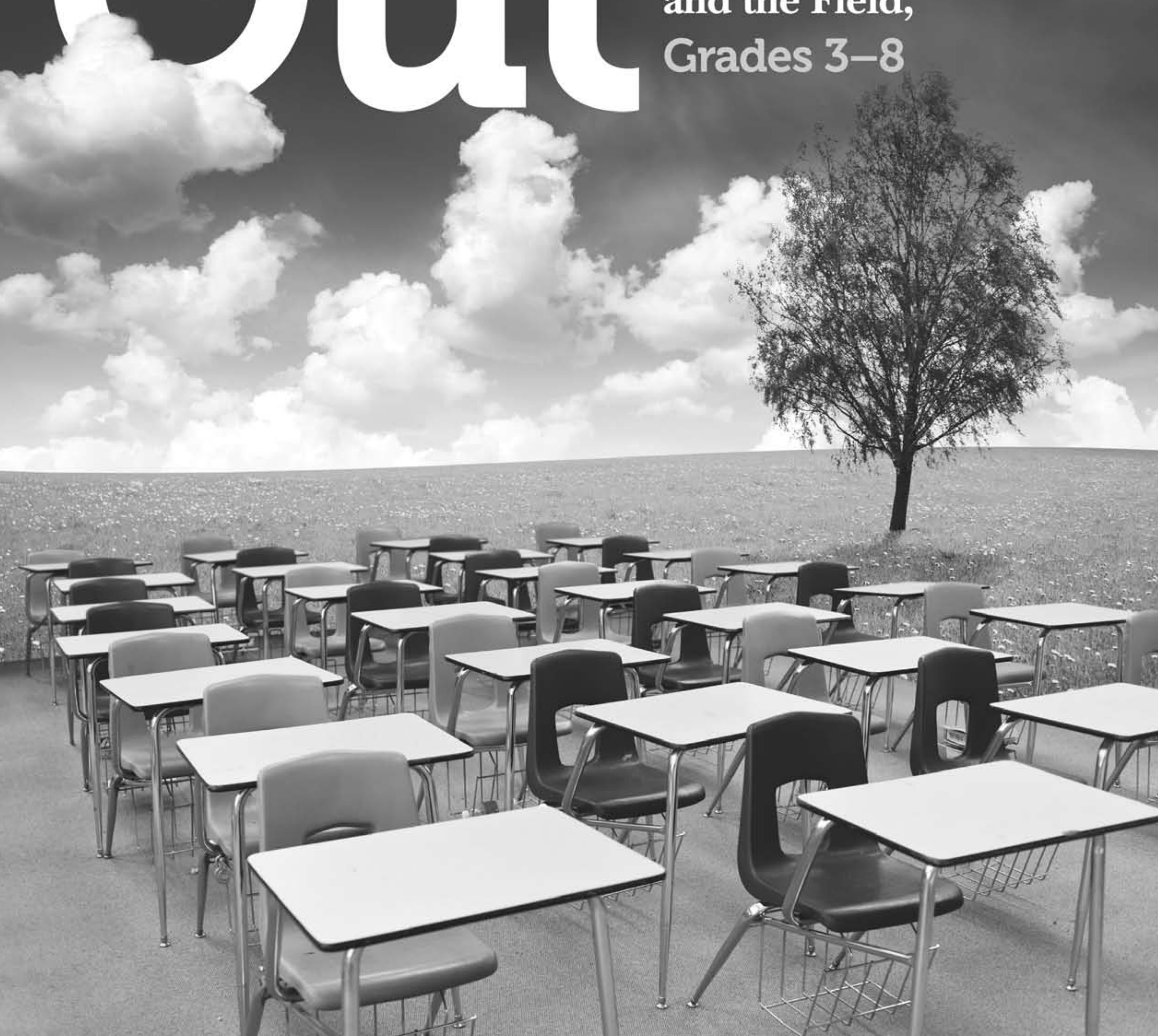
Inside-Out

Environmental Science in the Classroom and the Field, Grades 3–8



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Environmental Science in the Classroom and the Field, Grades 3–8

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Dedication

To our parents

Dr. Robert W. and Carol Blake
Dr. A. Bruce and Norma N. Frederick
Bonnie and Gary Rogers
Margaret and Charles P. Colby Jr.

