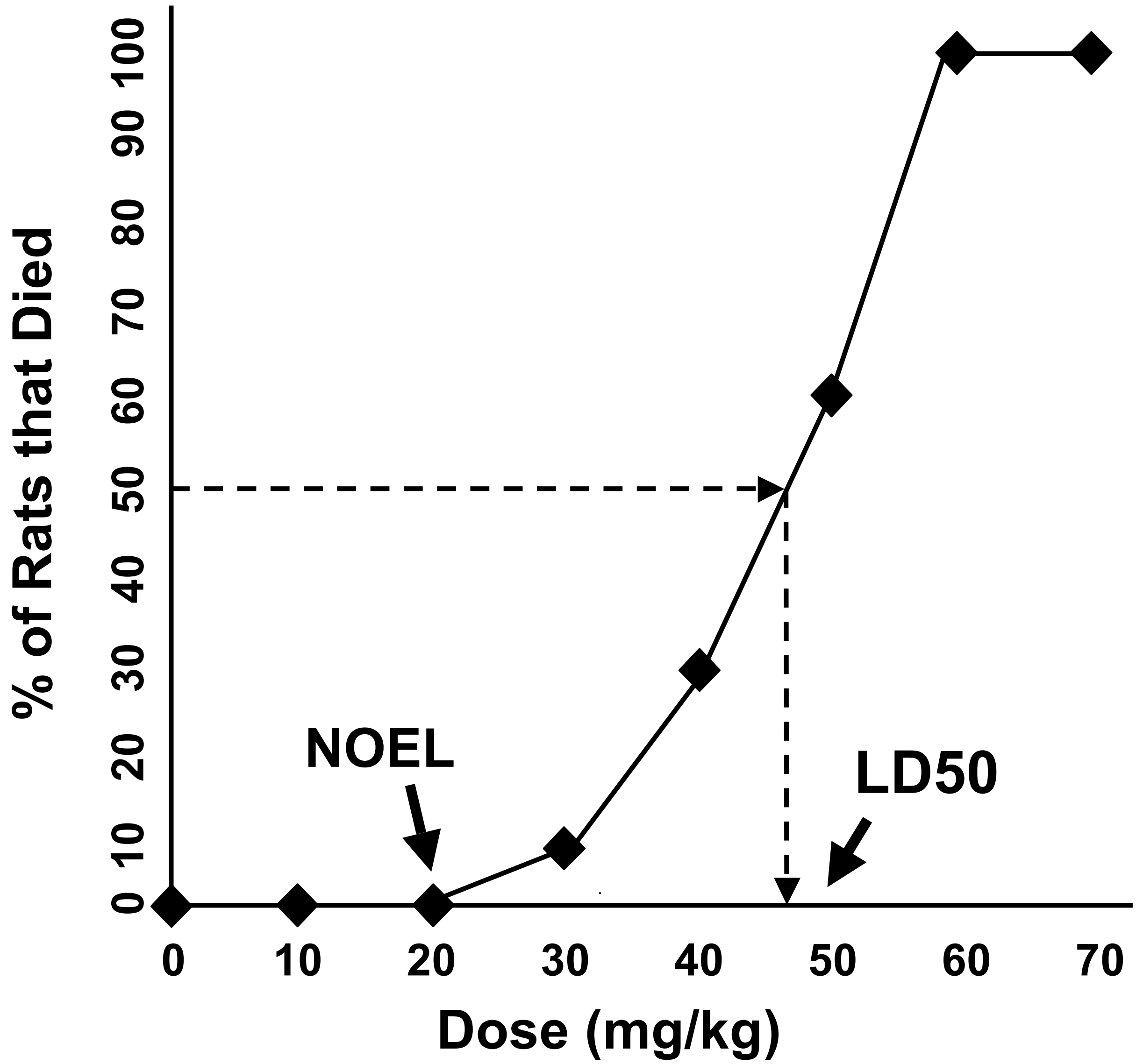
Worksheet 2: Dose-response curve for the toxicity of the herbicide 2,4,5-T toward developing hamster fetuses following exposure of the pregnant mother to the chemical.



LD_{50} for fetal death = 28 mg/kg

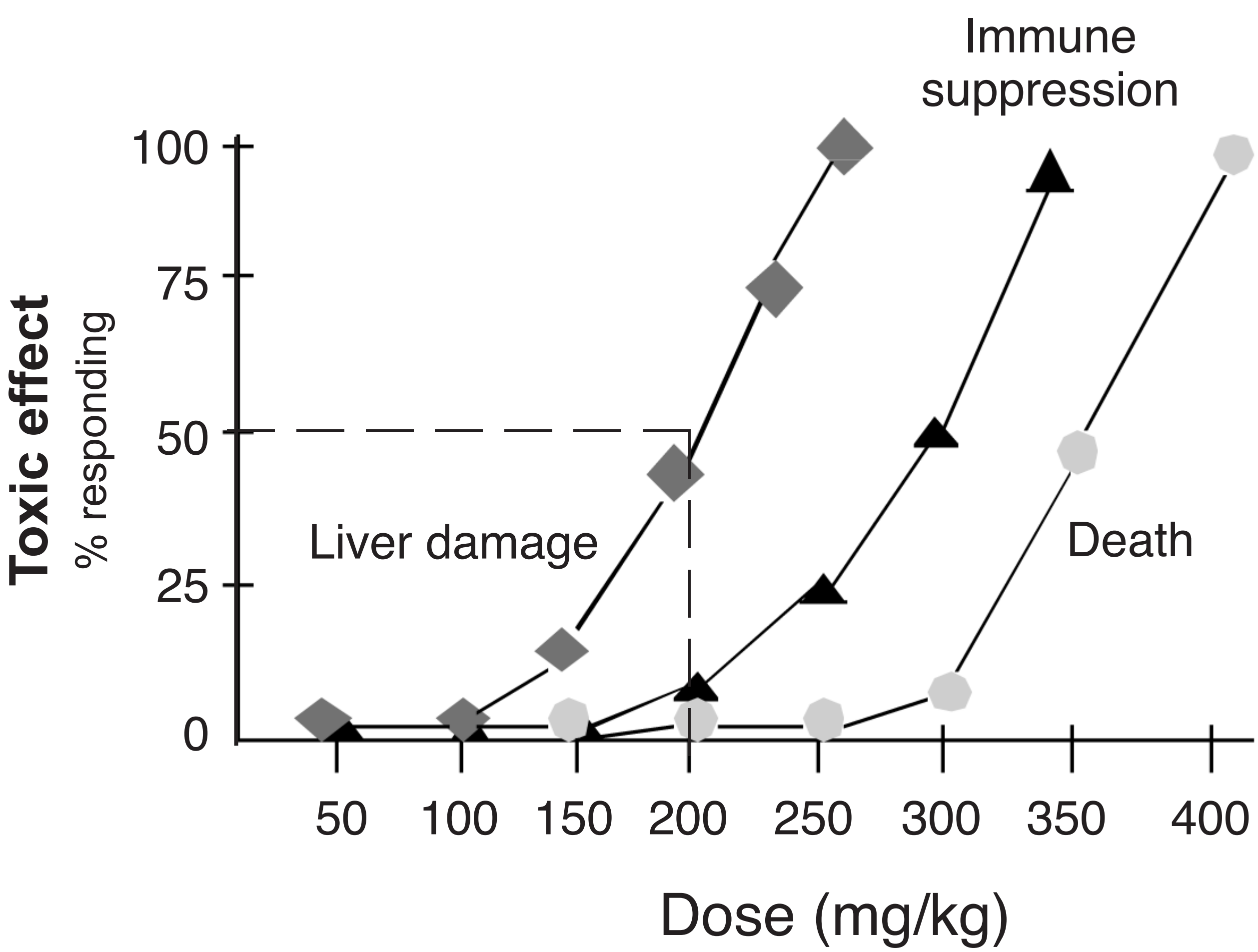
Transparency 1

Dose-response Curve

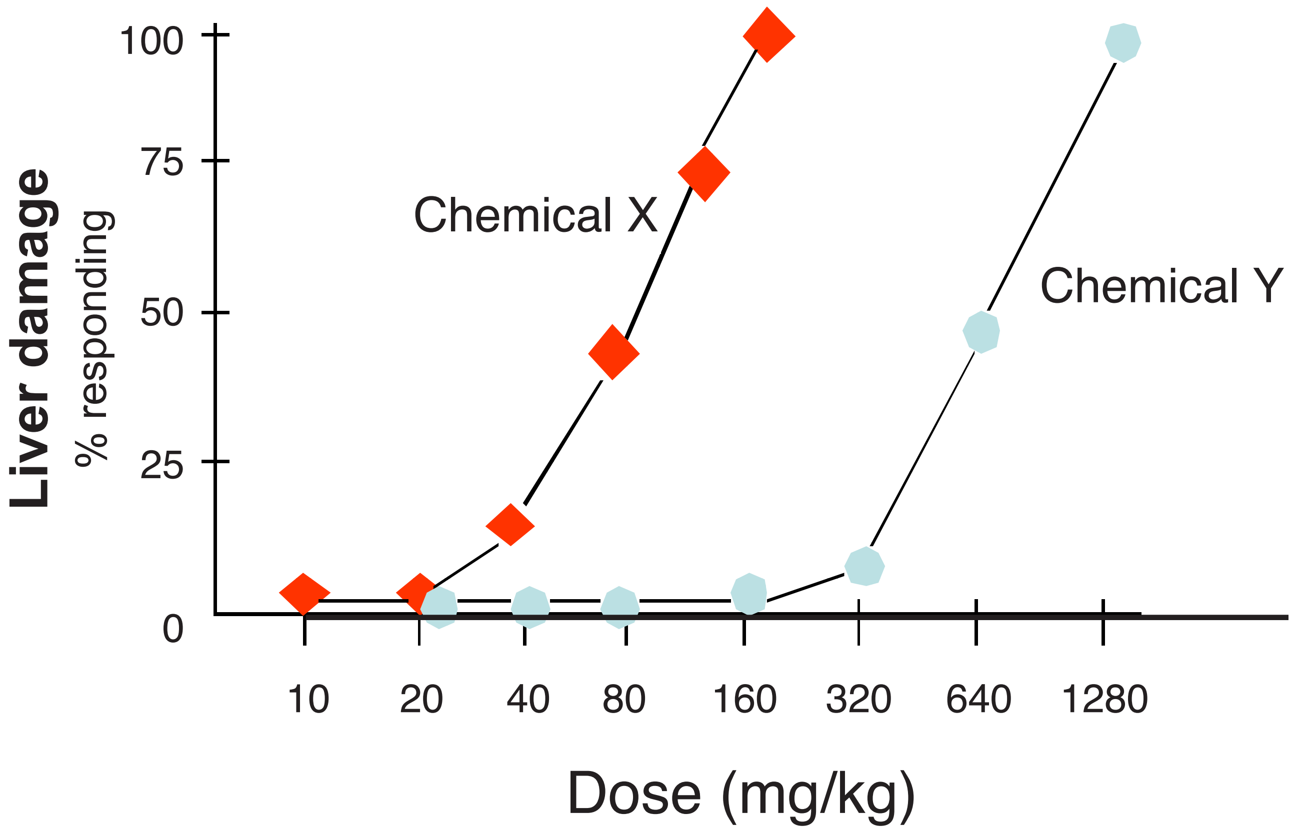


Dose(mg/kg)	Number of Deaths (%)	Dose(mg/kg)	Number of Deaths (%)
0	0/10 (0)	40	3/10 (30)
10	0/10 (0)	50	6/10 (60)
20	0/10 (0)	60	10/10 (100)
30	1/10 (10)	70	10/10 (100)

Dose Responses for Toxicity of "X"



Liver Damage Caused by Chemicals "X" and "Y"



Lethal Doses of Common Chemicals

Chemical	LD_{50} for Rats (mg/kg)	Approximate Amount for a Human*
Botulinum toxin (Botox®)	0.000001	microscopic
Aflatoxin (mold on peanuts)	2	minute dot
Rattle snake venom	10	0.1 teaspoon
Acetominophen (Tylenol®)	110	1.75 teaspoons
Aspirin	200	1 Tablespoon
Caffeine	200	1 Tablespoon
DDT	400	2 Tablespoons
Roundup®	>5000	1.5 cups

*Calculated from the LD_{50} for rats for a 160 lb human

Student Pages for

TOXICITY TESTING

Follow this Page

Toxicology – The Dose Makes the Poison

Paracelsus (1493), known as the "father of toxicology," said the following: "All substances are poisons; there is none that is not a poison." This means that any substance can be harmful if the dose is big enough. *Toxicology* is the science that studies the ability of chemicals to cause harmful effects. The harm a chemical causes a living organism is known as its *toxicity*. Examples of toxic effects from chemical exposure include cancer, birth defects and changes in different organs in the body (brain, liver, kidney, etc.)

The toxicity of any chemical depends on the following: properties of the individual substance, dose, frequency, duration, route of exposure, and individual susceptibility.

Properties of Individual Chemicals

Substances vary in their toxicity or harmful effects on humans based on their chemical structure and physical and chemical properties. These properties determine how quickly the chemical is absorbed in the body, how it is metabolized, the amount excreted, and what organs are affected. All chemicals interact with the body in different ways.

Dose

The amount of a substance that enters the body is called the *dose*. A common dose measurement is *mg/kg*, which stands for milligram of chemical per kilogram of body weight.

For example, the recommended dose of ibuprofen (the active ingredient in Advil) is 4 mg/kg. That would equal 200–400 mg for an adult weighing 50–90 kg (110–200 lbs). In comparison, the recommended dose for a 5-year-old who weighs 20 kg (45 lbs) is only 80 mg. The adult dose is more than twice as much as a child's dose and would be harmful if given to a small child. Children weigh less than adults, so it makes sense that they would take a smaller amount.

Frequency, Duration, and Route of Exposure

1. **Frequency (how often) –** Frequency of exposure refers to the number of times a person is exposed and the time between exposures. For example, drinking several cups of coffee a day for a year would not harm you, but drinking the amount of caffeine in all of those cups of coffee at one time would kill you.
2. **Duration (for how long)** – Duration refers to the length of the exposure. If it is once or twice in a short period of time, such as a week or less, it is referred to as an **acute exposure**. **Chronic exposure** is long-term or lifetime exposure, which for humans is considered 7 years or more.
3. **Route (exposure)** – Exposure occurs through eating, breathing, and skin absorption. The route of exposure influences how much is absorbed into the body and what the toxic effects will be.

Individual Susceptibility

When people are exposed to the same amount of a hazardous substance, different responses can occur. The variability in harmful effects results from *individual susceptibility*. Toxicity varies from person to person based on several factors:

- Body weight
- Gender
- Personal health
- Age
- Genetics

Dose-response Relationship

How do we know what amount of a substance is toxic? Because studies with humans are not allowed, toxicologists use animal models to determine the toxic effects that a chemical can cause and the doses at which those effects occur. Mice and rats are the subjects used in the majority of toxicology studies. Since the only human toxicology data on pesticides and industrial chemicals come from accidents, suicides, or occupational exposures, the animal data are used to predict safe levels of exposure for humans to these chemicals. In most cases, chemicals are tested in cell cultures to determine the mechanisms by which chemicals cause toxicity.

Toxicity Units

Toxicity of a chemical can be described in many different ways. Three common terms used are:

- **Lethal Dose 50 (LD_{50}) –** LD_{50} is the dose of a chemical that causes the death of 50% of an experimental group of animals. If the result of the exposure is not death but another effect, *toxic dose 50 (TD_{50})* is used. (See Table 1.)
- **Toxic Concentration 50 (TC_{50}) –** TC_{50} is the term used when observing the toxic effects of a solution of a chemical on experimental subjects (for example, fish, cells, or in this activity, radish seeds). It is the concentration of the chemical that causes 50% of the tested subjects to show the toxic effect.
- **No Observed Effect Level (NOEL) –** NOEL is defined as the highest dose or concentration tested at which the toxic effect is zero. The value for the NOEL is extrapolated from a dose-response curve.

Table 1. LD_{50} – Ingestion or Absorption of Various Substances

Substances	LD_{50} in mg/kg (for rats or mice)	Approximate amount for a 160 lb person*
Botulism bacteria (Botox)	0.000001	microscopic
Nicotine	1	minute dot
Caffeine	200	3 teaspoons
Metam sodium	750	4 Tablespoons
Roundup®	5,000	1.5 cups
Alcohol (ethanol)	7,000	2 cups

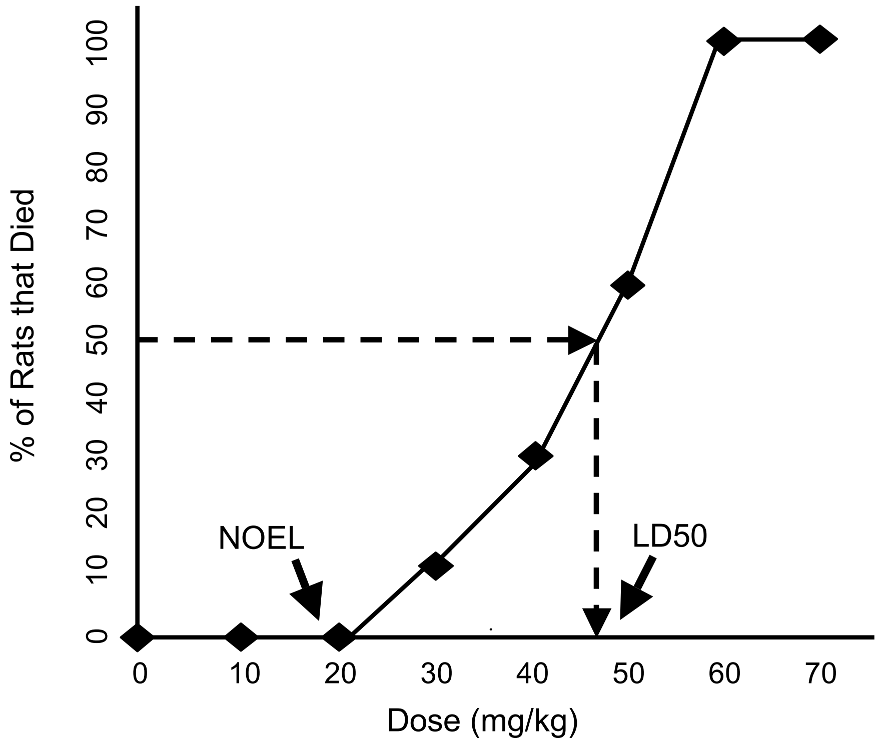
*Calculated from data on rats.

Reading, Page 3

Dose-response Curve

The LD_{50} and NOEL are determined from a graph called a *Dose-response Curve.* The graph is made from data collected during an experiment on rats to test the lethal dose of a chemical. There were 10 rats given each dose. The dose given to the rats in milligrams/kilogram body weight (mg/kg) is plotted on the X-axis. The percent of rats that died in each dose group is plotted on the Y-axis.

The LD_{50} (Lethal Dose 50) is determined by extrapolating a line from 50% dead on the Y-axis to the curve and then down to the X-axis as shown by the dotted line on the graph. The LD_{50} for this chemical is 46 mg/kg. The NOEL (No Observed Effect Level) for the chemical is shown with the arrow. It is the last dose on the graph for which there was no effect (zero deaths) in the experimental group of rats.



What Is Your Risk?

Risk is a measure of the probability that harmful effects will occur as a result of exposure to a certain chemical. Here's a good way to think about risk.

- If there is no exposure, there is no risk. If you do not smoke cigarettes or inhale second-hand smoke, then you have no risk of getting lung cancer from cigarette smoke.
- The duration of exposure affects the risk. If you begin smoking at an early age, you are at a higher risk of getting lung cancer than someone who starts smoking as an adult, because you have a longer exposure to the chemicals in cigarette smoke.
- The size of the dose affects the risk. If you smoke one pack of cigarettes per day, you are at greater risk of developing lung cancer than if you smoke one cigarette a day for the same time period.
- Your individual characteristics affect the risk. If you have asthma, you are at greater risk of developing lung cancer from cigarette smoke than someone without asthma. If you have a parent who has developed lung cancer, then your genetics increase your risk as well.