For providing our childhood with opportunities and
the freedom to explore the outdoors

Acknowledgments

The impetus for this project was a 2002 Eisenhower Grant, and the book idea was launched after NSTA's national conference in Philadelphia in 2003. We realized then that our emphasis on increased content knowledge, combined with a passion for outdoor learning, was a key to both teacher and student engagement in high-quality, meaningful learning experiences in environmental science. Our combined 60 years of science teaching experience at all levels of the professional continuum convinced us that what we had to say was significant and timely. However, to dare say that what we present here is all our own is against our fundamental belief that "the reason we can see for miles is because we stand on the shoulders of giants." Without such giants, or those that came before, the task of writing this book would have been close to impossible. Thus, in our attempt to acknowledge those we can readily remember, we will also most likely fail to mention many more who have shaped our thinking and practice along the way.

We first would like to thank those granting agencies that believed in our ideas as we engage teachers and students in field-based learning. These include the U.S. Department of Education with the Maryland Higher Education Commission (Eisenhower Grant program, award number E01-21-113), the National Oceanic and Atmospheric Administration (NOAA, award number NA03NMF4570216)[1], the American Forest Foundation (AFF) and Project Learning Tree (PLT), and the Chesapeake Bay Trust. Without these critical funds we would not have been able to pursue our passion.

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1 Award number NA03NMF4570216 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

Acknowledgments

As you read this book, you will also find resources from a wide array of agencies and organizations related to science education. As we explain in the introduction, web-based resources are almost endless, thus it is difficult to acknowledge all that have affected our work. Having said this, and although many web-based materials are of public domain, we still would like to thank specific groups that gave us permission to use their materials. These include the Maryland Department of Natural Resources, the Virginia Save Our Streams Program, the United States Geological Service, the University of Rhode Island, the Maryland Sea Grant College program, the Chesapeake Bay Program, the National Oceanic and Atmospheric Administration, Environmental Concern, the Laboratory for Atmospheric and Space Physics, the University of Colorado, and BioWorld Products LLC (Visalia, CA).

Next, we would like to thank those in the peer review process, all of whom contributed significant time and effort to provide well-constructed feedback and suggestions for revisions. Although we did not agree with all comments about changes to the text, this process did shape the final format, and we greatly value the practice and acknowledge that the book is better for it. We also wish to thank the editors for supporting our belief that content knowledge is a prerequisite to meaningful learning. While we realize that "knowing" does not guarantee high-quality teaching, content understanding does provide confidence in creating varied learning experiences for children.

Laboratory experiences that are directly linked to field-based inquiry are essential for the overall learning process in science. We thank Jeff Morgen, the former science education specialist at the SciTech education program of the Center of Marine Biotechnology (COMB), located in Baltimore, Maryland, for providing such experiences. Without Jeff's leadership and "can do" attitude we would not have been able to provide laboratory and field-based learning for elementary teachers, interns, and students.

We also would like to acknowledge additional contributors to this book. We thank Debbie Freels, Mark Herzog, Steve Lev, Pam Lottero-Perdue, and Christine Wolfe for their help.

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Finally, we thank our families for their understanding and contributions to this task. Specifically, we thank Dr. Robert W. Blake, Sr., and Dr. A. Bruce Frederick for their input and editorial skills. We thank our wives, Jennifer Blake and Lisa Frederick, and our husbands, Tom Haines and John Lee, for unwavering support. We thank our children—MacKenzie Blake; Christopher, David, and Elaina Frederick; and Andrew and Adam Haines—for their continued interest in spontaneous field-experiences that persist to remind us of the importance of these learning experiences.