Reading for Understanding Questions

1. In your own words, describe what is meant by the phrase, "The dose makes the poison." Give an example.

2. Define the following terms.
   a. Toxicity:

   b. NOEL:

   What is the NOEL for the chemical shown on the *Dose-response Curve* ________mg/kg

   c. Lethal Dose 50:

   In Table 1, which substance has the highest toxicity (lowest LD_{50}?) ________________

   d. Toxic Concentration 50:

3. Name the six factors that affect the toxicity of a chemical.

4. In your own words, describe how the concepts of toxicity and risk relate to each other. Give an example that includes the six factors listed in question 3.

Instructions 1

Chemical Dilution Setup

Materials for Each Group:

- ☐ Six 50 mL beakers
- ☐ One 25 mL graduated cylinder
- ☐ One 10 mL graduated cylinder
- ☐ 50 mL of chemical in a 100 mL beaker (see chemicals to be tested)
- ☐ 100 mL of distilled water in a beaker
- ☐ Eyedropper
- ☐ Masking tape
- ☐ Permanent marker
- ☐ Safety glasses
- ☐ Latex gloves

Procedure:

1. Put on the latex gloves and safety glasses.
2. Use the masking tape and marker to label each of the six empty 50 mL beakers with numbers 1 to 6.

Beaker #	Amount of Water	Amount of Chemical	Total Volume of Liquid	% Concentration of Chemical
1	20 mL	0 mL	20 mL	0%
2	18.75 mL	1.25 mL	20 mL	6.25%
3	17.5 mL	2.5 mL	20 mL	12.5%
4	15 mL	5 mL	20 mL	25%
5	10 mL	10 mL	20 mL	50%
6	0 mL	20 mL	20 mL	100%

3. Use the 10 mL and 25 mL graduated cylinders to measure the correct amount of water. Pour the water into each of the labeled beakers according to the above table. Use the eyedropper for small corrections.
4. Use the 10 mL and 25 mL graduated cylinders to measure the correct amount of chemical. Pour the chemical into each of the labeled beakers of water according to the above table. Use the eyedropper for small corrections.

Instructions 1, Page 2

5. When you have finished, check that all the beakers contain 20 mL of chemical solution. If a beaker contains more or less than 20 mL, consult the above table and repeat the procedure for that beaker. Place the beakers in order on the tray, with 0% concentration on the left and 100% concentration on the right.
6. Return any unused chemical to your teacher. Wash all other containers and put them away.

Toxicity Testing on Seeds

Materials for Each Group:

- ☐ Masking tape
- ☐ Permanent marker
- ☐ Six sheets of 2-ply paper towels
- ☐ Six petri dishes (or resealable plastic sandwich bags)
- ☐ Latex gloves
- ☐ Safety glasses
- ☐ Six beakers containing 20 mL chemical solutions being tested (0% to 100% concentrations)
- ☐ Sixty radish seeds (about 1 teaspoon)

Toxicity Testing Setup – Procedure:

1. Before starting the experimental setup, define the problem and write a hypothesis based on testing the *dose* (your chemical at various concentrations) to a *response* (seeds not germinating). Record on Worksheet 1 what you think will happen to the seeds as the concentration changes.
2. Fold six sheets of paper towels into fourths (fold in half, and then fold in half again to make a square).
3. Place one folded paper towel into each petri dish or bag.
4. Write each group member's initials and the concentration of each chemical (0%, 6.25%, 12.5%, etc.) on a piece of masking tape. Make six labels, one for each petri dish or bag. See Table 1: Toxicity Testing on Germinating Seeds.

   Note: Petri dishes should be labeled on the bottom (not on the top) so you can see the seeds. If using resealable bags, put the label near the top.
5. Put on safety glasses and protective gloves. Starting with lowest concentration (0% control), carefully pour 20 mL onto the paper towel in the appropriate dish or bag.
6. Count out 10 radish seeds. Place the seeds on the moistened paper towel. Space out the seeds evenly so they have space to germinate.
7. Seal the container. If using resealable bags, gently flatten and squeeze out the air. Petri dishes should be taped shut on the sides (not on the top) so you can see the seeds.
8. Repeat steps 5–7 for the remaining chemical solutions.
9. Stack the dishes or bags with the seeds facing up. Your teacher will put them in a dark, warm area for 3 days.
10. Over the next 3 days, count the number of seeds that have not germinated. Record your data in Table 1.

Instructions 2, Page 2

Graphing Data

1. On graph paper, label the X-axis *Dose of*, insert name of chemical (*% concentration*), and label the Y-axis *Response (number of seeds not germinated)*.

2. Determine a scale for the X-axis, which represents the percentage of concentrations of your chemical: 0%, 6.25%, 12.5%, etc. Spread out the numbers so that they take up more than half of the graph.

3. On the Y-axis, make a scale from 0 to 10, which represent the number of seeds being tested. Again, spread out the numbers so that the 10 is more than halfway.

4. Plot the number of seeds that did not germinate for each concentration of chemical.

5. Draw a line that connects the points. It should not be a straight line, but a dose-response curve.

6. On the same graph, plot the test results from a different chemical that was tested. Draw the dose-response curve for this chemical using a different-color pen or pencil.

7. Make a key and title your graph.

8. Determine the Toxic Concentration 50 for each chemical and record your answer on Worksheet 1, page 2. In this experiment, you recorded the concentration of the chemical used rather than the dose (mg/kg). Use the same method explained in your reading for using a graph to find the LD_{50} of a chemical.

Worksheet 1

Name______________________________

Date_________________ Period______

Toxicity Testing on Seeds Lab Report

Problem:

Define the problem. (What are you trying to solve?)

What are the doses in your experiment?

What is the intended toxic response? (What will you measure?)

Hypothesis:

For example, "If various concentrations of chemical X are tested on the germination of radish seeds, I think that… (what will happen to the seeds?)"

Toxicity Testing Results:

Chemical tested ____

Important label words____

Table 1: Toxicity Testing on Germinating Seeds

Dish or Bag #	Dose % concentration	Response Day 1 # of seeds not germinated	Day 2 # of seeds not germinated	Day 3 # of seeds not germinated
1	0% (control)			
2	6.25%			
3	12.5%			
4	25%			
5	50%			
6	100%			

Worksheet 1, Page 2

Name______________________________

Date_________________ Period______

Conclusion Questions:

1. Read the product label of the chemical you tested. Describe what it is used for, if it has a signal word, and any recommendations for safe storage and handling.

2. What is the most likely route of exposure for humans to this chemical?

3. Toxic Concentration 50 results:
   a. What is the TC_{50} of the chemical you tested?
   b. What is the TC_{50} of the other chemical that you graphed?
   c. Which chemical is more toxic to radish seeds?

4. Explain the results of your experiment. In other words, put into words what you learned from your graph.

5. If another scientist were to repeat this experiment, what improvements would you recommend?

Worksheet 2

Name ______________________________

Date _________________ Period ______

Student Assessment

Toxicologists study the adverse effects of herbicides and pesticides in animal models before these chemicals are released for sale. Chemicals are often tested in laboratory animals such as rats or hamsters because the biological effects of the chemicals closely resemble what happens in humans.

In the past, 2,4,5-T was a commonly used herbicide. In 1971, two scientists named Collins and Williams tested the toxicity of 2,4,5-T on hamster fetuses. They gave different doses of 2,4,5-T to pregnant hamsters and collected the data below on how many of the developing hamster fetuses died. Based on data like this, federal agencies decided to regulate the use of this chemical.

Fetal Toxicity of 2,4,5-T*

Dose of 2,4,5-T to Mother (mg/kg)	Percent of Fetal Deaths
0	3%
20	32%
40	74%
50	85%
60	90%
80	94%
100	100%

**Collins and Williams, 1971*

1. Use this data to plot a dose-response curve on graph paper. Be certain to label the axes and title your graph.
2. Calculate the LD_{50} for 2,4,5-T in fetal hamsters. LD_{50} = _________________.

BACKGROUND ACTIVITY 3

PUMP IT UP! PART I – ANALYZING PUMPS

Description:

Students disassemble and reassemble a piston pump from a spray bottle, hand pump, or squirt gun to understand how a piston pump works.

Rationale:

During the Hydroville Pesticide Spill Scenario, the mechanical engineers need to apply general engineering principles because they will design and construct a pump to remove the pesticide.

Purpose/Goals:

Students will be able to:

- dissect and analyze the functional pieces of a squirt gun or spray bottle to understand how a piston pump works
- identify each functional part of a disassembled piston pump and describe how each part works
- describe the sequence of events that take place for a piston pump to work, i.e., how a squirt gun squirts water

Prerequisites:

None

Time Estimate:

Prep: 70 minutes (purchasing or collecting piston pumps/spray bottles and assembling or borrowing tools, dissecting one pump and gluing the parts to cardboard)

Activity: One 50-minute period

Materials:

Each Student:

- ☐ Hydroville Science Journal

Each Pair of Students:

- ☐ One squirt gun or hand pump (represents piston pump)
- ☐ One flathead screwdriver (for use as a prying tool)
- ☐ Safety glasses
- ☐ Beaker or dish tub filled with water (to test pump)

Class Materials on Tool Table:

- ☐ Assorted pumps (hand lotion bottles, bike pumps, spray bottles, etc.)
- ☐ Paper towels
- ☐ One disassembled piston pump (squirt gun/hand pump) with all the functional parts on display (optional)

Pages to Photocopy:

One copy/student of one of the following:

- (For squirt guns): Worksheet 1: *A Squirt Gun Dissection*
- (For hand pumps): Worksheet 1a: *A Hand Pump Dissection*
- (For both): Worksheet 2: *How Does a Squirt Gun Work?*

Teamwork Skill:

- Ask teammates for help if you need it.

Terminology:

Piston	Pressure	Volume
Pump cylinder	One-way flow valves	Reservoir
Inlet nozzle	Vacuum	Valve
Outlet nozzle	Nozzle	Spring
Positive displacement pump		

Background Information:

To understand the squirting mechanism of a piston pump, it is necessary to understand how a positive-displacement pump works. Positive-displacement pumps move a constant volume of fluid with each pumping action. In general, pumps work by making a space (volume) alternately bigger or smaller, thereby decreasing or increasing pressure.

A piston pump (Figure 1) works by moving a piston up and down in a cylinder. When the piston is lifted, the intake valve opens and fluid moves in to fill the empty space (as volume increases, pressure decreases). When the piston is moved downward, the outlet valve opens and the fluid is pushed out (as volume decreases, pressure increases). Therefore, by opening and closing valves at the right times, the pump can move fluid by creating differences in volume, which decreases pressure (vacuum) or increases pressure (spray).

Examples of piston pumps are everywhere. The pumps on bottles of kitchen cleanser, certain brands of hand lotion and shampoo, bicycle pumps, spray bottles, and squirt guns are all piston pumps.

When the piston (the trigger) on a squirt gun is released, a small piston pump draws water into the pump cylinder from a water source through an inlet. Once the cylinder is filled, a valve prevents the water from leaking back into the water source. When the piston/trigger is squeezed, another valve opens and the piston forces water out of the pump cylinder, tubing, and nozzle of the gun (Figure 2).

An alternative to using squirt guns is for students to dissect a hand or squirt pump. This is also a piston pump (Figure 3).

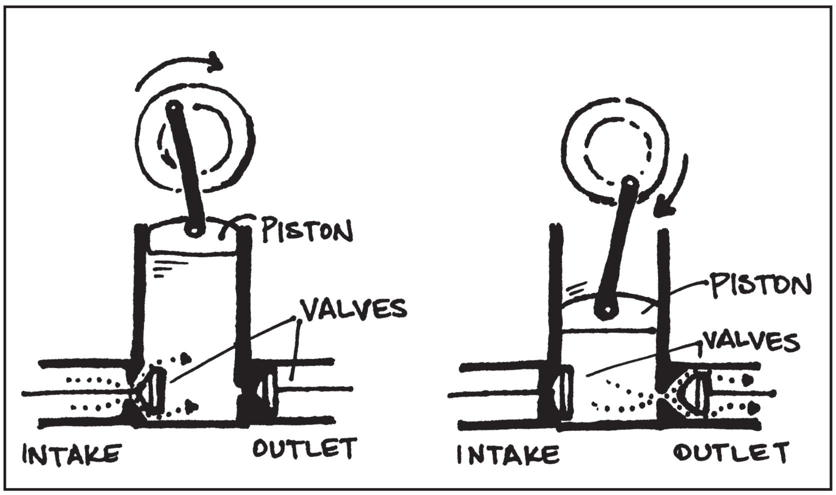


Figure 1. A Piston Pump

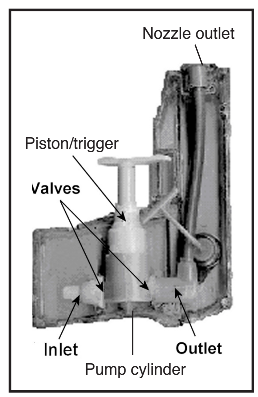


Figure 2. Squirt Gun as a Pump

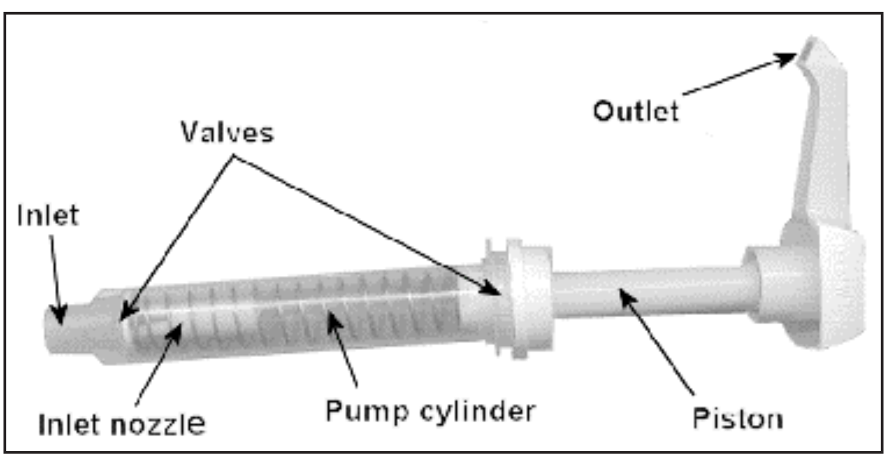


Figure 3. Parts of a Squirt Pump

Suggested Lesson Plan:

Getting Started

1. **Concerns about gun replicas in schools**: It may be necessary to obtain permission from your school administration before doing this activity. One option is to disassemble the plastic casing from the squirt guns prior to the start of the lab, which also saves class time. Give students the internal parts, which will no longer look like a gun. Also, spray bottles or hand pumps that students bring from home can replace the squirt guns in this activity.
2. Assemble materials for each pair of students. Have tables and equipment available for students to dissect squirt gun casings using metal flathead screwdrivers. To save class time, you may opt to dissect the squirt gun casings yourself.
3. Display the various pumps that you have collected (hand lotion bottles, bike pumps, spray bottles, etc.) to assess what students know about pumps and how they work.
4. **Journal Prompt**: "Describe how a squirt gun or spray bottle works."

Doing the Activity

1. Give each pair of students a squirt gun or pump from a spray bottle. Students need to dissect a squirt gun (piston pump) in order to understand how the parts fit together and their function.
2. **Safety Issues:** Caution students to be careful when removing the plastic casing, and make sure safety glasses are worn at all times. If safety glasses are not available, then it's a good idea for you to do the initial dissection.
3. **NOTE:** Removing the plastic casing from the squirt gun without damaging the inside pump mechanisms is the hardest part of this activity. To crack open the casing, use a flathead screwdriver and then work the screwdriver between two halves of the pump at the glue seam. Once the screwdriver is wedged between the casing, pry the plastic casing until you hear the plastic *pop* or *give*. Carefully repeat this process along all edges of the pump until the halves separate.
4. Display a disassembled pump with all the function parts for comparison. If students destroy their pumps upon dissection, there is a sample pump intact for reference.
5. Once the plastic casing is removed, students can disassemble the pump mechanism inside the squirt gun. Set up beakers of cups or water for them to use to observe how a piston pump operates.
6. Have students label the functional part of a pump (on their student worksheets) before moving on to step 2.

7. Check to see that students succeeded in reassembling their piston pumps. Do the squirt guns still squirt water? **NOTE**: Some tips for getting reassembled pumps to squirt include: (1) ensuring that all of the seals are tight and (2) making sure that the valves that surround the piston are replaced in the correct direction.

Wrap-up

1. **Journal Prompt:** "Why does the water flow into the pump cylinder when the trigger on the pump is released?"

   Answer: When the trigger is released, the piston in the pumping mechanism moves upward, increasing the volume of air within the cylinder. As a result, an area of low water pressure or a vacuum is created. Water will fill the pump cylinder to equalize the pressure inside and outside the cylinder. A one-way valve will close to keep the water contained within the cylinder.

2. Assign Worksheet 2: *How Does a Squirt Gun Work?*

Assessment:

How Does a Squirt Gun Work?

1. Did the student explain how a squirt gun (piston pump) works?
2. Did the student include and describe the function of all six parts?
3. Did the student include an explanation of pressure and volume?

Extensions:

Language Arts Extensions

1. Research the life of Robert Boyle on the Web.
2. Write the sketch of his life, setting it in today's culture. Write a 1-page article for *Weekly Parade*, the insert in the Sunday newspaper.
3. Remember to include interesting facts, a glimpse at his personality, and a clear description of his discoveries. In other words, who is Robert Boyle, what was he like, how did he investigate and discover the relationship between the volume of a gas and the pressure applied to it?
4. Have your article reviewed and proofread by one of your classmates, and then revise the article.

   Students can share their articles with the class by reading them aloud.

Resources:

- Toys-R-Us and other party stores carry small squirt guns in their "party favor" section (about $4 for a pack of 10).
- An industrial cleaning supply store will sell the pumping mechanism without the bottle. To order individual "trigger sprayers" without a spray bottle (about $1 each), contact MSC Industrial Supply Co., 1-800-645-7270.
- How Stuff Works. How Water Blasters Work. Tom Harris. The Classic Water Gun.
- The Internet Glossary of Pumps. (See Piston Pump).
- See the Hydroville Web site for links to Web resources for this activity at http://www.hydroville.org/links/ps_resources.aspx.

Teacher Key

Worksheet 1

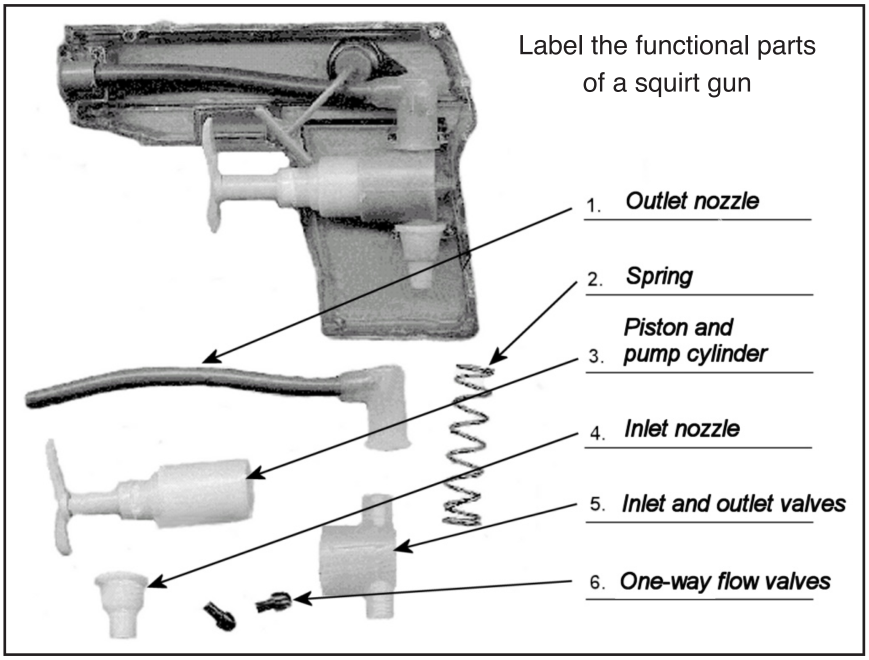


Figure 4. Functional Parts of a Squirt Gun

Worksheet 1a

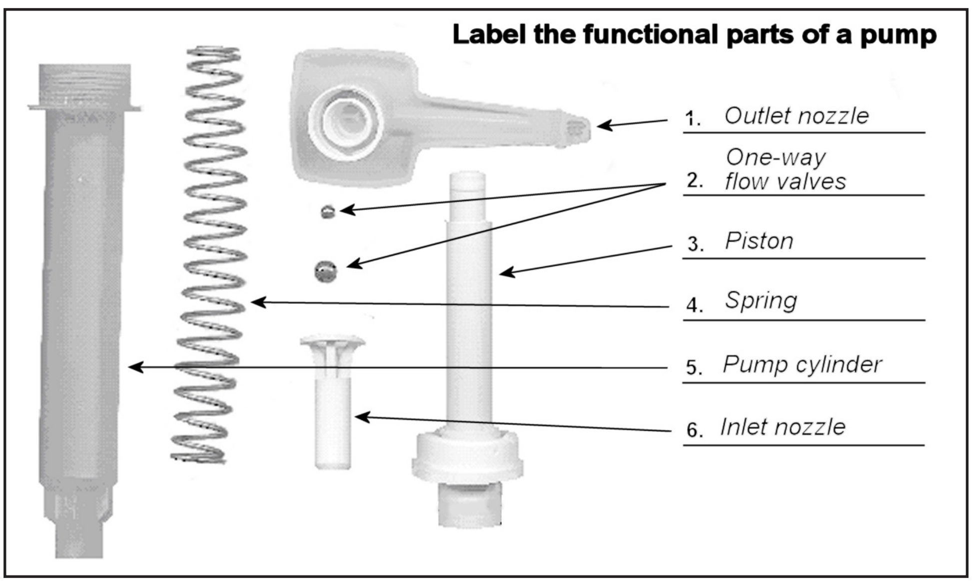


Figure 5. Functional Parts of a Hand Pump

Worksheet 2

When the trigger on a squirt gun is released, a small piston (housed in a cylinder) and controlled by a spring moves upward. When the piston moves upward, the space or volume inside the cylinder increases. When the volume in a closed container increases, the air pressure inside decreases. This is known as an opposite or inverse relationship between pressure and volume.

By creating a low-pressure area or vacuum, the water that is stored in the base of the squirt gun gets drawn up through an inlet into the cylinder. Once the cylinder is filled with water, a one-way valve closes and prevents the water from leaking back into the reservoir.

When the trigger is squeezed, the piston pump moves downward, decreasing volume and increasing pressure, which forces water out of the pump cylinder and through an outlet or nozzle. The one-way valve opens at the top, allowing the water to spray out, and the one-way valve at the bottom closes.

Student Pages for

PUMP IT UP! PART I – ANALYZING PUMPS

Follow this Page

Worksheet 1

Name________________________________

Date__________________ Period_______

A Squirt Gun Dissection

Materials:

Each Student:

- ☐ Hydroville Science Journal

Each Pair of Students:

- ☐ One squirt gun or hand pump (represents piston pump)
- ☐ One flathead screwdriver (for use as a prying tool)
- ☐ Safety glasses
- ☐ Beaker or dish tub filled with water (to test pump)

Safety Issues:

Use caution when removing the plastic casing. Make sure you are wearing safety glasses when dissecting the squirt guns.

Procedure:

1. Working in pairs, dissect a squirt gun to learn how a piston pump operates.
2. To pry open the plastic casing, wedge the tip of the screwdriver between two halves of the casing at the glue seam. Once the screwdriver is wedged between the two halves of the plastic casing, pry the casing until you hear the plastic *pop* or *give*. Carefully repeat this process along all edges of the pump until the halves separate. **NOTE:** Try not to damage the inside mechanisms.
3. Remove the internal pump mechanisms of the squirt gun. Before disassembling it, spray it to figure out how it works. Use the water source to test it out.
4. Identify the function of each part of the pump mechanism, and label the functional pieces of a squirt gun in the diagram.
5. In your Science Journal, write a step-by-step procedure that describes how a pump, such as that found in a squirt gun, moves water.
6. Reassemble the pieces of the pump mechanism so that it will squirt water. Show your teacher.

Name______________________________

Date_________________ Period______

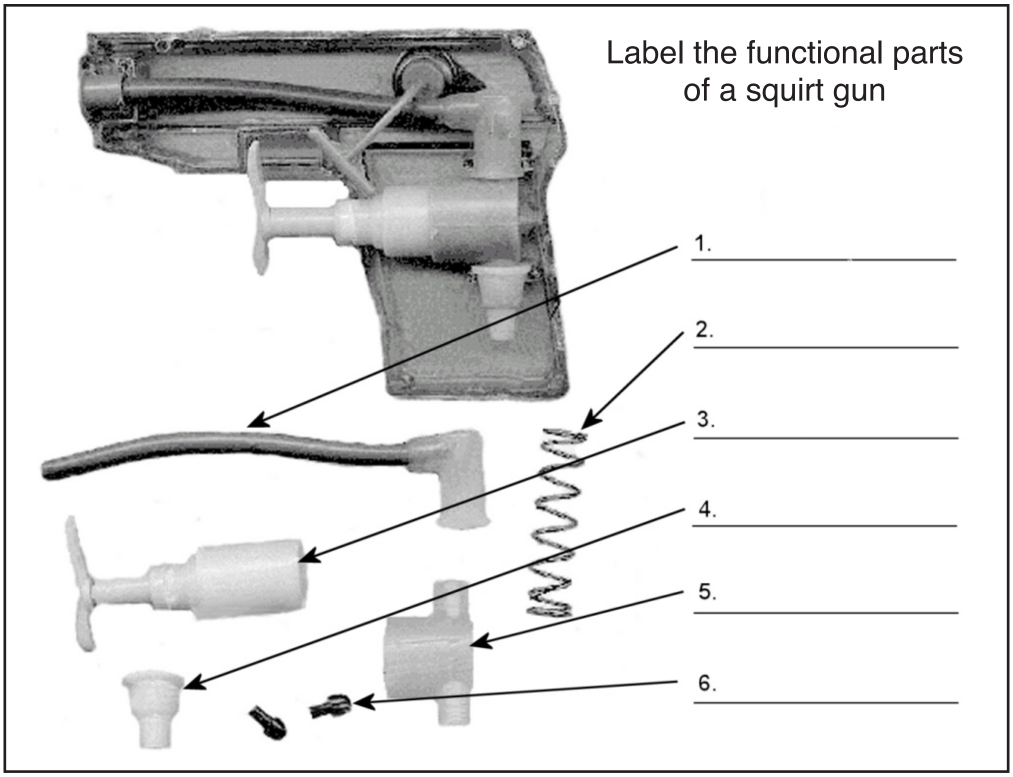


Figure 4. Functional Parts of a Squirt Gun

- **One-way flow valves:** Allows water to flow in one direction.
- **Piston and pump cylinder:** The piston moves back and forth, increasing or decreasing the volume of space in the pump cylinder.
- **Outlet nozzle:** Releases pressurized water, which flows in a concentrated stream.
- **Inlet nozzle:** Allows water to enter into the pump cylinder from a reservoir.
- **Spring:** The mechanism that controls the piston.
- **Inlet and outlet valves:** Controls the flow of water entering and leaving the pump cylinder.

Worksheet 1a

Name______________________________

Date_________________ Period______

A Hand Pump Dissection

Materials:

Each Student:

- ☐ Hydroville Science Journal

Each Pair of Students:

- ☐ One hand pump (represents piston pump)
- ☐ Beaker or cup filled with water (to test pump)

Procedure:

1. Working in pairs, dissect a hand pump to learn how a piston pump operates.
2. Remove the internal pump mechanisms of the hand pump. Before disassembling it, spray it to figure out how it works. Use the water source to test it out.
3. Identify the function of each part of the pump mechanism, and label the functional pieces of a hand pump in the diagram.
4. In your Science Journal, write a step-by-step procedure that describes how a pump, such as that found in a hand pump, moves water.
5. Reassemble the pieces of the pump mechanism so that it will squirt water. Show your teacher.

Name________________________________

Date__________________ Period______

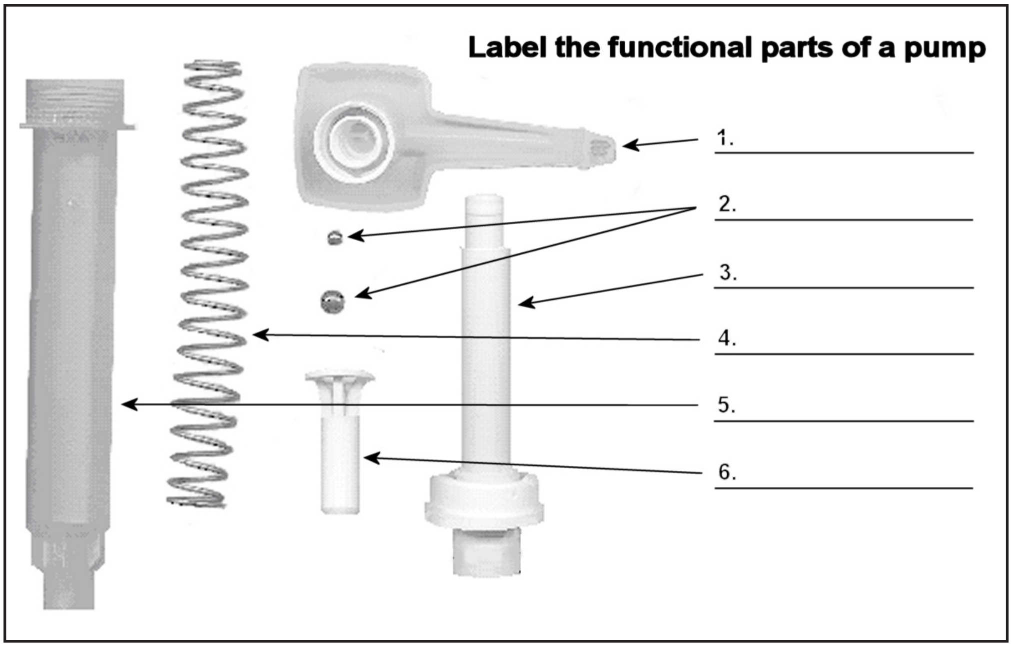


Figure 5. Functional Parts of a Hand Pump

- **One-way flow valves:** Allow water to flow in one direction.
- **Piston:** The piston moves upward or downward, increasing or decreasing the volume of space in the pump cylinder.
- **Pump cylinder:** The pump cylinder houses the piston.
- **Outlet nozzle:** Releases pressurized water, which flows in a concentrated stream.
- **Inlet nozzle:** Allows water to enter into the pump cylinder from a reservoir.
- **Spring:** The mechanism that controls the piston by moving it up or down, which increases or decreases the volume.
- **Inlet and outlet valves:** Control the flow of water entering and leaving the pump cylinder.

Worksheet 2

Name ______________________________

Date _________________ Period ______

How Does a Squirt Gun Work?

Imagine you are writing a description of how a squirt gun works for the Web site, "How Things Work." Since many school-age children access this site, you need to write at a level that a third-grader would understand.

1. Review the step-by-step procedure you wrote that describes how a pump works.

2. In your Science Journal, combine these steps into a few paragraphs that explain the sequence of events that takes place to squirt water from a squirt gun. Start with a paragraph that describes how the water enters the inlet nozzle. Include all of the steps until you end your essay with a description of how water exists the outlet nozzle.

3. When you describe how a squirt gun or hand pump (piston pump) works, what new terms or words need to be defined? Give the word, followed by a brief phrase in parentheses. For example, "A piston is a round disk that moves inside a cylinder like a flat bubble in a straw." This is your first draft.

4. Revise your draft to include the following information:
   - A series of steps which describe the entire process – when water enters the inlet nozzle and continues until water exists the outlet nozzle.
   - Include all of the functional parts: one-way flow valves, piston, pump cylinder, outlet nozzle, inlet nozzle, spring, and inlet and outlet valves.
   - Describe the relationship between pressure and volume and how this interaction causes a pump to work.
   - Use illustrations to help explain the process.
   - Include title and purpose statement.

5. Have your essay reviewed and proofread by a classmate.

6. As you revise your paper, check your spelling, grammar, and punctuation.

7. Now you are ready to publish.

BACKGROUND ACTIVITY 4

PUMP IT UP! PART II – DESIGNING A SUPER SOAKER

Description:

Students apply their understanding of piston pumps to create a functional Super Soaker-type pump.

Rationale:

During the Hydroville Pesticide Spill Scenario, the mechanical engineers need to demonstrate their understanding of pump design by applying it in a new situation using similar materials.

Purpose/Goals:

Students will be able to:

- apply prior knowledge of piston pumps to design a Super Soaker-type pump
- design and build a functional Super Soaker that meets specific requirements
- organize a team presentation to explain how the Super Soaker model works

Prerequisites:

Background Activity 3: Pump It Up! Part I – Analyzing Pumps

Time Estimate:

Prep: 45 minutes to assemble materials (have students bring in plastic soda bottles)

Activity: Three or four 50-minute periods:

- Day 1: A Super Soaker Demonstration and Model Design
- Day 2: Build and Test Model
- Day 3: Super Soaker Competition
- Day 4: Team Presentation of Models (Language Arts Extension – optional)

Materials:

- ☐ Drill and 17/64" drill bit (for drilling holes in soda bottle lids)

Each Student:

- ☐ Hydroville Science Journal

Each Group of Two to Three Students:

- ☐ Two tubing (shut-off) clamps
- ☐ One 60 cc syringe
- ☐ One 1/8" Y-connector (fits 1/8" inner-diameter vinyl tubing)
- ☐ Three feet of 1/8" inner-diameter vinyl tubing (1/4" outer diameter)
- ☐ One 20-oz. plastic soda bottle WITH LID

Class Materials on Tool Table:

- ☐ One Super Soaker-type squirt gun (for demonstration)
- ☐ Scissors
- ☐ Paper towels
- ☐ Waterproof tape, duct tape, or electrical tape
- ☐ Hot glue gun with glue sticks

Additional Supplies:

- ☐ Extra shut-off clamps
- ☐ Lids with two holes drilled
- ☐ 1/8" T-connectors
- ☐ 1/8" Y-connectors
- ☐ Various nozzles to attach to end of tubing

Pages to Photocopy:

One copy/student:

- Worksheet: *Designing a Super Soaker Model*

Teamwork Skill:

- Encourage others in the group to participate.

Terminology:

Super Soaker

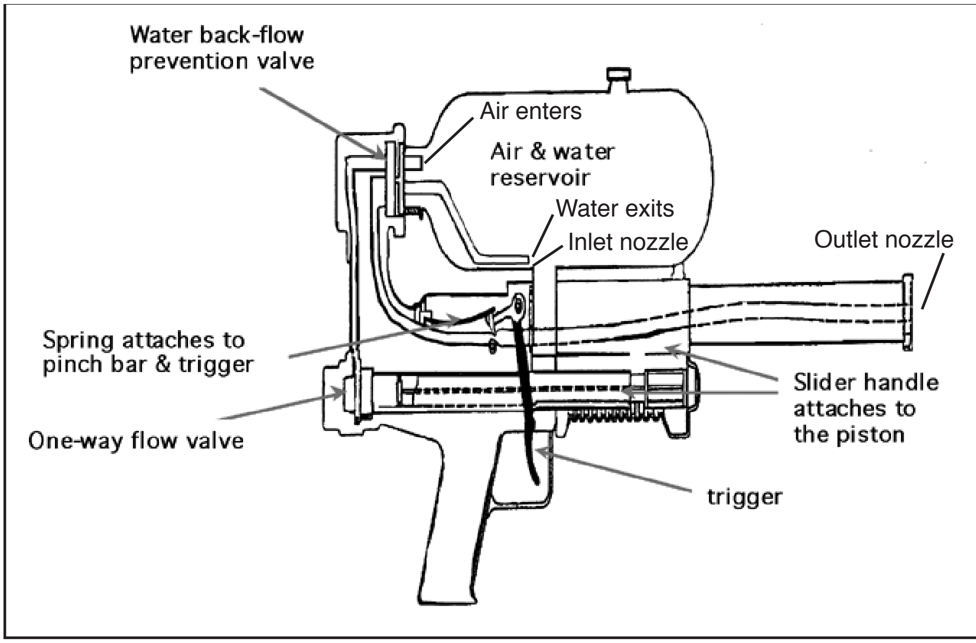


Figure 1. Super Soaker Cross-section with Labels

Background Information:

Super Soakers operate like a regular squirt gun, with one exception: a Super Soaker has a manually operated pump incorporated into the design of the soaker (Figure 1). The water reservoir in a Super Soaker is also a reservoir for air. As the slider handle is pumped, the pressure of the air in the reservoir increases. The water in the pressurized reservoir is released through the nozzle at this high pressure when you pull the trigger. Since the water leaving the nozzle is pressurized, the water stream is propelled further and lasts longer than a regular squirt gun. In contrast, regular squirt guns release only as much water as is contained in the piston pump chamber with each squeeze of the trigger.

Suggested Lesson Plan:

Getting Started

1. **Concerns about gun replicas in schools:** It may be necessary to obtain permission from school administration before doing this activity.
2. Order supplies from the following suppliers: Fisher Scientific, 1-800-766-7000, or Ward's, 1-800-962-2660. You may also find these items at a hardware store.
3. Have students bring in 20-oz. plastic soda bottles with lids. Drill 17/64" size holes in bottle lids. Some lids can have two holes (at the students' request). Or you may allow your students to drill holes. Assemble class materials for tool table.
4. **Journal Prompt:** "How do you think a squirt gun differs from a Super Soaker?"
   Answer: A squirt gun will squirt a consistent amount of water and should have a limited range when the trigger is squeezed. The air and water reservoir of a Super Soaker (analogous to the pump cylinder in a squirt gun) makes it possible to squirt a large amount of water for long

distances, since pumping the Super Soaker will build up pressure in the reservoir.

5. Have one student demonstrate a Super Soaker for the class and share ideas about what is happening. Suggested questions for discussion:
   - What happens if you completely fill the reservoir with water?
     It should be difficult to pump the gun, because the Super Soaker has a common reservoir for both air and water.
   - What happens if you hold the trigger down for a long time?
     The stream of water from the Super Soaker should decrease in velocity the longer the trigger is held down.
   - What happens if you don't pump the gun?
     The Super Soaker will not shoot as far or as long when the pressure in the reservoir is low.
   - How does it feel as you continue to pump the Super Soaker?
     The more you pump the Super Soaker, the more difficult it will be to pump as more air is forced into the air and water reservoir.
   - What is the difference between pumping the gun once instead of multiple times?
     The water should be expelled from the gun at a greater velocity when the gun is pumped multiple times.
6. After observing the demonstration, have students complete page 1 of the Worksheet. They need to describe how they think a Super Soaker works. If time allows, have them research this information. See Resources for a list of Web sites.

Doing the Activity

1. Introduce *Step 2. Super Soaker Model Design* as a scientific inquiry. Present students with the challenge: "As a team, you will create a pump, using the materials provided, that shoots a spray of water at least 5 feet for 15 seconds."
2. Explain to students that there will be a contest for the Super Soaker that meets all of the performance criteria. Which model will shoot the farthest for the longest amount of time?
3. Have students work in groups of two or three to create/draw a design for a pump using the materials provided. They need to identify the parts of the pump and explain how it will work on the diagram of the design.
4. Students should have a drawing and an explanation of their design BEFORE starting to build. Some teachers require two possible designs, which helps the students think through which would be more effective.
5. In *Step 3. Super Soaker Design Approval*, review each group's design and make certain that they meet the design requirements before

building the models. The pumps need to have a water/air reservoir and a way of building up the pressure in the reservoir before the water is expelled.