Safety Practices

Safety Out-of-Doors Practices

1. Teachers should always visit out-of-doors areas to review potential safety hazards prior to students' carrying out activities.
2. Keep clear of out-of-doors areas that may have been treated with pesticides, fungicides, and other hazardous chemicals.
3. When working out-of-doors, students should use appropriate personal protective equipment (PPE), including safety glasses or goggles (when working with hazardous chemicals), gloves, close-toed shoes, hat, long-sleeve shirt and pants, sunglasses, and sunscreen protection. When working near deep water, use life preservers or other floatation devices.
4. Caution students relative to poisonous plants (ivy, sumac, etc.), insects (bees, wasps, ticks, mosquitoes, etc.), and hazardous debris (broken glass, other sharps, etc.).
5. Caution students about trip and fall hazards such as rocks, string or rope, and so on when walking out-of-doors.
6. Teachers need to inform parents in writing of on-site field trips relative to potential hazards and safety precautions being taken.
7. Teachers need to check with the school nurse about student medical issues such as allergies, asthma, and so on. Be prepared for medical emergencies.
8. Teachers need to have a form of communication available, such as a cell phone or two-way radio, in case of emergency.
9. Wash hands with soap and water after doing activities dealing with hazardous chemicals, soil, biologicals (insects, leaves, etc.), or other materials, as well as after returning to the classroom from out-of-doors activities.

10. Contact the main office before bringing classes out of the building for activities.

Safety in the Classroom Practices

1. When working with glassware, metersticks, hazardous chemicals (including soil testing kits), and so on, students should use appropriate personal protective equipment (PPE), including indirectly vented chemical splash goggles, gloves, and aprons.
2. Always review Material Safety Data Sheets (MSDS) with students relative to safety precautions in working with hazardous chemicals.
3. When dealing with hazardous chemicals, an eyewash station is required should a splash accident in the eyes occur.
4. When heating liquids, use only heat-resistant glassware (Pyrex- or Kimax-type equipment).
5. When heating liquids on electrical equipment such as hot plates, use ground fault protected circuits, or GFI.
6. Always remind students of heat and burn hazards when working with heat sources such as hot plates and light bulbs.
7. Wash hands with soap and water after doing activities dealing with hazardous chemicals, soil, biologicals (insects, leaves, etc.), or other materials.

Introduction

My grandmother, Mary E. E. Kready, took to the field early in the morning just outside of West Chester Normal School (est. 1871) in the spring of 1924. This was a favorite activity of the 18-year-old undergraduate student, not because she needed samples of plant material for her field botany class but—very simply—because she loved it. The serenity, peacefulness, and sense-provoking environment are what she longed for. Nothing was required but her sense of wonder, her sense of place. Surrounded by the inspiration of towering oaks and peeking bloodroot, Mary was at home. Probably very little interference entered her world once in the wooded realm. On this particular day she was searching for elusive ginger to add to her collection. Although it was nearly invisible to the passerby, Mary found the ginger and added it to her field bag with no doubt a great sense of triumph, then continued on her trek.

Bloodroot, a sure sign of spring

As I sift through my grandmother's herbarium paper samples, so cleanly preserved and so neatly pressed,

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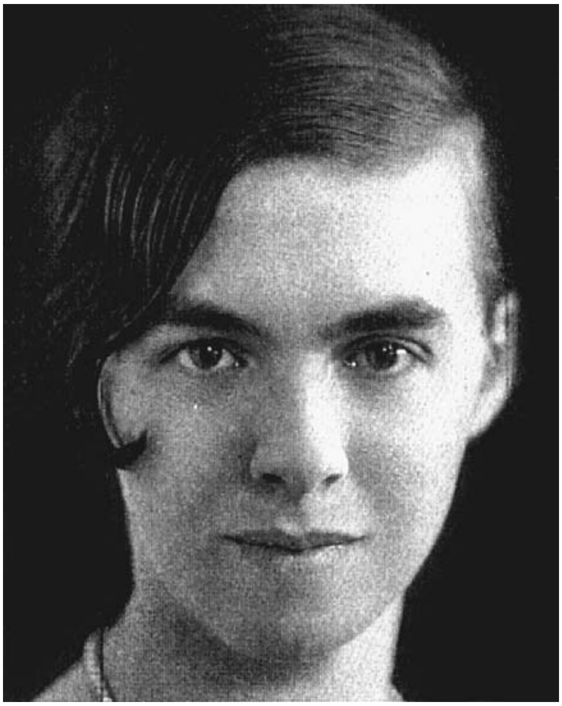
it gives me great pause and the realization that we must carry stories like this forward to better our teaching and learning of science in our schools and to develop educators with a thirst to walk as Mary did.