6. Once their design has been approved, the group should build a prototype of their pumping system ("Super Soaker") that meets the criteria in *Step 4. Build and Test Model for Competition.* Allow students to test their models and make as many modifications to their design as they need and as time allows.
7. **Safety Issues:** Students should be instructed on how to safely operate a hot glue gun. Also, students should be advised in drilling holes in the bottle lids if you have not already done so.

   Classroom Hints:

   - Students should understand how the materials represent the various functional parts of a piston pump (squirt gun). For example, the syringe represents the pump and pump cylinder. The clamps act as one-way valves and the bottle is the reservoir.
   - The major problem with building a functional "Super Soaker" is the inability to form tight seals around the bottle lids so that pressure can be built up in the bottle.
   - Hot glue may be used to form a seal around the tubing that enters the lid. When using the glue gun, it is advisable to avoid gluing near the threading of the cap. If students hold the glue guns too close to tubing or plastic, it will melt. Silicon may be used, but it takes longer to dry. Other materials that may be used include electrical tape or duct tape.
   - Models that meet the performance criteria will have the reservoir filled only halfway with water, leaving plenty of space for air to pressurize in the bottle.
   - Some teachers use an additional day for students to modify their designs and have a second contest.
8. Hold a "Super Soaker" contest outside. Check performance criteria of each model.

Wrap-up

1. Review *Step 5. Super Soaker Model Presentation* with groups. Give students time to prepare speeches.
2. Teams demonstrate and explain to the class or to other groups how their Super Soaker-type pump works.
3. Save all materials for the *Mechanical Engineer Expert Group*.

Assessment:

1. Building a model
2. Grade students on meeting the performance criteria.
3. Teamwork
4. (optional) Team presentation (Language Arts)

Extensions:

Science

1. Have students design and build a pump that will draw up or expel the water in some way other than using a piston.
2. See if students can vary their design to increase the distance that the water is propelled by the pump, or if they can design a pump that can propel the water more than 30 feet.

Language Arts

1. Have students conduct a Web search of the U.S. Patent and Trademark Office for squirt gun patents. Students should write a patent description of their Super Soaker design.
2. Read the description of Boyle's Law found at http://members.aol.com/profchm/boyle.html. You are to teach the principles of Boyle's Law to 5th graders. Your assignment is to design a handout using the action of a syringe or the diaphragm to illustrate Boyle's Law. As you work on your handout, think about what 5th graders know about the concept of gases, pressure, and volume. What information do they need? Use simple illustrations and brief explanations. Is there an activity that you could ask the 5th graders to do that would demonstrate whether they understood your explanation?

Social Studies

1. Students can create a detailed timeline tracing the changes in squirt gun design and construction since their inception. The timeline should be broken into decades.
2. Students should try to make connections between major historical events/trends and changes in squirt gun design. (*For example, the late 1960s may have brought about more space travel-influenced designs.*)

Resources:

- U.S. Patent & Trademark Office Searchable Database.
- Searchable database by Patent Number.
  "Pinch trigger pump water gun" Patent Number: 5,305,919
  "Double tank pinch trigger pump water gun" Patent Number: RE35, 412
- How Stuff Works. How Water Blasters Work. Tom Harris.
- See the Hydroville Web site for links to Web resources for this activity at http://www.hydroville.org/links/ps_resources.aspx.

A Super Soaker Demonstration

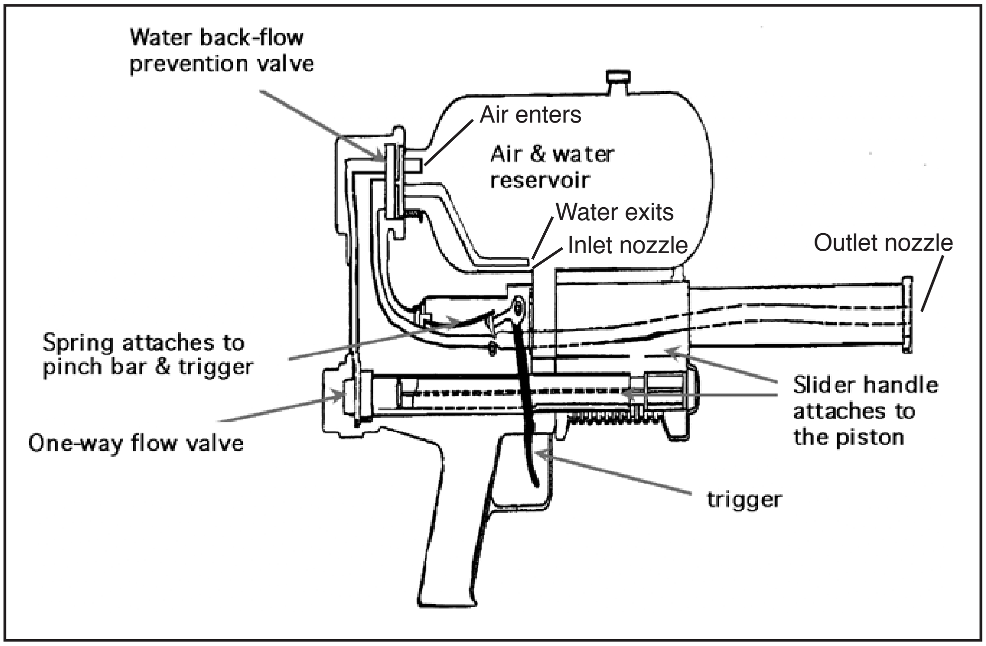


Figure 1. Super Soaker Cross-section with Labels

Step 2. Super Soaker Model Design

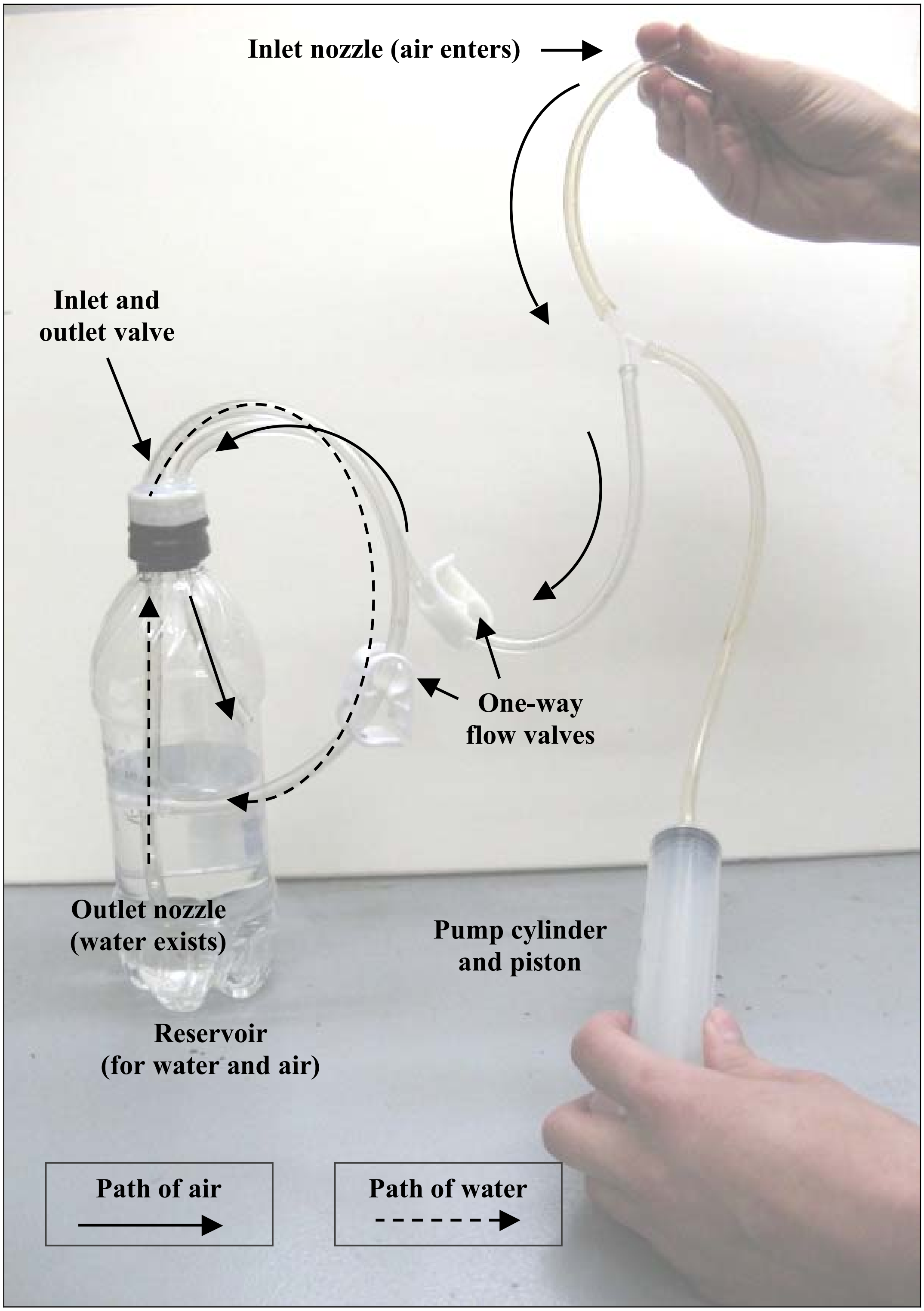


Figure 2. Example of Super Soaker Model

Student Pages for

PUMP IT UP! PART II – DESIGNING A SUPER SOAKER

Follow this Page

Worksheet

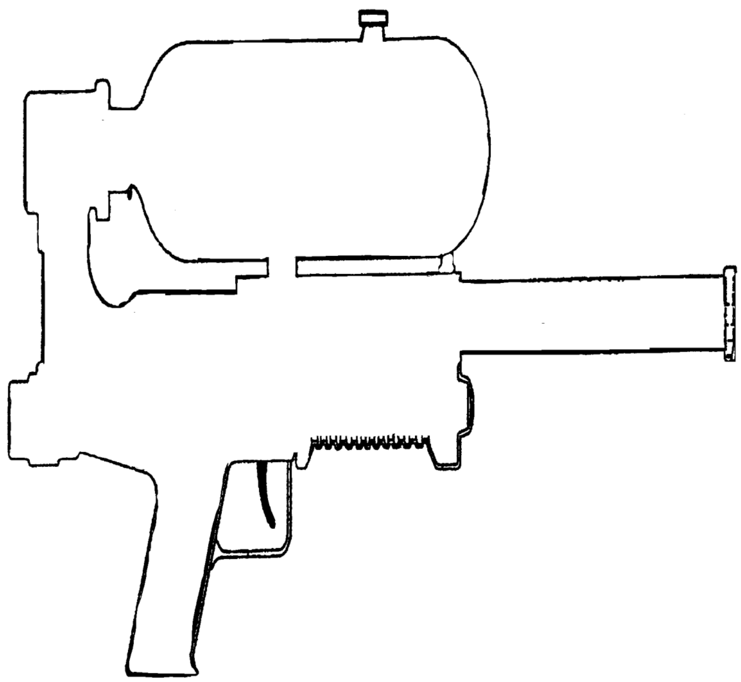
Name ______________________________

Date ________________ Period ______

Designing a Super Soaker Model

Step 1. A Super Soaker Demonstration

1. Observe the demonstration of a Super Soaker.
2. Using the drawing below and your knowledge of piston pumps, draw in the parts on the diagram and explain in a series of steps how the Super Soaker pumping system works.
3. Label reservoir, trigger, one-way flow valves, spring, piston, cylinder, inlet nozzle, and outlet nozzle.



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Worksheet, Page 2

Name____________________________

Date________________ Period______

Step 2. Super Soaker Model Design

Materials:

Each Student:

- ☐ Hydroville Science Journal

Each Group of Two to Three Students:

- ☐ Two tubing (shut-off) clamps
- ☐ One 60 cc syringe
- ☐ One 1/8" Y-connector (fits 1/8" inner-diameter tubing)
- ☐ Three feet of 1/8" vinyl tubing
- ☐ One 20-oz. plastic soda bottle WITH LID
- ☐ Materials on tool table

Procedure:

1. Working in groups of two to three students, design a model of a Super Soaker-type pump. The pump must have the following performance criteria:
   - Be constructed using only the materials provided.
   - Propel water at least 5 feet.
   - Shoot water for at least 15 seconds.
2. Draw your design in your Science Journal.
3. Label the functional parts of the soaker on your drawing, including:
   - Piston
   - Pump cylinder
   - Inlet nozzle
   - Outlet nozzle
   - One-way flow valves
   - Reservoir
   - Inlet and outlet valves
4. Briefly describe the function of each part, next to the label.

Step 3. Super Soaker Design Approval

Have your instructor review and initial your design before beginning to build your model.

____

Worksheet, Page 3

Name ______________________________

Date _________________ Period ______

Step 4. Build and Test Model for Competition

1. Using your approved design, build and test your model of a Super Soaker.
2. You may need to modify the design of your model after running a few preliminary tests.
3. Check to see if your model meets the following performance criteria:

Performance Criteria

☐ Get teacher's approval for Super Soaker design.

☐ Constructed from only the materials provided?

☐ Propel water at least 5 feet?

☐ Shoot water for 15 seconds?

☐ All participants participated in designing, building, and testing the model?

_________ **Score**

5 = Excellent
4 = Very Good
3 = Okay

Step 5. Super Soaker Model Presentation

1. Your team will have 5 minutes to present and describe your model to the class.
2. Choose a leader to help the team plan the presentation.
3. All members of the team should participate in planning the presentation and design of materials.
4. Agree on the key information to share.
5. Elect a spokesperson who will talk while others demonstrate.
6. Show your design plans and Super Soaker model.
7. **Practice** your presentation.

BACKGROUND ACTIVITY 5

CONSTRUCTING AND ANALYZING GRAPHS – CIRCUMFERENCE AND DIAMETER

Description:

Students learn how standards are derived by finding the mathematical ratio *pi* and applying this standard to unknowns.

Rationale:

During the Hydroville Pesticide Spill Scenario, the analytical chemists create a standard for metam sodium to determine unknown concentrations.

Purpose/Goals:

Students will be able to:

- understand that standards can be used to identify unknown data
- practice taking accurate measurements
- construct a graph with a line of best fit
- recognize that pi is a standard

Prerequisites:

Students are able to:

- use measurement tools accurately
- determine a reasonable scale to use when graphing
- plot points on a coordinate graph
- find the slope of a line
- draw a line of best fit (trend line)

Time Estimate:

Prep: 10 minutes

Activity: One 50-minute period

Materials:

Each Student:

- ☐ Hydroville Science Journal
- ☐ Graph paper (five squares/inch)

Each Group of Two Students:

- ☐ Round objects
- ☐ Rulers
- ☐ Tape measures (or string)
- ☐ Calipers (optional)
- ☐ Calculators (for calculating slope)

Pages to Photocopy:

One copy/student:

- Worksheet 1: *Constructing and Analyzing Graphs*
- Worksheet 2: *Scored Classroom Assignment – Mathematics* (optional)

Teamwork Skill:

- Everyone contributes and helps.

Terminology:

Π, Pi	Standard	Independent variable
Circumference	Quality check	Trend line
Diameter	Unknowns	Line of best fit
Scatter plot	Dependent variable	Slope

Background Information:

Origins of Measurements

In ancient times, the body ruled when it came to measuring. The length of a foot, the width of a finger, and the distance of a step were all accepted measurements. At first an inch was the width of a man's thumb. In the 14th century, King Edward II of England ruled that 1 inch equal 3 grains of barley placed end to end lengthwise. In ancient times, the foot was 11-1/42 inches. Today it is 12 inches, the length of the average man's foot. A yard was originally the length of a man's belt or girdle, as it was called. In the 12th century, King Henry I of England fixed the yard as the distance from his nose to the thumb of his outstretched arm. Today it is 36 inches, about the distance from nose to outstretched arm of a man.

For more information, see "Notes on Pi." Witcombe, Chris. *Earth Mysteries*. Sweet Briar College. September 29, 1999. http://witcombe.sbc.edu/earthmysteries/EMPi.html

Suggested Lesson Plan:

Getting Started

1. Assemble a variety of round objects for students to measure the circumference and diameter. Select objects that are <40 centimeters in diameter.
2. Cut 2-inch strips of transparencies for students to use when drawing in the line of best fit. This allows them to see the data points when they draw the trend line.
3. **Journal Prompt:** "What is a standard? Write a sentence or phrase containing the word *standard* that shows you know what it means. Can you think of how standards may be used?"
   A standard is something set up and established by authority as a rule for the measure of quantity or weight. For example, the acre was selected as approximately the amount of land tillable by one man behind an ox in one day. The modern yard is a compromise between the old British and American standards, and is calibrated against the meter. Standards may also be used to size shoes or clothes, although, as you may have learned, there is variation in this standard.

Doing the Activity

1. Working in pairs, students will measure the circumference and diameter (in centimeters) of at least five circular objects. Students can also use 50-inch lengths of string and a ruler instead of tape measures, but they are not as acccurate. If very small objects are to be measured, you may want to consider providing calipers. Data is entered in the data table on Worksheet 1.
2. Students create a scatter plot from the data they have collected. They can make scatter plots on the graph paper provided or use graphing calculators or computers. Students will choose a reasonable scale and plot "Diameter" as the independent variable on the X-axis and "Circumference" as the dependent variable on the Y-axis. Discuss the meaning of independent vs. dependent data. In this case, the circumference of any circular object is dependent on that object's diameter.
3. Hand out a plastic transparency to each pair of students so they can draw a "line of best fit" for the plotted points. Be certain that they draw a straight line that best fits through their data points, not a jagged line that connects the individual data points.
4. Students can calculate the slope of their trend line and compare it to other students' answers to check the accuracy of their work. If a student's slope is incorrect, instruct the student to adjust his

or her trend line. You may also compile class data onto one graph using large rolls of Post-It® graph paper (from 3M) that make it easy to compile class data. The slopes of the lines should be near pi (3.14), and students should be aware that this is an industry "standard."

Wrap-up

1. Students complete *Step 4. Finding Unknowns*.
2. Assign Worksheet 2: *Scored Classroom Assignment – Mathematics*.
3. **Journal Prompt:** "Why is Π (pi) a standard?"
   Answer: Pi is a standard because it is a mathematical constant that does not change. It is always 3.14 because of the ratio of the circumference of a circle to its diameter.

Assessment:

- Students submit their completed worksheets that include the graph and their responses to specific questions.
- Students may be tested on the relationship between circumference and diameter.
- Students may also be tested on their ability to interpret a graph to predict results.
- Students complete Worksheet 2: *Scored Classroom Assignment – Mathematics*.

Extensions:

Mathematics

1. Students can use existing measurements to graph the relationship between diameter and area of circles.
2. Students can research information about pi.
3. Graphs from newspapers or magazines can be interpreted and analyzed. (One example is in *The Oregon Mathematics Teacher*, December 1999, p. 33.) Social studies courses provide a wealth of these graphs.
4. If students have a solid algebra background, they can determine the equation of their graphed lines.

Social Studies

1. Students can find and graph the average gas price/year in the U.S. from 1935 to 2000, placing years on the X-axis and gas prices on the Y-axis.
2. Students can identify the years that there were significant spikes or dips and then research those high- and low-price years to discover

what historical events may have created the spikes and dips (for example, *1967 – war in Middle East*).

Language Arts: Writing a Science News Article

1. Students can locate and bring to class a current article in the local newspaper that describes a scientist's recent discovery.
2. Students can analyze the content and writing style of the news article in preparation to write their own article.
    a. Direct the students to observe the journalist's construction of the article: Where are the key pieces of information located? How does the article describe the discovery? In what way will this work leave an impact? What are the long-term implications of the discovery?
    b. Ask the students to analyze the writing style. How long are the sentences? Are the subject and verb usually placed early in the sentences with clauses following? Note examples of names, dates, and facts. Where are they located and how are they used? How long are the paragraphs? Are there quotations? Illustrations? How does the text refer to illustrations or graphs? What about a title? Does it catch your attention?
3. Have the students read the Web biography of Archimedes (287–212 B.C) (http://www.shu.edu/projects/reals/history/archimed/html).
4. Students can write a short news article for their local newspaper, imitating the content and style of the news article they analyzed. The article should cover one of Archimedes' discoveries. This can be a two-member team project or individual assignment.
5. Have students share their articles in their language arts class or in the science class where they are involved in the Hydroville Project.

Resources:

- St. Louis PIDAY Page includes What is Pi, Uses of Pi, History of Pi, Pi Pics, etc.
- "Archimedes and the Computation of Pi." University of Utah.
- Issues of *The Oregon Mathematics Teacher*, Journal of the Oregon Council of Teachers of Mathematics.
- See the Hydroville Web site for links to Web resources for this activity at http://www.hydroville.org/links/ps_resources.aspx.

Teacher Key

Worksheet 1

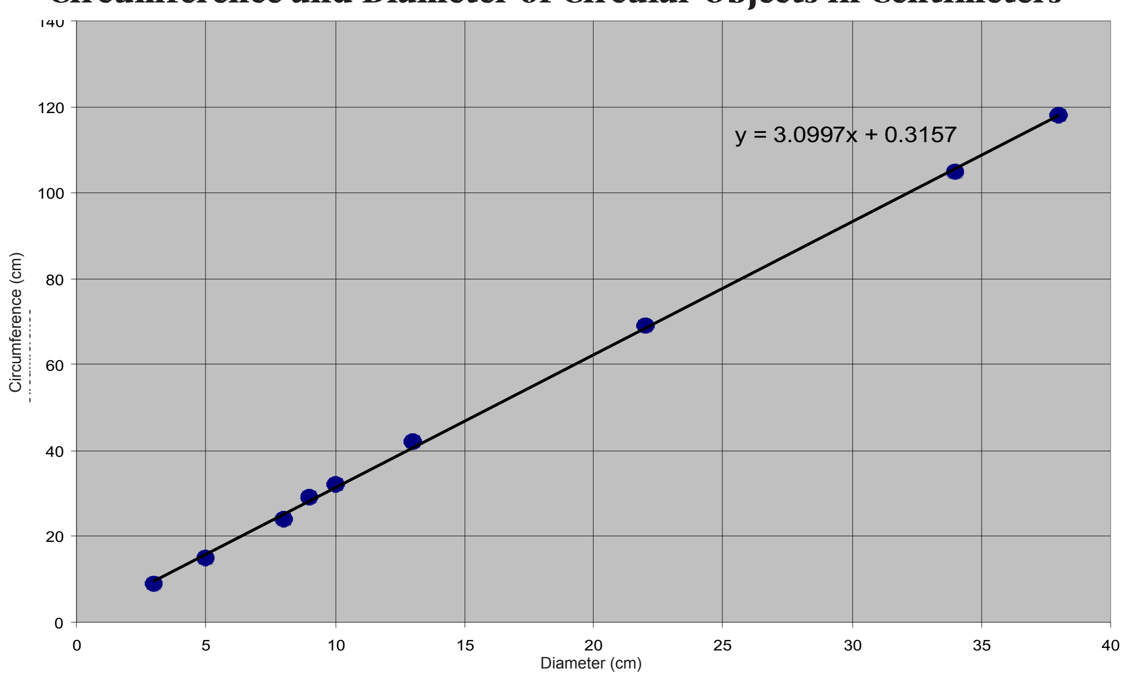
Step 1. Collecting Data

Find objects in the classroom that appear to be circular. As accurately as you can, measure the diameter and circumference of each object to the nearest 0.1 of a centimeter, and record in Table 1.

Table 1. Diameter and Circumference of Circular Objects

Object	Diameter (cm)	Circumference (cm)
Doorknob	10.1	31.7
Waste basket	34.4	108
Clock face	38.3	120
Coffee mug	7.7	24.2
Overhead lamp	9.5	29.8
Roll of tape	5.0	15.7
Flowerpot	13.9	43.6
Paper plate	22.6	71.0
Key ring	3.3	10.4

Circumference and Diameter of Circular Objects in Centimeters



Teacher Key

Step 2. Creating a Standard

1. How does the range of the data you gathered affect the size of the scale you will choose for your graph?
   If the range is small, the scale can use small increments, but if the range is large, the scale will need to be adjusted to larger increments.
2. Graph your measurements. Plot the diameter on the X-axis, and the circumference on the Y-axis. This is a scatter plot, so you will not be connecting your points after you plot them. Instead, when all your points are graphed, you will need to draw a "line of best fit" (trend line).
3. Identify two points *on* the trend line that you have drawn. Point 2 should be higher up the trend line than Point 1. Record their coordinates (x,y) here.
   Answers will vary.
4. Use these two points to find the slope, *m*, of the line. Show your work here.

   $m = \frac{y_2 - y_1}{x_2 - x_1} =$ *m should be close to pi (3.14).*
5. Compare your slope with that of another student. How close are they to being the same? How close do they compare with pi?
6. Compile the class results when everyone is finished.

Step 3. Quality Check

To ensure that everyone in the class has accurately measured and plotted the circumference and diameter data and drawn an accurate trend line, there will be a quality check.

1. Using your graph, determine the circumference of a flowerpot that has a diameter of 13.0 cm. If your trend line is accurately drawn, the circumference you determine from the graph should be 41 cm. If your circumference is not close to 41 cm, you should redraw your trend line.
2. Looking at the class results, are all of the individual slopes near the same number? What do you think that number should be?
   The individual slopes should all be around pi, which is approximately 3.14. The variation results from inaccurate measurements.

Step 4. Finding Unknowns

1. In your own words, define pi.
   Answer: Pi, or Π, is the most famous ratio in mathematics. Pi is approximately 3.14 – the number of times that a circle's diameter will fit around the circle.
2. Why is pi recognized as a standard?
   Pi is a standard because it is a mathematical constant that does not change. It is always 3.14 because of the ratio of the circumference of a circle to its diameter.
3. Use your standard graph to predict the circumference of a ring with a diameter of 2.0 cm.
   Its circumference would be approximately 6.3 cm.

Teacher Key

4. Suppose you encountered a circular lake with a circumference of 50 meters. Use your graph (or your knowledge of pi) to calculate the diameter of the lake. Provide an example of why it would be useful to know the diameter of a lake.

   $$\frac{\text{Circumference}}{\text{Diameter}} = 3.14$$

   $$\frac{\textit{50 meters}}{X} = 3.14$$

   X = 15.9 or 16 meters

5. Now it's time for you to write your own story problem. Have someone else try to solve for an unknown length (circumference or diameter) using the standard graph. Make sure that you have tested it and have the correct answer first.

   Create your own math problem for solving an unknown here.
   Answers will vary.

Teacher Key

Scored Classroom Assignment: Mathematics

Name: ______________________________

Date: ______________________________

Class: ______________________________

Period: ______________________________

Content Area:

_____ Algebraic Relationships

_____ Probability and Statistics

__X__ Geometry

State Scoring Guide Score

Conceptual Understanding
1 2 3 4 5 6

Processes and Strategies
1 2 3 4 5 6

Communication
1 2 3 4 5 6

Verification
1 2 3 4 5 6

_____ Precisely Correct

_____ Essentially Correct

_____ Not Correct

Instructions:

You will be scored on how well you show your understanding of mathematics and how well you explain it to others. Your solution should include these four parts:

- Tell what the problem is about in your own words.
- Show all the steps you used to come to your solution.
- Explain your thinking from start to finish.
- Check your answer and explain how you know your answer makes sense.

Jesse and Nathan are riding their bicycles to school. Jesse's bike has wheels with a 20-inch diameter, and Nathan's wheels are 24 inches in diameter. The ride to school is 3 miles. Show how many more revolutions Jesse's wheels will turn than Nathan's wheels in riding the 3 miles.

(One mile = 5,280 feet; C = pi x D where pi @ 3.14)

Note: This problem is from the 1997–98 Oregon State Assessment.

This problem is asking me to compare the number of revolutions that Jesse's bike will make to the number that Nathan's will make when each travels 3 miles. I will need to calculate the revolutions by dividing the 3-mile distance by the circumference of each bike wheel.

Jesse's bike has a 20-inch diameter wheel, so its circumference is 20 x 3.14 = 62.8 inches.
Nathan's bike has a 24-inch diameter wheel, so its circumference is 24 x 3.14 = 75.36 inches.
3 miles = 3 x 5,280 = 15,840 feet. 15,840 x 12 = 190,080 inches.

Jesse's bike travels 190,080 /62.8 = 3,026.75 revolutions (approximately)
Nathan's bike travels 190,080 /75.36 = 2,522.29 revolutions (approximately)
So the difference in revolutions is 3,026.75 – 2,522.29 = 504.46 revolutions

Student Pages for

CONSTRUCTING AND ANALYZING GRAPHS

Follow this Page

Worksheet 1

Name ______________________________

Date _________________ Period ______

Constructing and Analyzing Graphs

Materials:

Each Student:

- ☐ Hydroville Science Journal
- ☐ Graph paper (five squares/inch)

Each Group of Two Students:

- ☐ Round objects
- ☐ Tape measures (or string)
- ☐ Rulers
- ☐ Calculators
- ☐ Calipers (optional)

Step 1. Collecting Data

Find objects in the classroom that appear to be circular. As accurately as you can, measure the diameter and circumference of each object to the nearest 0.1 of a centimeter, and record in Table 1.

Table 1. Diameter and Circumference of Circular Objects

Object	Diameter (cm)	Circumference (cm)

Worksheet 1, Page 2

Name______________________________

Date_________________ Period______

Step 2. Creating a Standard

1. How does the range of the data you gathered affect the size of the scale you will choose for your graph?

2. Graph your measurements. Plot the diameters on the X-axis, and the circumferences on the Y-axis. This is a scatter plot, so you will not be connecting your points after you plot them. Instead, when all your points are graphed, you will need to draw a "line of best fit" (trend line).

3. Identify two points on the trend line that you have drawn. Point 2 should be higher up the trend line than point 1. Record their coordinates (x,y) here.

   Point 1 __________ Point 2__________

4. Use these two points to find the slope, m, of the line. Show your work here.

$$m = \frac{y_2 - y_1}{x_2 - x_1} =$$

5. Compare your slope with that of another student. How close are they to being the same? How do they compare with pi?

6. Compile the class results when everyone is finished.

Step 3. Quality Check

To ensure that everyone in the class has accurately measured and plotted the circumference and diameter data and drawn an accurate trend line, there will be a quality check.

1. Using your graph, determine the circumference of a flowerpot that has a diameter of 13.0 cm. If your trend line is accurately drawn, the circumference you determine from the graph should be 41 cm. If your circumference is not close to 41 cm, you should redraw your trend line.
2. Looking at the class results, are all of the individual slopes near the same number? What do you think that number should be?

Worksheet 1, Page 3

Name______________________________

Date_________________ Period______

Step 4. Finding Unknowns

1. In your own words, define pi.

2. Why is pi recognized as a standard?

Now that you have graphed a standard, let's see if you can use your graph to predict the circumference or diameter of unknown objects.

3. Use your standard graph to predict the circumference of a ring with a diameter of 2.0 cm.

4. Suppose you encountered a circular lake with a circumference of 50 meters. Use your graph (or your knowledge of pi) to calculate the diameter of the lake. Provide an example of why it would be useful to know the diameter of a lake.

5. Now it's time for you to write your own story problem. Have someone else try to solve for an unknown length (circumference or diameter) using the standard graph. Make sure that you have tested it and have the correct answer first.

   Create your own math problem for solving an unknown on the back page.

Worksheet 2

Name ______________________________

Date __________________ Period ______

Scored Classroom Assignment: Mathematics

Name: ______________________________

Date: ______________________________

Class: ______________________________

Period: ______________________________

Content Area:

_____ Algebraic Relationships

_____ Probability and Statistics

_____ Geometry

State Scoring Guide Score

Conceptual Understanding
1 2 3 4 5 6

Processes and Strategies
1 2 3 4 5 6

Communication
1 2 3 4 5 6

Verification
1 2 3 4 5 6

_____ Precisely Correct

_____ Essentially Correct

_____ Not Correct

Instructions:

You will be scored on how well you show your understanding of mathematics and how well you explain it to others. Your solution should include these four parts:

- Tell what the problem is about in your own words.
- Show all the steps you used to come to your solution.
- Explain your thinking from start to finish.
- Check your answer and explain how you know your answer makes sense.

Note: Use back side of page if needed.

Jesse and Nathan are riding their bicycles to school. Jesse's bike has wheels with a 20-inch diameter, and Nathan's wheels are 24 inches in diameter. The ride to school is 3 miles. Show how many more revolutions Jesse's wheels will turn than Nathan's wheels in riding the 3 miles.

(One mile = 5,280 feet; C = pi x D where pi = 3.14)

BACKGROUND ACTIVITY 6

USING PAPER CHROMATOGRAPHY

(Adapted from: *Forensic Science Activities*. University of Colorado Boulder Hughes Initiative, www.colorado.edu/Research/hughes/web.forensics.html.)

Description:

Students will use paper chromatography to separate ink molecules and identify a pen from an unknown sample of handwriting.

Rationale:

During the Hydroville Pesticide Spill Scenario, the analytical chemists analyze gas chromatograms to identify the concentration of the metam sodium at the spill site in Hydroville. Students apply their understanding of how molecules move in paper chromatography to gas chromatography.

Purpose/Goals:

Students will be able to:

- understand the uses and process of chromatography
- conduct qualitative analyses of various dyes in ink pens
- calculate the retention factor of each dye
- use evidence gathered from scientific data to support conclusions

Prerequisites:

Background Activity 5: Constructing and Analyzing Graphs – Circumference and Diameter

Time Estimate:

Prep: 15–20 minutes

Activity: Two 50-minute periods

Materials:

Each Student:

- ☐ Hydroville Science Journal
- ☐ Pencil
- ☐ Ruler
- ☐ Calculator
- ☐ Safety glasses

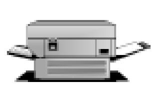
Each Group of Three to Four Students:

- ☐ Four test tubes (20 x 150 mm) in a test tube rack or large plastic cup
- ☐ Three strips of chromatography paper (1 cm x 16 cm)
- ☐ One strip of chromatography paper (1 cm x 16 cm) with crime scene ink
- ☐ 50 mL of isopropyl alcohol
- ☐ Non-permanent marking pen or wax pencil

Class Materials on Tool Table:

- ☐ Five sets of black ink pens labeled "A," "B," "C":
  - A**:** Sanford® Sharpie permanent marker, fine point
  - B**:** Paper Mate® Write Bros. Stick Ballpoint, fine point
  - C**:** Sanford® Uni-Ball® Vision Rollerball, fine point
- ☐ Five sets of black ink pens labeled "D," "E," "F":
  - D**:** Sanford® Uni-Ball® Vision waterproof/fade-proof, fine point
  - E**:** Pentel® Rolling Writer® Rollerball, medium point
  - F**:** Paper Mate® Flexgrip Ultra® ballpoint, fine point
- ☐ Paper towels
- ☐ Colored pencils

Pages to Photocopy:



Transparencies:

- Transparency 1: *What Is Chromatography?*
- Transparency 2: *Calculating Retention Factors*

One copy/group:

- Instructions: *Using Paper Chromatography*

One copy/student:

- Worksheet 1: *Paper Chromatograms*
- Worksheet 2: *Paper Chromatography Analysis*

Teamwork Skill:

- Identify where there is disagreement in the group.

Terminology:

- Chromatography
- Chromatogram
- Paper chromatography
- Gas chromatography (GC)
- Qualitative analysis
- Quantitative analysis
- Molecule
- Analyte
- Analytical chemistry
- Mobile phase
- Retention factor (R_f)
- Stationary phase

Background Information:

What is Chromatography?

Chromatography is a laboratory method that is widely used for the separation and identification of chemical components of a complex *mixture*. More specifically, chromatography separates compounds based on differences in their structure, size, and/or composition. *Analytical chemistry* uses chromatography to conduct qualitative analysis (identify the components) and quantitative analysis (determine the concentration) of unknown substances. No other separation method is as powerful and generally applicable as chromatography.

Qualitative Analysis – identifying chemicals (what kind?)

- Species identification, e.g., "killer" bees can be distinguished from native bees by comparing gas chromatograms of cuticle extracts
- Tracing contraband sources and detecting drugs in urine

Quantitative Analysis – finding concentrations (how much?)

- Each peak corresponds to a separate component in the mixture.
- The area of each peak is proportional to concentration.

How Does Chromatography Work?

There are many different chromatography techniques; however, they all use a *stationary phase* and a *mobile phase*. The part that stays in one place is called the stationary phase; the part that moves is called the mobile phase. Substances have different attractions for the stationary and the mobile phases and can be separated by these different attractions. Components of a mixture are carried through the stationary phase by the flow of a gaseous or liquid mobile phase. Each sample will migrate through the stationary phase at a different rate.

Using Paper Chromatography

In *paper chromatography*, a small amount of the substance to be analyzed (called the *analyte*) is placed on a strip of paper (the stationary phase) above the level of the *solvent* (mobile phase). In this activity, you will be using ink as the analyte and alcohol as the solvent. As the alcohol moves up the paper, the dye *molecules* from the ink mixture will move with it. If they are more strongly attracted to the alcohol molecules (mobile phase) than to the paper molecules (stationary phase), the dyes will continue to move up the paper. If the dye molecules are more strongly attracted to the paper than the alcohol, they will move more slowly than the alcohol or not at all. If two or more dyes have been mixed to form ink, then they may move at different rates as the alcohol moves up the paper. If this happens, they will separate out as different bands of color and can be identified by analyzing the paper *chromatograms*. Each paper chromatogram displays a unique pattern formed by the separation of the visible bands of dyes. Different mixtures of ink are specific for each brand of pen.

Retention Factors:

$$R_f \text{ (Retention Factor)} = \frac{\text{Distance Traveled by Band}}{\text{Distance Traveled by Solvent}}$$

Each separated band on a chromatogram can be assigned a *Retention Factor* (R_f), which is characteristic of each specific dye. The R_f is a ratio of the distance the band travels to the distance the solvent (alcohol) travels. The R_f is calculated by dividing the band distance by the solvent distance. This ratio should be a constant that is characteristic of the dye(s) in a particular spot under a particular set of chromatographic conditions (i.e., paper chromatogram, alcohol solvent, etc.). (See Transparency 2: *Calculating Retention Factors*.)

Each component of the mixture will move a definite distance on the paper in proportion to the distance that the solvent moves. This ratio, R_f , can be calculated for each component to aid in identification. R_f values are dependent upon the paper, the solvent, and the amount of sample used.

Suggested Lesson Plan:

Getting Started

1. Purchase one roll of 1 cm-wide chromatography paper from Fisher Scientific. Cut into 16 cm strips. Since students will be working in groups of three or four, you will need to cut 30–32 strips of chromatography paper, one for each student (or four strips/group if students are testing three pens).
2. Select at least three pens from the list below. Purchase enough for the class to share. Label each pen “A,” “B,” and “C.” If you would like a second set of pens to complicate the experiment, use additional pens and label them “D,” “E,” and “F.” (See Class Materials on Tool Table for specific pens.)

3. Prepare chromatography paper samples of the pen used on the crime scene note. On each strip, use a pencil to draw a line 2 centimeters from the bottom. Choose one of the pens to represent the *Crime Scene* pen; this is the one that the suspect used. Using the *Crime Scene* pen, draw a line over the pencil mark and label *Crime Scene* on top of strip. Prepare enough paper chromatography samples for every group (three to four students/group).
4. Present a crime scene scenario. For example, police discover a forged check at a crime scene, with the signature signed in an unusual type of black ink. Police confiscate black ink pens from three possible suspects (suspects A, B, and C) in the forgery case.