J. Adam Frederick, May 2008

Why This Book and Why This Way?

Why an Emphasis on Content?

Children love the outdoors and have many questions pertaining to their natural surroundings, but all too often in elementary and middle schools either students learn very little science in the classroom or the time is usually spent on textbook and direct classroom instruction (NRC Committee on Science Learning, Kindergarten Through Eighth Grade 2007). As an elementary teacher you are a generalist, expected to know a lot about many topics and to teach many subjects. Unfortunately, when it comes time to teach students science, many of you probably feel unprepared in both content understanding and your ability to provide students with meaningful experiences in science and to actively engage them within the learning process. The lack of content understanding and the ability to know how to apply this knowledge in learning can be an impediment to you and your ability to integrate content with activities. Our fundamental aim for this book, therefore, is to enhance your understanding of basic environmental science concepts and to instill confidence in your ability to engage students in the process of science and learning experiences both inside and outside your classroom.



A 1924 yearbook photograph of Mary E. E. Kready at West Chester Normal School

Why the Elementary Level?

Our use of the term *teacher* is inclusive of both inservice and preservice educators in the elementary and middle school classrooms. Within the concept of *lifelong learner* the National Science Foundation (NSF) coined the term *Teacher Professional Continuum* (TPC); the purpose of the TPC program is to "improve the quality and coherence of teacher learning experiences across the continuum" (NSF 2006). In the current education environment we hear of a need for better STEM (science, technology, engineering, and mathematics) experiences for students and a need for better teachers of STEM subjects. Much of the emphasis on improving STEM education and educators is at the undergraduate and high school levels and on the preparation of those going into STEM professions. Unfortunately, this discussion does not include much talk about the need for better science teaching at the elementary grades and, most important, the need for enhancing a scientific worldview, a viewpoint that is impor-

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tant for the intellectual capabilities of all people in all walks of life. If we truly believe in a continuum, then helping you, the elementary teacher, learn science content and then use the content to engage students in meaningful and active learning experiences will provide a critical foundation for an overall STEM initiative.

Why Field-Based Learning?

Research and Field-Based Learning

The National Science Education Standards (NRC 1996, p. 13) encourage teachers to help students "experience the richness and excitement of knowing about and understanding the natural world" and "use appropriate scientific processes and principles in making personal decisions." From a research perspective there are a variety of studies indicating that taking students outside to study and understand the natural world is beneficial to their learning. For example, Hungerford and Volk (1990) demonstrated that exposing students to environmental investigations resulted in positive changes in behavior toward the environment. Research by Lieberman and Hoody (1998) and others (Bartosh 2003; Falco 2004; NEETF 2000; SEER 2000) suggests that using the environment as an integrating context for learning (the EIC Model) leads to a host of positive outcomes for students and teachers, including greater academic achievement in reading, mathematics, science, and social studies; increased motivation to learn; and decreased disciplinary issues.

Duffin, Powers, Tremblay, and PEER Associates (2004) reported that the more students are exposed to the EIC approach, the greater their attachment to a sense-of-place ("a special collection of qualities and characteristics, visual, cultural and environmental that provides meaning to location"; Project Learning Tree 2006, p. 25), involvement in environmental stewardship, actual time spent outside, and degree of civic engagement. Additional studies indicate that constructing and maintaining schoolyard gardens is an excellent means for increasing student science achievement scores ("Youth in Horticulture" 2005). For those students diagnosed with attention deficit/hyperactivity disorder, Taylor and Kuo (2009) suggested that simply providing walks in a natural setting increases attentiveness of this particular group of students.

Finally, Louv (2005), in his book *Last Child in the Woods*, coined the term *nature deficit disorder*. Louv described a trend in today's society in which children are not spending significant amounts of time outdoors being exposed to nature. He claimed that there are complex reasons for this phenomenon, which can lead to a host of academic and health-related problems for our youth. Perhaps partially in response to the attention garnered by *Last Child in the Woods* and the groundswell of public opinion that has resulted from it, the U.S. House of Representatives voted on and passed H.R. 3036, the No Child Left Inside Act of 2008 (September 18, 2008). Of the eight main objectives of the bill, four link directly to the purposes of our book:

- To "create opportunities for enhanced and ongoing professional development" in environmental science
- To ensure that environmental education programs are aligned with national, state, and local content standards, to promote "interdisciplinary courses that include strong field components"
- To "bring teachers into contact with working environmental professionals"
- To "establish programs to prepare teachers to provide environmental

education professional development to their colleagues and programs to promote outdoor education activities as part of the regular school curriculum" (H.R. 3036—110th Congress 2007)

An Elementary School Principal and Field-Based Learning

Taking all of these reports and studies into consideration, we believe that Debbie Freels, a former elementary school principal, says it best:

> *As an elementary school principal, I cannot recall hearing about any student not wanting to go outside for an activity! Students yearned for the opportunity to be outdoors during the school day. By providing instruction through project-based teaching and learning, teachers were able to integrate cross-curricular objectives in science-oriented projects.*
>
> *I remember conducting formal observations of a teacher teaching a measurement lesson in the field behind the school and of another teacher who taught a writing lesson on descriptive words as students gazed at the changing leaves on the trees on a fall day. Students and teachers alike were energized by being able to extend instruction beyond the walls of the school. Teachers and parents both found that when students were provided with instruction that addressed*

Dr. Robert Blake and preservice teachers exploring a stream on the Towson University campus

cross-curriculum content within a science theme and the outdoors was utilized as a classroom, student interest, enthusiasm, and engagement increased as students saw connections between their classroom and the real world. In addition, most students experienced greater academic achievement and understood the importance of environmental stewardship and giving back to the community. I truly believe that these experiences will help to shape future citizens who not only care about the environment, but actively participate in preserving it. (e-mail to Robert Blake, October 22, 2009)

A Practical Reason for Field-Based Learning

Although we often hear from teachers that there "isn't time," "it's not in my curriculum," or "it's not within my structural obligation," it is quite clear from the perspective of both researchers and administrators" that integrated outdoor learning for teachers and students has many benefits, both academic and emotional. In addition, going outside—while rarely an educational objective—is just plain fun, and having fun is one way to increase motivation. Increased motivation leads to greater student and teacher involvement and creates ownership of activities and projects. As Debbie Freels implies, these experiences can be active, integrated, contextualized, and meaningful, allowing both you and your students to move beyond the classroom walls and investigate ideas outside.

Why So Many Web Resources?

As teachers we value the almost unlimited amount of resources available on the World Wide Web, yet we have also struggled with finding pertinent and useful information within a relatively short period of time. We have spent years searching for material that is useful, trustworthy, and relevant for our own teaching. Recently a colleague received the following e-mail from a 30-year veteran of marine education at Oregon Sea Grant who was openly frustrated at not locating curricular information on the web about climate change:

> *What was causing my frustration, was that I was searching the web using the search words "climate change curriculum... and climate change teaching activities" and finding not much of anything.... Wrong headed. When entered NOAA education, EPA education, NASA education, NANOOS, and MBARI also has an education section with climate change..... a whole new world has opened up. Lots of stuff. One of the sites directed me to NSTA "NSTA Sci Links" which has reviewed science teaching materials and links to what they consider the best. There was also climate change listed there as well. (Vicki Osis, marine educator [retired], Hatfield Marine Science Center, Oregon State University, September 15, 2009)*

This is just one example of how difficult it can be to find relevant web-based material quickly, and it shows that although web material may be "easily accessible," it is not always a simple matter of using what you find.