Classroom Hints:

- Name the suspects after each of the six characters from the board game CLUE (e.g., Colonel Mustard, Professor Plum, etc.) or teachers in the school.
- "I get more pens and put a different student's name on each so they are the suspects. I also do two chromatograms, one in water and one in alcohol. I do both chromatograms for each pen ahead of time and pick one that was close to several others. Maybe all were the same with alcohol, but one had a slight difference with water or vice versa. I tell them that I have been taking pens from each of them over the last couple of weeks! Some even believe me! Then they compare with the crime scene and they need to prove who did it (or if it is them, prove someone else did it)."
- "I have also done a whole production with something like *who kidnapped the principal*. The teachers are suspects and there was a ransom note. Prepare teachers ahead of time to have a certain type of pen. Have intercom announcements every day giving clues ('so and so was seen exchanging pens with so and so'). It ended up being really fun."

Doing the Activity

1. Students will work in groups of three or four. Hand out Instructions to each group.
2. Have students set up the lab at the very beginning of the period, since it may take 20–45 minutes for the ink to separate into bands of color, depending on room conditions. Set up the test tubes in a fume hood or well-ventilated area.
3. Remind students to use pencil when marking the starting line on the paper chromatograms.
4. Students should check the paper chromatograms every 5 minutes. The chromatography process is complete when the solvent is clear and there are no more bands of colored dyes.

5. **Safety issues**: The chromatography solvent, isopropyl alcohol, can produce unpleasant, noxious fumes. Use in a well-ventilated area under a hood. **Isopropyl alcohol is flammable.**
6. While waiting, introduce chromatography to the students. Read the Introduction on Worksheet 1 and discuss Transparency 1.
7. **Journal Prompt 1:** "List the words that are in italics in the Introduction. Consider these new terminology and write definitions for them."

   Students should look up the words in a dictionary, or you can provide definitions found in the Pesticide Spill Glossary.
8. Remind the students that they are conducting this lab to prove without a doubt that the suspect is guilty. Encourage them to make accurate observations and measurements. Students draw their paper chromatograms on Worksheet 1 and reproduce their results using color pencils so that it matches the paper chromatograms exactly.
9. On Worksheet 2, students will calculate the Retention Factor (R_f) for the crime scene pen and for the suspect's pen. Show Transparency 2: *Calculating Retention Factors* and walk students through the example.
10. The crime is solved when the students match the chromatogram from the suspect's pen to chromatogram from one of the unknown pens. Compare individual retention factors for each pen and compile class data. It is likely that the R_f values will not be identical. But the separations are sufficiently distinct that students can identify the components qualitatively.

Wrap-up

1. Students complete Conclusion Questions.
2. **Journal Prompt 2:** "In your own words, explain how paper chromatography works."
   Chromatography separates mixtures of chemical compounds, such as the various dyes that are found in ink (ink pens). The dyes can be separated because they have different attractions (affinity) for the stationary phase (paper) and for the mobile phase (solvent). Since the dyes have different attraction to the paper and solvent, they are separated out into bands of color, each color represents one of the color of dyes that are blended together in a mixture of ink.

Assessment:

- Students complete the student worksheet and turn in a lab report.
- Students research chromatography procedures on the Web and explain in their own words how it works. See "Resources" for recommended Web sites.

Extensions:

- At the same time that the "suspect" inks are separating, have students perform paper chromatography on ink samples from Sanford® Uniball Vision pens, and then have students explain why the ink does not separate into its component pigment molecules. *This ink is composed of only one pigment.*
- If you want to make the mystery more complex, add another clue. Perhaps the pen or check also has lipstick on it. Be creative! Here is a list of other chromatography labs:
    - Lipstick Analysis – Hughes Undergraduate Biological Science Education Initiatives. www.colorado.edu/UCB/Research/hughes/for_teacherguide.pdf
    - Separate Colors in a Green Leaf Using Chromatography. http://photoscience.la.asu.edu/photosyn/education/colorchange.html
    - Candy Chromatography (testing FD&C dyes from M&M's and Skittles). www.woodrow.org/teachers/chemistry/institutes/1986/exp3.html
    - Grape Kool-Aid Column Chromatography. www.chem.vt.edu/RVGS/ACT/lab/Experiments/Exp_14-Kool-Aid.html
    - Analysis of Mr. Sketch Ink by Paper Chromatography. www.chem.csustan.edu/chem1002/msketch3.htm

Resources:

- The slightly irreverent guide to the world of Gas Chromatography and Analytical Chemistry. http://home.att.net/~gcresource/GCmain.html
- General Chemistry On-line. Companion Notes: Matter: "Chromatography." http://antoine.frostburg.edu/chem/senese/101/matter/chromatography.shtml
- The Chemistry HyperMedia Project. www.chem.vt.edu/chem-ed/scidex.html
- Gas Chromatography. Sheffield Hammond University. www.shu.ac.uk/schools/sci/chem/tutorials/chrom/gaschrm.htm
- See the Hydroville Web site for links to Web resources for this activity at http://www.hydroville.org/links/ps_resources.aspx.

Teacher Key

Worksheet 1. Paper Chromatograms

Chromatograms will vary. Compare class data for accuracy.

Worksheet 2. Paper Chromatography Analysis

Retention factors will vary. Compare class data for accuracy.

Conclusion Questions

1. Compare the patterns on the four chromatograms. Do any of the patterns appear to match? Which ones? Explain your answer.
   Only one of the unknown strips should match the chromatogram from the crime scene ink. Other chromatograms may have similar bands, but not all will be identical.
2. What can you conclude about the suspects in this case? Which suspect(s) can you exclude (if any)? Which suspect(s) can you link to the crime scene?
   Answers will vary depending on the crime set-up. All of the suspects are innocent, except the one whose pen matches the chromatogram.
3. If you were hired as an expert witness in a jury trial, how would you explain your ink chemical analysis evidence to a jury? Include information about the Retention Factor.
   Typically, an expert would try to provide quantitative evidence in court. Unfortunately, this lab activity provided only qualitative evidence. Showing a jury the matching chromatograms based on observational data alone may be insufficient to persuade them. If each of the bands of dye are measured and the retention factor is calculated for each and compared to the retention factor of the crime scene ink, then it appears as more concrete evidence.
4. Why do some molecules move further than others on a chromatogram in the same amount of time? Use your new vocabulary words in your answer.
   Molecules have different affinities for the mobile phase and thus are separated out based on this attraction.

What Is Chromatography?

Chromatography is a technique used to separate, detect, and measure individual chemical compounds in a **mixture.**

Mixture: Two or more chemical compounds mixed together, e.g., two different colored dyes in ink

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Chromatography separates chemicals based on their **affinity** to either the **stationary phase** or **mobile phase**.

Affinity: attraction

Stationary phase: part that stays in one place (paper)

Mobile phase: part that moves, such as an solvent (alcohol)

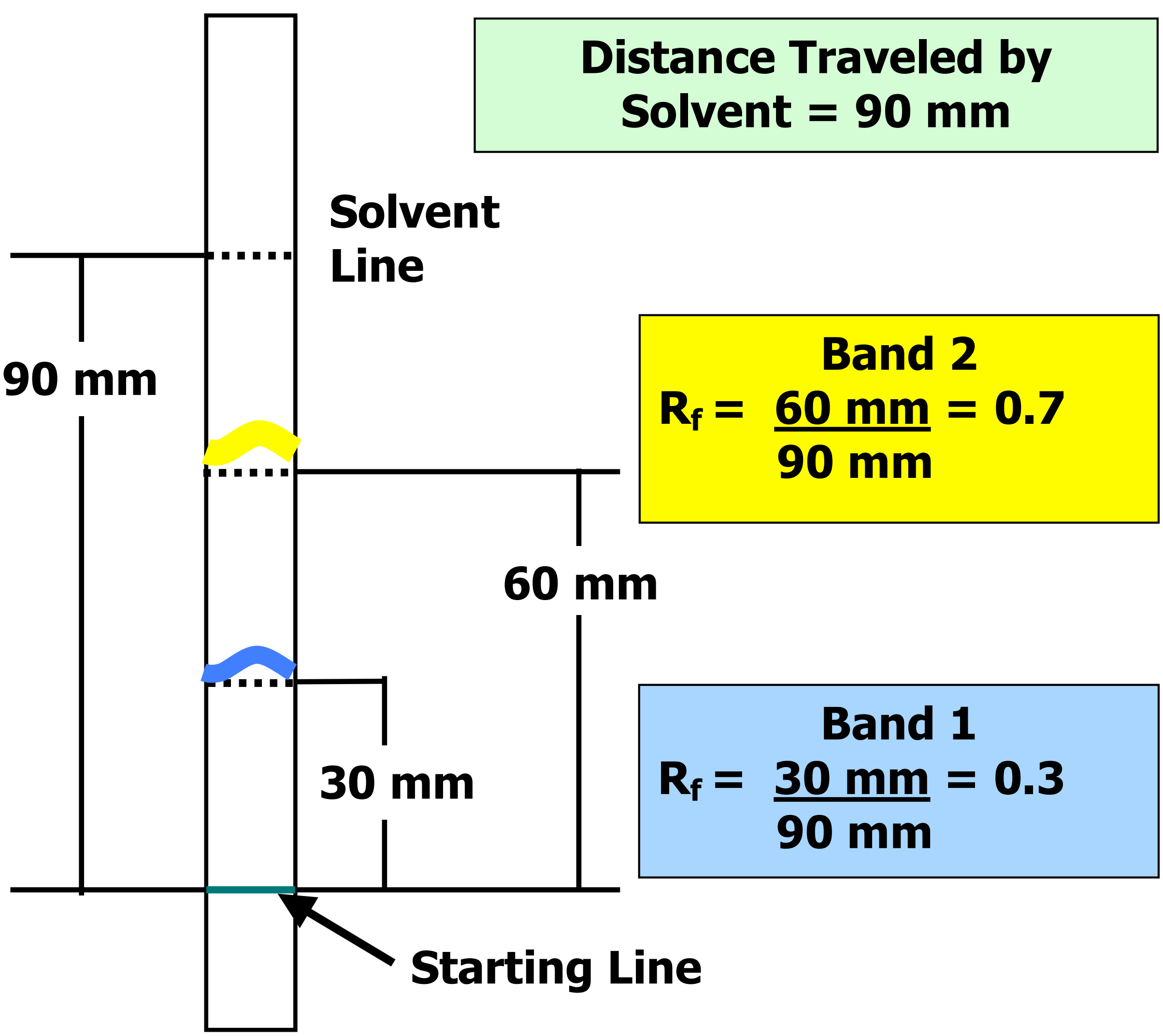
Chromatography is recorded on **chromatograms**.

Chromatogram: a graph that shows the individual compounds, e.g., dyes in an ink

Calculating Retention Factors

Retention Factor (R_f) is the migration rate of a compound, that is, how far each band of dye travels in relation to the solvent. Every dye has a unique R_f value.

$$R_f = \frac{\text{Distance traveled by band (mm)}}{\text{Distance traveled by solvent (mm)}}$$



Student Pages for

USING PAPER CHROMATOGRAPHY

Follow this Page

Using Paper Chromatography

Introduction:

In this activity, you will use chromatography to distinguish different brands of ink pens used by each of the suspects and compare them to ink on a forged check found at a crime scene.

There are many types of *chromatography*. In this lab, you will be using *paper chromatography*. In the analysis of the pesticide spill, you will be using *gas chromatography*. But all chromatography works on the same principles. Chromatography separates a *mixture* of chemical compounds by the affinity or attachment of the substance to a *stationary phase* (in this case, paper) and a *mobile phase* (the solvent alcohol). The ink molecules that are most attracted to the solvent will travel up the paper with the solvent while leaving others behind. This results in a paper strip with different colors of ink going up the paper. The same inks will produce the same patterns so that you can match the *chromatogram* of a known pen with the crime scene ink to make a positive identification.

Materials:

Each Student:

- ☐ Hydroville Science Journal
- ☐ Pencil
- ☐ Ruler
- ☐ Calculator
- ☐ Safety glasses

Each Group of Three to Four Students:

- ☐ Four test tubes (20 mm x 150 mm) in a test tube rack
- ☐ Three strips of chromatography paper (1 cm x 16 cm)
- ☐ One strip of chromatography paper (1 cm x 16 cm) with crime scene ink
- ☐ 50 mL isopropyl alcohol
- ☐ Non-permanent marking pen or wax pencil
- ☐ Three “suspect” pens – A, B, C or D, E, F
- ☐ Colored pencils

Procedure:

In this experiment, you will conduct a qualitative analysis of various dyes in ink.

1. Each group receives three strips of chromatography paper.
2. Using a pencil **(NOT a pen!)**, draw a horizontal line 2 centimeters on the end of each strip (see Figure 1).
3. Using a pencil **(NOT a pen!)**, label the top of the three strips "**A,**" "**B,**" and "**C**" (or "D," "E," "F") to represent pens from each of the suspects (See Figure 1).
4. Draw a thin, horizontal line of the appropriate pen on top of the pencil line on each strip of filter paper labeled A, B, and C.
5. Obtain a crime scene ink chromatography paper from your instructor.

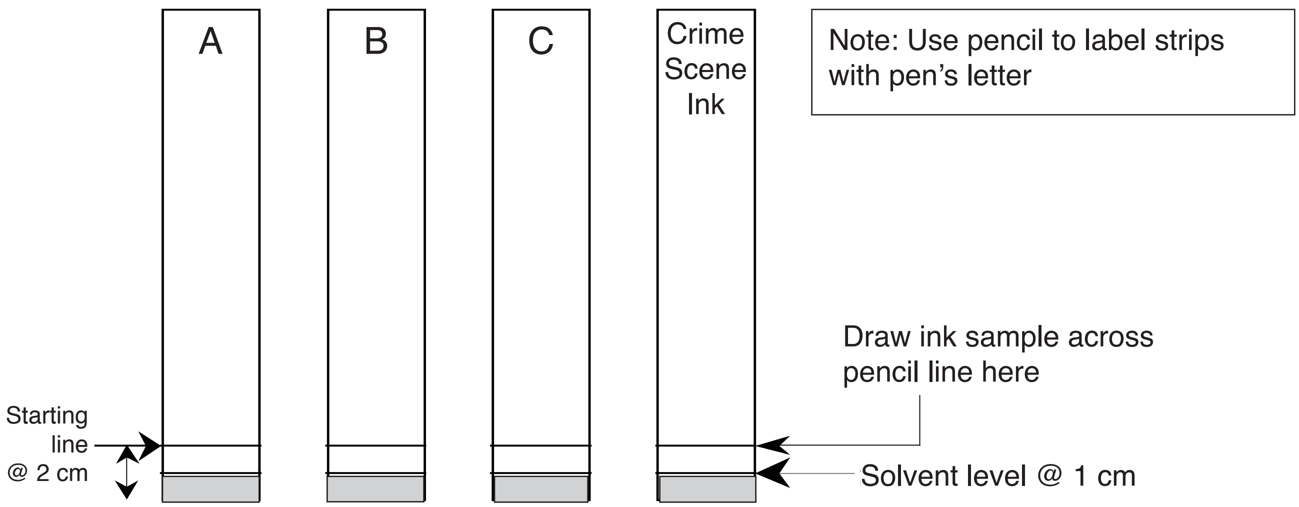


Figure 1. Setup for Paper Chromatography

WARNING: Isopropyl alcohol can produce unpleasant, noxious fumes. Use in a well-ventilated area under a hood. **Isopropyl alcohol is flammable.**

6. With a ruler, measure 1 centimeter from the bottom of the test tube and draw a line with a marking pen or wax pencil. This is your fill-line mark. Now fill each test tube with solvent (isopropyl alcohol) to this fill line.

Instructions, Page 3

Read Steps 7–10 Before Continuing

7. Place paper chromatogram strips in the test tubes, one per test tube. Place the ink line toward the bottom of the test tube. The paper should be submerged into the isopropyl alcohol, but the ink **must not touch the solvent**. Fold the top of the strips over the lip of the test tube. Make sure the strips are not flattened against the side of the test tube.
8. Leave the strips in the test tube for 30–45 minutes in a fumehood or well-ventilated area.
9. Remove paper strips from test tubes. Before the solvent dries, use a **PENCIL** to draw a line on the filter paper that will indicate how high the solvent reached. Label it *Solvent Line*. Draw a line on the bottom edge of each band. Then allow the filter paper to dry.
10. Tape the paper strips on Worksheet 1.

Calculating Retention Factors

1. When comparing the unknown samples of ink to the ink used at the crime scene, you must show concrete evidence of an ink match. Therefore, it is important to calculate the Retention Factor (R_f) for each band in every ink sample.
2. We can use retention factors as a tool to help answer several questions about the inks. In this investigation, you will analyze two chromatograms: the paper chromatograms of the Crime Scene Ink, and the one you think is from the Suspect.
3. On the crime scene chromatogram, measure the distance in millimeters from the starting line to the solvent line. Record this measurement in the column labeled *Distance Traveled by Solvent (mm)*.
4. To determine the exact location of each band on the crime scene ink chromatogram, measure the distance in millimeters from the starting line to the **bottom of each band**. Record this measurement in the column labeled *Distance Traveled by Band (mm)*.
Note: Measure all of the bands that appear on the chromatogram.
5. Calculate the R_f for each band by dividing the *Distance Traveled by Band* by the *Distance Traveled by Solvent*.
6. Repeat steps 3–5 for the chromatogram of the ink you think is from the suspect's pen.
7. Compare the R_f values of the bands from the *Crime Scene Ink* chromatogram and the *Suspect* chromatogram. If the values for R_f are similar, then you've found your suspect.

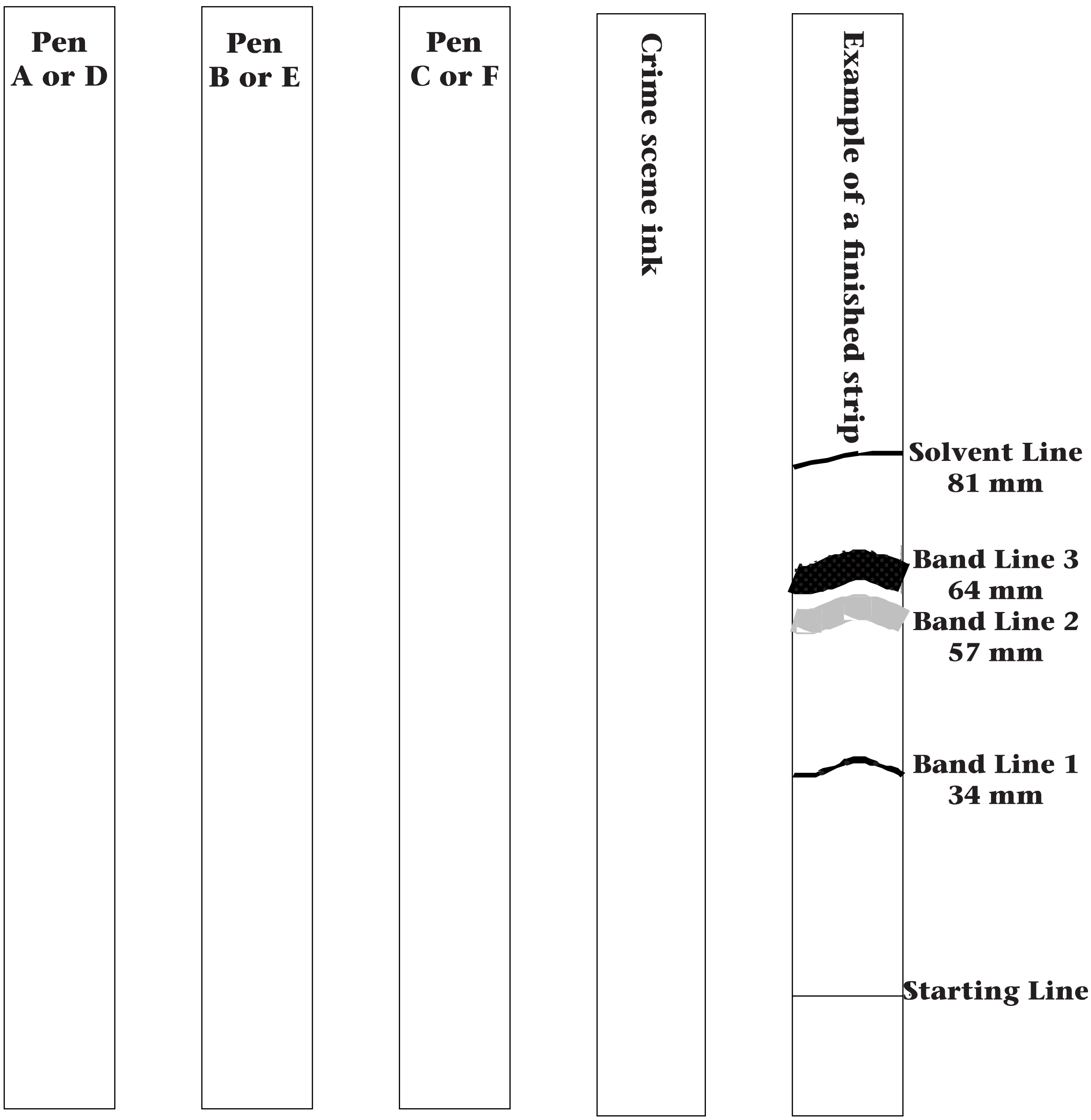
Worksheet 1

Name______________________________

Date_________________ Period______

Paper Chromatograms

Tape paper strips here, or draw in lines using colored pencils.