The web resources presented here are a culmination of literally years of searching the web for useful information in environmental science. We know that these resources do not represent everything that is available, but they do represent the best that we have found so far. Certainly more web resources will become available, and some will disappear. We encourage you to continue to "surf the web" looking for useful information for your teaching. However, if time is of the essence, what we provide here will get you started.

Introduction

Concerns Over Regionalism

Our activities focus on the context of our geographic region, with an emphasis on the Chesapeake Bay and its associated watersheds. Providing students who live in the Chesapeake Bay watershed with a "meaningful watershed experience" is a stated goal of the Chesapeake 2000 agreement (Chesapeake Bay Program 2000) and has become a priority for the Maryland State Department of Education. However, the information and activities that we present can be applied to any local ecosystem in different states and different watersheds around the country. For example, if we lived in western New York or western Pennsylvania our watershed focus could be one of the Great Lakes (Lake Erie or Lake Ontario). If we lived in the Seattle, Washington, area we could study Puget Sound. The goals of environmental education and preservation are similar regardless of locale, and the activities in this book are generic enough to apply across various locations and scales.

Why the Environment and Why the Field?

As science educators our purpose with this book is to engage you, teachers of elementary and middle school students, in field-based activities that integrate the scientific disciplines inherent in the study of the environment (Earth science, chemistry, physical geography, and life science). An essential part of this multidisciplinary approach is to better understand the intertwined relationship between the abiotic and biotic factors within an ecosystem and how this can be communicated more clearly. We want you to move your students out of the classroom and into the field to study the natural and physical world through direct observation and inquiry. We also want to help you become comfortable with conducting laboratory and classroom activities that complement and inform field-based learning. Ultimately, it is what you do with your students that will have the greatest impact on them as lifelong learners.

Organization of the Book

Why This Way?

Over the years our work as science educators in preservice teacher preparation and inservice professional development has allowed us to conduct numerous workshops and fieldwork related to the study of the environment. The material in this book represents our current best synthesis of the science content and classroom-tested activities and presents them in an order that we deem useful for teachers. Most of the experiences presented here are based on our work in Professional Development Schools[1], which includes continuous faculty development and preservice teacher preparation.

We want to emphasize the different nature of our presentation. We focus on the content for the simple reason that we believe that content understanding is essential for good teaching. While simply "knowing" does not ensure high-quality teaching, knowing about what you teach is certainly better than not knowing. We also want to emphasize that this is not a curriculum guide or a unit to be followed in a linear sequence. Although we like the sequence, each chapter can stand alone, with you the teacher deciding on what to read, what to use, and in

[1] "A Professional Development School (PDS) is a collaboratively planned and implemented partnership for the academic and clinical preparation of interns and the continuous professional development of both school system and institution of higher education (IHE) faculty. The focus of the PDS partnership is improved student performance through research-based teaching and learning." (Maryland State Department of Education 2007)

Introduction

what order. We strongly believe in your professionalism and your quest for continuing to better your teaching and the experiences that you provide for your students. We provide but one model and one pathway of how to engage teachers and students in field- and laboratory-based activities that promote inquiry and project-based learning. Ultimately, it is you who will make the decisions of what to use as you seek to engage your students in meaningful learning.

Chapter Organization

In Chapters 1–7, we will first discuss and display the content material of each chapter title and then present activities that engage students in learning and applying the content knowledge. Activities are mainly field based but do include a number of classroom-based laboratory-type settings. Each activity follows a generalized format to promote student inquiry. This format includes

- at least one driving question for each activity, to provide the initial engagement for the students and open the potential for inquiry;
- a list of materials needed for the activity (including resources on how to make or find the materials);
- the procedure for each activity; and
- a "Think About" section with open-ended questions that link directly to the driving question(s) and promote further student inquiry.

Chapter 1 focuses on the topic of topography. We begin with map interpretation and then apply our understanding of the topic to the form and structure of the landscape through the use of topographic maps.

In Chapter 2 we describe concepts related to physical geography. We explore the physical geography of a local area within the context of the natural resources, biomes, and habitats found in that area. We also integrate into this chapter the concept of a watershed, with an emphasis on the interaction between living and nonliving things as teachers and students investigate their surroundings.

Teachers using sieves to study the composition of the sediment in a stream bed

In Chapter 3 we turn our attention to water, an essential ingredient for life. The physical and chemical properties of water are discussed, as well as how these properties are important for sustaining biological organisms.

The focus of Chapter 4 is soil, and specifically the relationship between soil conditions and local flora. Students learn that an examination of the soil can tell much about the area under investigation and which plants (and therefore animal life) are likely to be found there.

In Chapter 5 we discuss energy and nutrients. We begin with the topic of light energy and the importance this has as the primary source of energy for biological organisms. Then we deal with essential nutrients and the role each has in sustaining life. The main idea here is to link an understanding of essential nutrients to the nutrient loading of an aquatic system and the negative impact that overloading can potentially have on a system.

Chapter 6 focuses on biodiversity, specifically the study of living organisms found within a terrestrial habitat such as a forest and an aquatic habitat such as a stream. By combining a study of the biotic nature of a system with the chemical analyses (abiotic) done in Chapter 5, a clearer picture of the health of a system is gained.

Our theme in Chapter 7 is action projects. Here we provide examples of teacher-constructed units and classroom-tested activities designed within the contexts of the content areas presented earlier. Our goal is to showcase actual teacher and student projects that have used field-based learning experiences and action projects.

Chapter 8, "Reflections on Implementation," provides vignettes from those involved in the implementation of active science learning. These real stories provide insight into the successes and challenges of engaging students in individual classrooms as well as entire schools in inquiry, project, and field-based learning experiences.

Finally, as science educators, we understand how difficult it is to feel that you always have to "reinvent the wheel" or design completely new and unique learning activities for your students. Through our partnerships over the years we have found a wealth of resources that are immediately accessible and usable to all of us. In fact, the U.S. Environmental Protection Agency, in its "Tips for Developing Successful Grant Applications," notes that there are many excellent existing materials on environmental education and recommends using these materials rather than new curricula (U.S. EPA 2009). We encourage you to collaborate with colleagues and form partnerships with outside agencies that enable you to spend more time in the planning and construction of materials that are engaging and contextualized, so students can have more direct experiences with learning in the field.

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Students and teachers at Piney Ridge Elementary School in Sykesville, MD, working on a wetland restoration project on school grounds

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3 Water

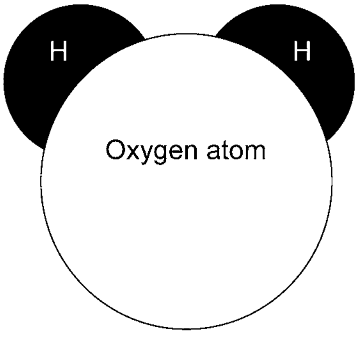
The same water that has existed on Earth for millions of years travels through a series of steps in a cycle from mountains to the sea, flows in and out of the cells in your body, and comprises 95% of the mass of a jellyfish. In short, water is the connective tissue that inextricably links you and the environment.

A Content Primer

What Is Water?

As the connective tissue of the environment, water is the principal transporter for all the essential nutrients, and the water cycle is the only one that connects all the interfaces of the Earth and its atmosphere (air-water and land-water, or vice versa). Water is a simple molecule composed of two hydrogen atoms and one oxygen atom (Figure 3.1), which are held together by strong bonds. Yet it is the simplicity of the molecule that gives it great versatility and importance.

FIGURE 3.1
Water Molecule



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Water

Rain forest

Desert

Known as the *universal solvent,* water has the ability to carry dissolved elements, compounds, molecules, and nutrients from one place to another across the entire planet. In addition, water is a limiting factor in the function of essential nutrient cycles (see Chapter 5, Energy and Nutrients). For example, the decomposition of plant material in a tropical rain forest is exceptionally rapid when compared with the same process in a desert, even though these biomes have similar temperatures, because the rain forest is significantly wetter. This process results in the release and recycling of essential nutrients more quickly in a rainforest ecosystem as compared with a desert.