Worksheet 2

Name ______________________________

Date _________________ Period ______

Paper Chromatography Analysis

Calculating Retention Factors

Crime Scene Ink

Band #	Distance Traveled by Band (mm)	Distance Traveled by Solvent (mm)	R_f (Retention Factor) = Distance Traveled by Band/ Distance Traveled by Solvent
1			
2			
3			
4			

Suspect Pen _______ (letter)

Band #	Distance Traveled by Band (mm)	Distance Traveled by Solvent (mm)	R_f (Retention Factor) = Distance Traveled by Band/ Distance Traveled by Solvent
1			
2			
3			
4			

Conclusion Questions

1. Compare the patterns on the four chromatograms. Do any of the patterns appear to match? Which ones? Explain your answer.

Worksheet 2, Page 2

Name______________________________

Date_________________ **Period**______

2. What can you conclude about the suspects in this case? Which suspect(s) can you exclude (if any)? Which suspect(s) can you link to the crime scene?

3. If you were hired as an expert witness in a jury trial, how would you explain your ink chemical analysis evidence to a jury? Include information about the Retention Factor.

4. Why do some molecules move further than others on a chromatogram in the same amount of time? Use your new vocabulary words in your answer.

BACKGROUND ACTIVITY 7

SOIL TEXTURE

(Adapted from: Soil Texture. *Soil Science*. Instructional Materials Laboratory, University of Missouri-Columbia. 1995. Pages 39–53.)

Description:

Students will use a soil texture triangle to identify and create a specific soil type from sand, silt, and clay. They will then test their soil using a soil texture flowchart.

Rationale:

In the Hydroville Pesticide Spill Scenario, the soil scientists will need to have adequate background knowledge in soil texture because they must identify the type of soil present at the spill site by using the texture triangle.

Purpose/Goals:

Students will be able to:

- understand that soil is a mixture of sand, silt, clay, and organic matter
- visualize that soils are classified by the amount of sand, silt, and clay present in a soil sample
- use a soil texture triangle to relate the soil type to the percent of clay, silt, and sand in the soil
- conduct a simple soil texture field test using a soil texture flowchart

Prerequisites:

The students need an understanding of how to use percents to calculate the number of grams of each soil component in a given soil type.

Time Estimate:

Prep: 40 minutes

Activity: One or two 50-minute periods (may be combined with Activity 8: *Soil Permeability*)

Materials:

Demonstration:

- ☐ One bag of M&Ms® brand chocolate candies (three different colors, e.g., brown, red, and yellow)
- ☐ 250 mL beaker

Each Student:

- ☐ Hydroville Science Journal
- ☐ Colored pencils

Each Group of Two or Three Students:

- ☐ Source of water (or a wash bottle)
- ☐ Aluminum pie plate or disposable plastic dinner plate
- ☐ Resealable plastic sandwich bags or containers with lids (such as cottage cheese containers)
- ☐ Permanent marker
- ☐ Overhead transparency pen
- ☐ 500 grams (8 oz) of coarse sand (Industrial Quartz – 20 mesh) – represents sand
- ☐ 350 grams (6 oz) of silt (if silt is not available, you can substitute fine sand: Industrial Quartz – 70 mesh)
- ☐ 275 grams (5 oz) of powdered clay (Ball Clay Kentucky – OM4)
- ☐ Balance (weighs up to 100 grams)

Pages to Photocopy:

Transparencies:

- Transparency 1: *Composition of Average Soil*
- Transparency 2: *Relative Sizes of Sand, Silt, and Clay*
- Transparency 3: *Soil Texture Triangle*
- Transparency 4: *Classes of Soil Texture*
- Transparency 5: *Soil Texture Flow Chart*

One copy/group:

- Instructions: *Soil Texture*

One copy/student:

- Worksheet: *Soil Texture*
- *Soil Texture Triangle* and *Soil Texture Flowchart (*back to back)

Teamwork Skill:

- Praise helpful actions or ideas.

Terminology:

Clay	Minerals	Silt
Loam	Organic matter	Soil texture
Minerals	Sand	

Background Information:

Soil scientists are trained to conduct various tests to characterize and identify soil, both in the field and laboratory. Soil characterization describes the physical and chemical characteristics of soil to determine land use, drainage problems, etc. In BA 7 and BA 8, students will determine soil texture of different soils, and test the soil permeability of sand, silt, and clay.

Soil Composition

Soil is composed of organic (living and once living) and inorganic (non-living) matter. Inorganic minerals, such as *sand, silt, clay,* and nutrients make up almost half (45%) of the composition of average soil. The other 5 percent is *organic matter,* which is the part of the soil that includes the decomposing remains of plants and animals; it is also referred to as humus. Water and air constitute the other half, which fills in the pore spaces between the soil particles. (See Transparency 1: *Composition of Average Soil*.)

Soil Texture

Soil texture is the relative proportion of various soil components, i.e., sand, silt, and clay. The texture is based on the size of the soil particles: sand is the largest particle, silt is intermediate, and clay is the smallest. (See Transparency 2: *Relative Sizes of Sand, Silt, and Clay.*) Soil texture is important because it enables soil scientists to determine how much water the soil will hold, how fast water will move through the soil, and the structure and consistency of the soil.

The particle-size distribution of each particle size group (sand, silt, or clay) can be sorted into a specific textural class. Soil can be described and classified as coarse, medium, or fine-textured. Coarse-textured soils are sandy. Medium-textured soils contain mainly silt with smaller amounts of sand and clay. Fine-textured soils have a high percentage of clay and less silt or sand. (See Transparency 4: *Classes of Soil Texture*.)

Soil scientists group soil textures into twelve classes. A *soil texture triangle* is used to classify the texture class of a soil. (See Transparency 3: *Soil Texture Triangle*.) Each side of a soil texture triangle is scaled 0 to 100% for sand (bottom), silt (right side), and clay (left side). Clay percentages are read from left to right across the triangle (horizontal lines). Silt is read from the upper right to lower left (downward, parallel lines). Sand extends from lower right toward the upper left portion of the triangle (upward, parallel lines). The boundaries of the soil texture classes are outlined based on the amount of sand, silt, and clay. The intersection of these three sides (representing sand, silt, and clay) on the triangle gives the *texture class*. For instance, if you have a soil with 60% sand, 30% clay, and 10% silt, it falls in the class called "sandy clay loam." It is a loam because it contains a combination of all three soil particles. Since the soil is made up of more than half sand and thirty percent clay, it is described as a "sandy" clay.

Soil texture is used to describe how a soil feels when dry or wet: gritty, smooth, soft, hard, sticky, etc. Soil texture is most easily determined by pressing and rubbing moist soil between the fingers and thumb. (See Transparency 5: *Soil Texture Flowchart.*)

Fine-textured soil is “slick” or plastic when moist. If pressed together, it forms a thin leaf or ribbon 2 inches long. Clay adheres readily to other particles and causes the soil to form hard clods, which is difficult to break apart when dry. This is the reason clay soils have limited land use. Clay, silty clay, and sandy clay are examples of fine-textured soil types.

Medium-textured soils feel floury or soft. They can also be pressed together to form a leaf or ribbon when moist, but the ribbon is only 1/2 inch in length. This type of soil breaks up readily and is more desirable than either fine or coarse-textured soils. It is used primarily for agriculture and buildings. Examples of medium-textured soil include clay loam, silty clay loam, sandy clay loam, silt, silt loam, loam, and sandy loam.

Coarse-textured soils feel gritty and will not form a leaf or ribbon when squeezed together. The clods of soil are easily broken, but do not retain plant nutrients because water moves through this soil very rapidly, which leaches fertilizers from the soils. In drought conditions, coarse-textured soils dry out and do not retain much water for plants. Examples include sand and loamy sand.

Suggested Lesson Plan:

Getting Started

1. Purchase 50 lb bags of coarse sand, silt or fine sand, and powdered clay. You can get coarse and fine sand from a sand and gravel company or a landscape equipment and supplier. Look for “Industrial Quartz” in 20-mesh (coarse sand) and in 70-mesh (fine sand represents silt). Powdered clay can be purchased from a store that specializes in pottery supplies.

   Classroom Hints:
   - To save time, prepare the five soil samples (A through E) ahead of time. See Table 1: *Soil Samples* in the student worksheet.
   - Show a video on soil weathering that uses the terminology and sets the stage for the activity.
   - Take students outside to observe the effects of water on different types of soil around the school.
   - This is a messy activity! Lay down newspaper or contain soil on trays to save time on cleanup.
   - Supply buckets to collect soil and other soil-related waste so you don’t clog the classroom sinks.

2. **Journal Prompt:** "What do you think soil is made up of?"
   a. After listening to student responses, show Transparency 1: *Composition of Average Soil.*
   b. *Answer: Soil is made up of almost half (45%) of a mixture of minerals: sand, silt, and clay, including nutrients such as nitrogen, phosphorus, and potassium. In addition, soil is composed of equal parts of water (25%) and air (25%). The remaining 5 percent of soil is "organic matter," which is the part of the soil that includes the decomposing remains of plants and animals. It is also referred to as humus.*

Doing the Activity

1. Show class Transparency 2: *Relative Sizes of Sand, Silt, and Clay* to define and explain soil texture. Point out to students that soil is a mixture and can be separated into the individual components by using different size screens (mesh) to sort out the particles based on their size.
2. **Soil Texture Demonstration:** You can introduce soil texture to students by using three different colors of M&M® brand chocolate candies to represent the soil particles: sand, silt, and clay. For example: brown (sand), yellow (silt) and red (clay). **Note:** Because the M&M® candies are all the same size, they do not represent the relative size of the soil particles. Consider using three different-sized items in three different colors, such as marbles (sand), other candy (Skittles® could represent clay), etc.
3. Count out 50 brown, 30 yellow, and 20 red M&Ms® and put them in a glass beaker in front of the class.
4. Tell the students that each candy represents one of the three soil particles: sand—brown, silt—yellow, clay—red. The mixture of M&Ms® represents soil. Have students make observations, and then guess the soil texture.
5. Give the students the amount of each M&M®:
   - 50 brown (sand)
   - 30 yellow (silt)
   - 20 red (clay)
6. To identify a soil, you must know the percentage of each soil particle in the sample. Review ratios with students, i.e., "part divided by the whole." Ask them to apply the same formula to calculate the ratio of each soil particle from the total soil sample.

   Soil Particle/Total Soil Sample x 100 = ______ %

   50/100 x 100 = 50% sand

   30/100 x 100 = 30% silt

   20/100 x 100 = 20% clay

7. Explain how to identify the soil texture of this soil sample using the *Soil Texture Triangle* (Transparency 3).
   a. A soil texture triangle has three sides, one for each soil particle: sand, silt, and clay. The scale on each side ranges from 0% to 100%.
   b. Start by finding the percentage of silt (30%) on the right side of the triangle. Follow the arrow and line downward from right to left. Draw a line with an overhead marker over this line.
   c. Find the percentage of sand (50%) on the bottom of the triangle. Refer to the direction of the arrows; they point right to left. Draw a line to indicate 50% sand. The lines drawn for silt and sand should intersect.
   d. Finally, find the percentage of clay (20%) on the left side of the triangle. Draw a horizontal line across where the three lines intersect.
   e. The intersection of the three lines indicates the soil texture class. Using this example (50% sand, 30% silt, and 20% clay), the soil is *loam*.
   f. If time permits, walk students through another example of how to use a soil texture triangle: 60% silt, 10% sand, and 30% clay is s*ilty clay loam*.
8. Display Transparency 4: *Classes of Soil Texture* and introduce the 12 classes of soil texture. Explain that the name of the soil is based on the composition of the soil and the percentage of the soil components: sand, silt, and clay. The component that appears first in a soil description has the highest percentage in the soil. For example, sandy loam contains more sand than silt or clay. If there is a second descriptor, that component has the second highest amount, e.g., silt clay loam is primarily composed of silt and then clay, and some sand. Loam represents all three soil particles present.
9. In this activity, students will work in groups of two or three. Hand out the Instructions to each group and a worksheet to each student. Distribute the *Soil Texture Triangle* and *Soil Texture Flowchart* either as paper copies or on transparencies (students can write on them using overhead markers).
10. Assign each group one soil sample to make. (Refer to samples A, B, C, D, or E listed on Table 1. *Soil Samples* in the worksheet.) You may have to assign a sample more than once.
11. In Part 1, students will use a soil texture triangle to identify the soil texture class of all five samples, and record in Table 1.
12. In Part 2: *Making Soil*, students calculate the amount of sand, silt, and clay needed to make 100 grams of their assigned soil sample. Tell students they are making a model of a soil since actual soil

also contains water, air, and organic matter. The soils purchased represent sand, silt, and clay based on their relative size.

13. Introduce Part 3: *Soil Identification Using the Soil Texture Flowchart*. Walk students through Transparency 5: *Soil Texture Flowchart*. Explain that soil texture (how it feels) is a result of how much sand, silt, and clay are in the soil. Students use the flowchart to identify their soil sample, and repeat the process for another group's soil sample.
14. Designate a container where you want students to dispose of the used soil.

Wrap-up

1. For homework, assign the Conclusion Questions on the worksheet.
2. **Journal Prompt:** "How will the texture of a soil influence its interaction with water?"
   Answer: Soils that are gritty (coarse-textured) may not absorb water, but may provide good drainage since it is not likely to form ribbons. Soils that are smooth and slightly sticky (fine-textured) may be able to retain water, but may have poor drainage.

Assessment:

1. Have students identify the texture of an unknown soil that you have mixed or that comes from around the school. Make sure they can explain how they will do that test. Have them propose a percent of sand, silt, and clay in the soil by using the soil texture triangle.
2. Mix an unknown soil type by using the soil texture triangle. Give the same unknown to the students. Students should be able to explain their decision-making process at each step of the soil texture flowchart and then categorize the soil type on the textural triangle.

Extensions:

Social Studies

1. Students can research the food and animal products produced in the United States. Students can then use an outline map of the U.S. and a map key to represent which crops and animal products (if any) are present, region by region, throughout the country. Students then hypothesize how the soil texture, climate, and vegetation in these regions determine the region's agricultural products. Students can also hypothesize how farmers in certain regions adapt to their environment in order to be productive and competitive.

2. Students can research the types of soils in their community. How has the type of soil influenced the use of the land in their community?

Language Arts

Silent Spring by Rachel Carson

1. Have students read Chapter 5, "Realms of the Soil," from Rachel Carson's *Silent Spring*.

   First published in 1962, Carson's book is recognized as one of the two most influential environmental statements in the 20th century, along with Aldo Leopold's *Sand County Almanac*. She traces the development of DDT and other chemical pesticides from the inception of World War II's chemical warfare. Some of these chemicals were found to be lethal to insects. The production of synthetic pesticides soared and pesticides were dumped indiscriminately into agricultural fields and streams, used to control weeds along highways and railroads, sprayed and dusted to control insect infestations in forests. Carson raises a serious red flag to the American public: "For the first time in the history of the world, every human being is now subjected to contact with dangerous chemicals, from the moment of conception until death" (15). Carson's purpose in writing *Silent Spring* was to alert the public to the dangers of pesticide use, post-World War II. She is communicating scientific information to the general public.

2. *Analysis Assignment*: Write a 2-page essay addressing the following issues:
   - What are some of Carson's techniques? (Example: on page 53, she defines lichens in the sentence with the brief phrase, "Lichen, the rocks' first covering, aided the process . . .") Note other examples of informing the reader of scientific data.
   - What problems does she pose to readers? (see page 56)
   - How does she answer them?
   - What examples does she use?
   - What is her conclusion?

3. *Interview Assignment*: Interview your county Extension agent to learn about soil practices by local farmers. Interview farmers as well. Based on interviews, students can write a 1-page report to the class about their findings.
   - What kinds of pesticides and herbicides do the farmers use in your area?
   - What problems do they face in production?
   - What do they use to control weeds and insects?

O Pioneers! by Willa Cather

1. Have students read *O Pioneers!* by Willa Cather.

   This book addresses the issues of American pioneers and their deep connection and dependence on their land and the soil. Alexandra Bergson, a strong, determined daughter of a Swedish immigrant, inherits her father's Nebraska land. With the land, she inherits the struggle to tame and farm the fierce, wild plain. In this novel, Cather contrasts Alexandra with her neighbor, Marie Tovesky, who does not share Alexandra's deep connection to the land and pursues a busy social life to fill up her loneliness. This book raises intriguing questions about the options open to women at the turn of the 20th century.

2. *Research Assignment*:
   - Research the early pioneers in your area.
   - How did they depend on the land?
   - What crops were successful?
   - How did they prepare the soil?
   - How is the rural land being used now? Who owns it? What is happening to it?
   - Write a 2-page short story of a fictitious character set as a pioneer in your area. What challenges does she or he face? How does the land shape her or his life?

Resources:

- Resources on soils and soil testing can be found on the GLOBE Program Web site: www.globe.gov/sda-bin/wt/ghp/tg+L(en)+P(soil/Contents)
- Carson, Rachel. *Silent Spring,* Houghton Mifflin, 1994 (or any other edition available in your library).
- Cather Willa. *O Pioneers!* Vintage Books, 1992.
- See the Hydroville Web site for links to Web resources for this activity at http://www.hydroville.org/links/ps_resources.aspx.

Teacher Key

Worksheet

Part 1. Soil Identification (Using a Soil Texture Triangle)

Table 1. Soil Samples

Soil Sample	Sand (%)	Clay (%)	Silt (%)	Soil Texture Class
A	70	10	20	Sandy loam
B	10	20	70	Silt loam
C	30	30	40	Clay loam
D	50	10	40	Loam
E	50	40	10	Sandy clay

Part 2. Making Soil

Note: *Each group is assigned one soil type to make. Because there may be more groups than soil types, you may assign a soil type more than once.*

Table 2. Assigned Soil Samples

	Amount needed to make 100 grams of soil				
Soil Sample	Sand (g)	Clay (g)	Silt (g)	Total (g)	Soil Texture Class
A	70	10	20	100	Sandy loam
B	10	20	70	100	Silt loam
C	30	30	40	100	Clay loam
D	50	10	40	100	Loam
E	50	40	10	100	Sandy clay

Part 3. Soil Identification (Using the Soil Texture Flowchart)

Use the *Soil Texture Flowchart* to identify the soil texture class of two different soil samples, and explain how you came up with your answer.

Answers for both samples will vary, but should include descriptions of sticky or hardness and gritty or smooth.

Conclusion Questions

1. What is the most abundant material or component found in average soil? Give examples.
   Mineral particles are most common, such as sand, silt, clay, and nutrients.
2. Use the *Soil Texture Triangle* to identify the class of soil that is composed of the following:
   a. 40% clay, 50% sand, and 10% silt *sandy clay*

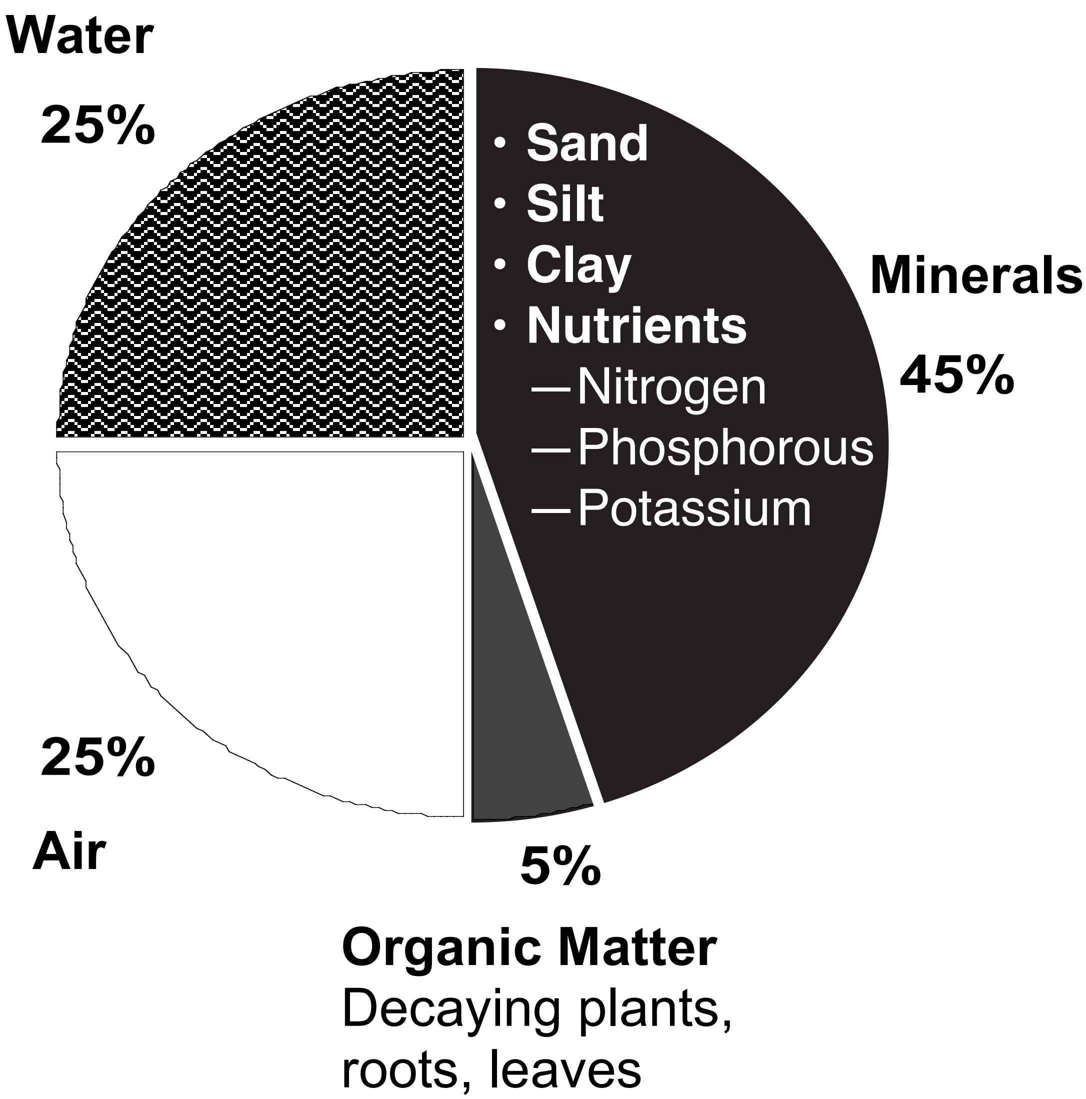
Teacher Key

b. Describe the soil texture of this soil. Include terms from the *Soil Texture Flowchart* and reasons why it would feel this way.
Since sandy clay is made up of half sand (50%), it feels gritty. Because it is almost half clay (40%), it is slightly sticky and easy to squeeze. It may form short ribbons.

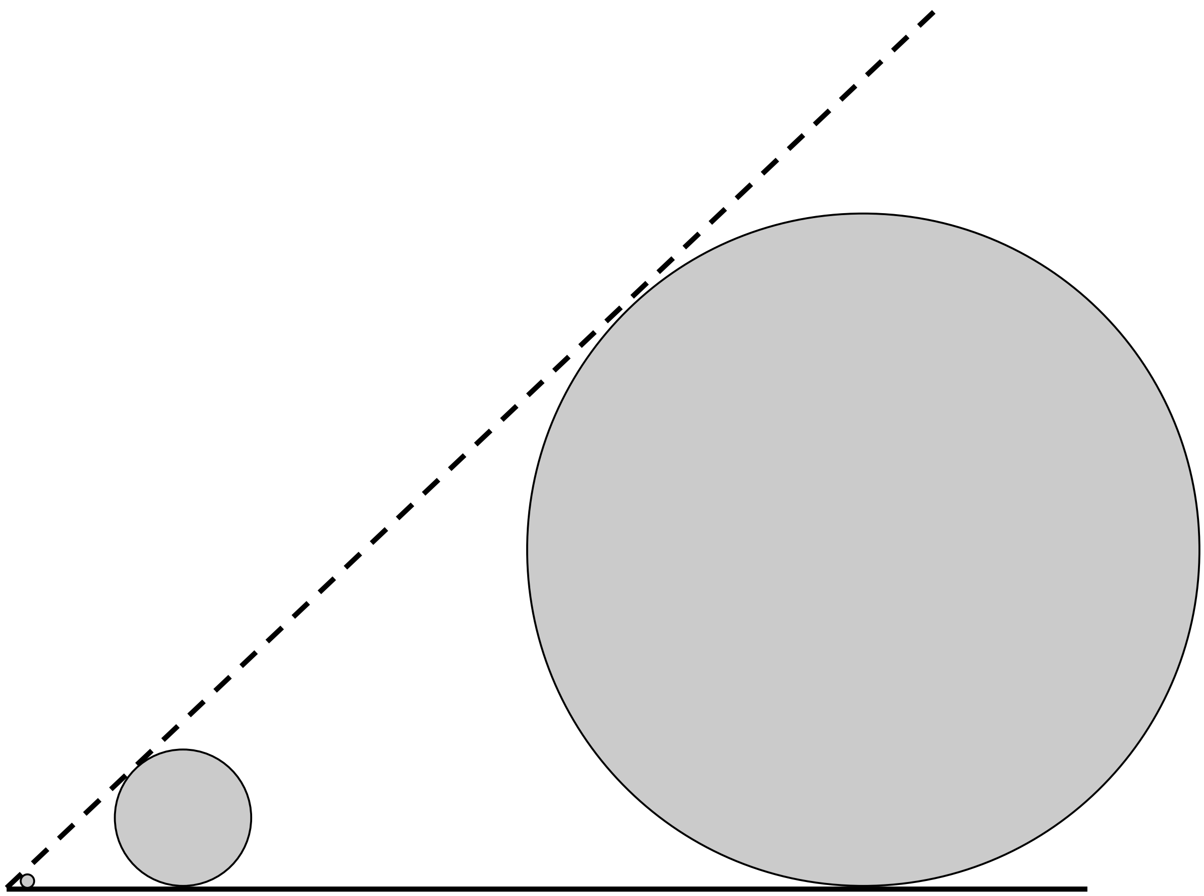
3. What percentage of sand, silt, and clay make up sandy loam?
Answers may vary. One example: 70% sand, 10% clay, and 20% silt.

4. Were you able to identify another soil sample (besides your own) using the *Soil Texture Flowchart*? If not, what could be possible errors?
Answers will vary.

Composition of Average Soil



Relative Sizes of Sand, Silt, and Clay



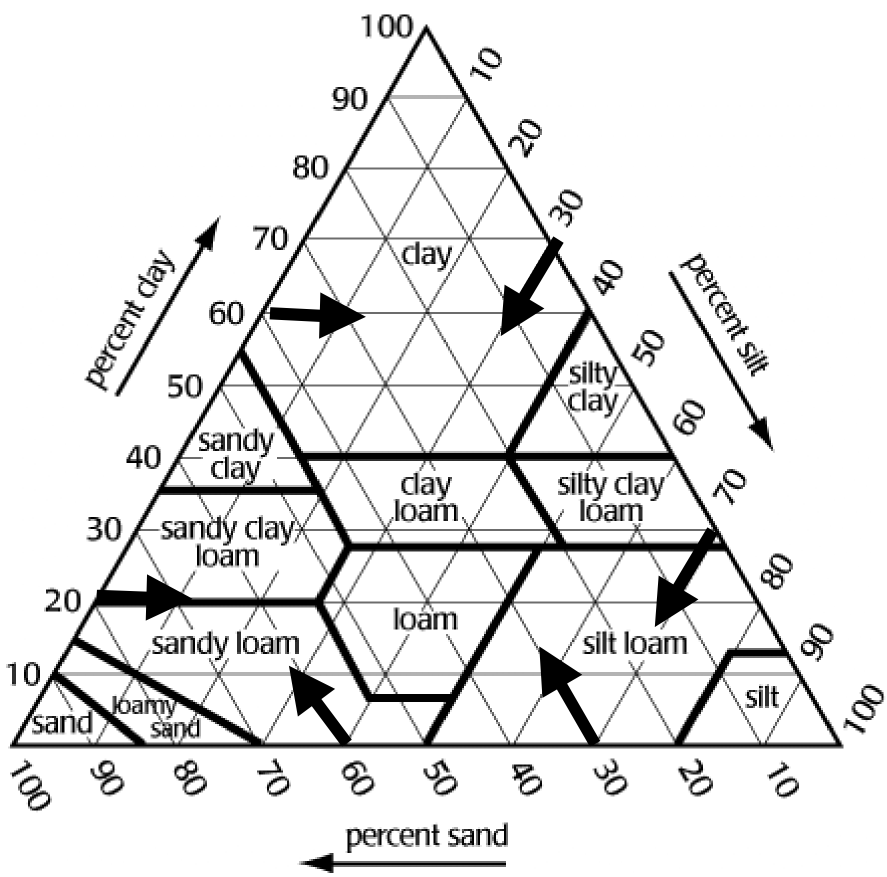
Clay **Silt** **Sand**

< 0.002 mm **0.05-0.002 mm** **0.05-1.0 mm**

Soil texture is the relative proportion of various soil components: **clay, sand**, and **silt**. The texture is based on the size of the soil particles.

Transparency 3

Soil Texture Triangle



Classes of Soil Texture

Soil Texture	Coarse	Medium	Fine
Soil Particle	**Sand**	**Silt**	**Clay**
Classes	**Sand** **Loamy sand**	**Sandy loam** **Loam** **Silt loam** **Silt** **Clay loam** **Sandy clay loam** **Silty clay loam**	**Clay** **Silty clay** **Sandy clay**
Example: ***loam***	***40% sand***	***40% silt***	***20% clay***

Soil Texture Flowchart

1) How easy is it to squeeze the soil? (dry pressure)

If the soil is extremely sticky and hard to squeeze, then it is

Clay

If the soil is sticky and easy to squeeze, then it is

Clay Loam

If the soil is only slightly sticky and easy to squeeze, then it is

Loam

2) How gritty does the soil feel? (dry feel)

If the soil is very gritty, then add the word "sandy" to the front of the name you identified in question 1.

Sandy Clay
Sandy Clay Loam
Sandy Loam

If the soil is neither gritty nor smooth, do not change the name you identified in question 1.

Clay
Clay Loam
Loam

If the soil is very smooth with no grittiness, add "silty" to the front of the name you identified in question 1.

Silty Clay
Silty Clay Loam
Silt Loam

Student Pages for

SOIL TEXTURE

Follow this Page

Soil Texture

Materials:

Each Student:

- ☐ Hydroville Science Journal
- ☐ *Soil Texture Triangle and Flowchart*

Each Group of Three to Four Students:

- ☐ Coarse sand
- ☐ Silt
- ☐ Powdered clay
- ☐ Balance
- ☐ Source of water (or a wash bottle)
- ☐ Aluminum pie plate or disposable plastic dinner plate
- ☐ Resealable plastic sandwich bag or containers with lids
- ☐ Permanent marker
- ☐ Overhead transparency pen (optional)

Part 1. Soil Identification (Using a Soil Texture Triangle):

1. The soil texture triangle is used to identify 12 classes of soil texture. It is similar to a graph, but has three axes instead of two. The corners of the triangle represent 100 percent sand, silt, or clay. You will practice using the soil triangle by identifying all five of the soils listed in Table 1: *Soil Samples*.
2. Let's begin with Soil A. Refer to the percentages of sand, silt, and clay in Table 1. You will also need a copy of the *Soil Texture Triangle*.
3. On the right of the soil triangle, find the percentage of silt in the soil sample. With a ruler, draw a line extending downward (follow the arrows), parallel to the lines on the soil texture triangle.
4. On the bottom of the soil triangle, find the percentage of sand in the soil sample. With a ruler, draw a line extending upward to the left (follow the arrows), parallel to the lines on the soil texture triangle.
5. On the left side of the soil triangle, find the percentage of clay in the soil sample. With a ruler, draw a horizontal line across the triangle.
6. Identify the soil texture where the three lines intersect. If the point falls directly on the line between two soil textures, record both soil textures. Record the soil type in Table 1.
7. Repeat steps 2–6 to identify soil samples B–E.

Part 2. Making Soil

Your instructor will assign your group one soil type from Table 1 to make by combining various amounts of sand, silt, and clay to make 100 grams of soil.

1. Read your assigned soil type in Table 2 on the Worksheet.
2. Before you begin mixing, use the *Soil Texture Triangle* to calculate the amount of sand, silt, and clay you would need to make 100 grams of your assigned soil (percent x 100 grams).
3. Record your data in Table 2.
3. Using a balance, measure the amount of sand needed to make your soil sample.
4. Pour into a resealable plastic bag or container with a lid.
5. Repeat steps 3 and 4 for silt and clay.
6. Mix the soil together and shake vigorously in the closed bag or container. Use a permanent marker to label the container with your name and soil type.
7. Remove 50 grams of the mixed soil and place on a plate.

Part 3. Soil Identification (Using the Soil Texture Flowchart)

You will learn to identify soil by conducting a texture or "feel" test. Soil scientists in the field use this method to identify soils. Sometimes they're even required to taste it, but we'll spare you. Follow the questions on the *Soil Texture Flowchart* to identify your unknown soil.

1. Place about half the size of a golf ball of soil (from your sample) in your palm.
2. Follow the *Soil Texture Flowchart* to identify your soil type.
3. Squeeze the soil in your hand to check dry pressure. How easy is it to squeeze? Is it sticky or does it fall apart?
4. Rub the soil between your fingers. Does it feel gritty or smooth?
5. Identify the soil.
6. Spray the soil with water to moisten it. Knead the soil, spraying with more water if needed, until it feels moist like putty.
7. Squeeze the ball of soil between your thumb and forefinger; try to form a ribbon. Sand will not ribbon, loam will form a broken ribbon, and clay will form a ribbon that holds together.
8. Record your soil type on the Worksheet.
9. Test another group's soil and see if you can identify it using the flowchart.
10. Dispose of your soil in an area designated by your teacher. *Do not throw soil down the drain.*

Worksheet

Name ______________________________

Date _________________ Period ______

Soil Texture

Part 1. Soil Identification (Using a Soil Texture Triangle)

Table 1. Soil Samples

Soil Sample	Sand %	Clay %	Silt %	Soil Texture Class
A	70	10	20	
B	10	20	70	
C	30	30	40	
D	50	10	40	
E	50	40	10	

Part 2. Making Soil

Table 2. Assigned Soil Samples

	Amount needed to make 100 grams of soil				
Soil Sample	Sand (g)	Clay (g)	Silt (g)	Total (g)	Soil Texture Class

Part 3. Soil Identification (Using the Soil Texture Flowchart)

Use the *Soil Texture Flowchart* to identify the soil texture class of two different soil samples, and explain how you came up with your answer.

Your soil sample from Part 2: ________________________________

Someone else's soil sample: ___________________________________

Worksheet, Page 2

Name ______________________________

Date _________________ Period ______

Conclusion Questions

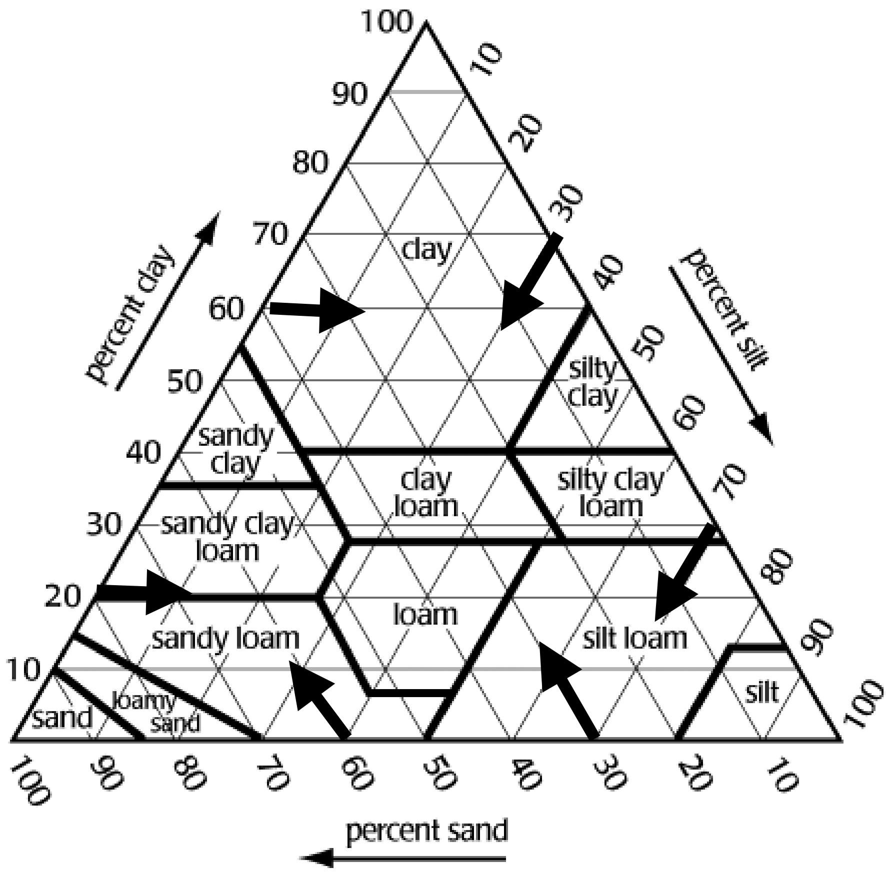
1. What is the most abundant material or component found in average soil? Give examples.

2. Use the *Soil Texture Triangle* to identify the class of soil that is composed of the following:
   a. 40% clay, 50% sand, and 10% silt ________________________
   b. Describe the soil texture of this soil. Include terms from the *Soil Texture Flowchart* and reasons why it would feel this way.

3. What percentage of sand, silt, and clay make up sandy loam?

4. Were you able to identify another soil sample (besides your own) using the *Soil Texture Flowchart*? If not, what could be possible errors?

Soil Texture Triangle



Soil Texture Flowchart

1) How easy is it to squeeze the soil? (dry pressure)

If the soil is extremely sticky and hard to squeeze, then it is → ***Clay***

If the soil is sticky and easy to squeeze, then it is → ***Clay Loam***

If the soil is only slightly sticky and easy to squeeze, then it is → ***Loam***

2) How gritty does the soil feel? (dry feel)

If the soil is very gritty, then add the word "sandy" to the front of the name you identified in question 1.

→ ***Sandy Clay***
Sandy Clay Loam
Sandy Loam

If the soil is neither gritty nor smooth, do not change the name you identified in question 1.

→ ***Clay***
Clay Loam
Loam

If the soil is very smooth with no grittiness, add "silty" to the front of the name you identified in question 1.

→ ***Silty Clay***
Silty Clay Loam
Silt Loam