The Water Cycle

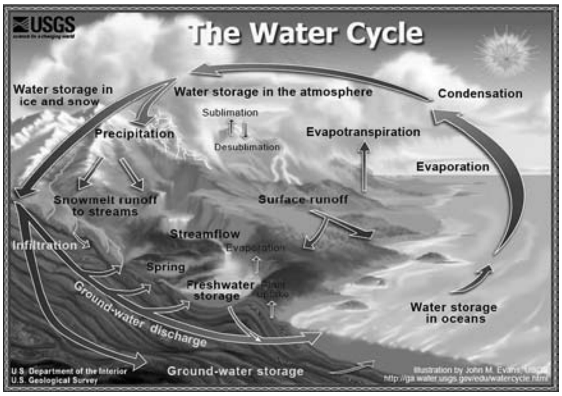
Precipitation is the manner in which water is returned to the Earth from the atmosphere. Once deposited on land water can take many pathways through an ecosystem. For example, water can

- be absorbed by soil and transferred to a plant through roots;
- travel through the ground and become part of the groundwater;
- run along the Earth's surface into a body of water, such as a stream, picking up minute amounts of dissolved salts and eventually making its way to the ocean; and
- be deposited on a mountaintop as snow or ice and remain locked or trapped there for many years.

Snow-covered mountain

The other main components of the water cycle include evaporation, condensation, evapotranspiration, and sublimation (see Figure 3.2). Visualizing the cyclical flow of water in this way provides a mental picture of the numerous possible pathways traversed by water in our ecosystem.

FIGURE 3.2
The Water Cycle



Source: U.S. Geological Survey, *http://ga.water.usgs.gov/edu/watercycle.html*

Other Aspects of Water

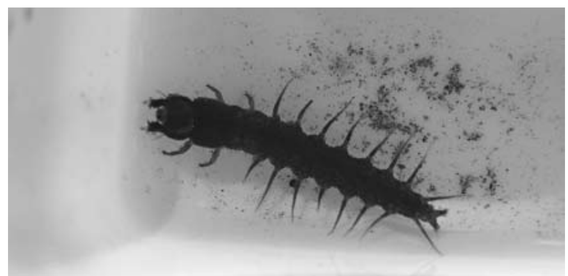
The pH, salinity, oxygen, and turbidity of water can greatly affect water's quality. Thus, we feel that the following content is essential for a fundamental understanding of the factors that impact the characteristics and quality of water.

pH in Water

As a measure of acidity, pH is dependent on the relative concentrations of hydrogen ions (H^+) in a solution. The scale of pH measurement (Figure 3.3) is 0–14. Solutions that measure 0–6 have a higher hydrogen ion concentration and are acidic; those that measure 8–14 have a lower hydrogen ion concentration and are alkaline (basic); and those that measure 7 are considered neutral.

The vast majority of aquatic organisms, particularly macroinvertebrates, are only able to tolerate fluctuations of pH levels within a narrow range of unit variation outside their preferred optimal range. Even small fluctuations in the pH of a body of water can have very serious consequences for the affected organisms (e.g., a pH change from 6.5 to 5.5).

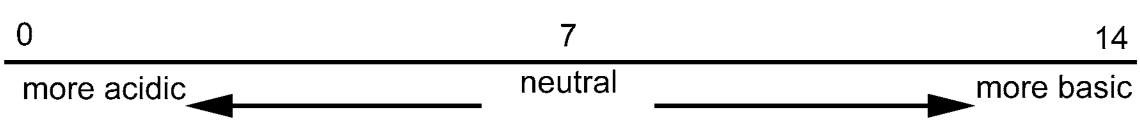
SCILINKS
THE WORLD'S A CLICK AWAY
Topic: pH Scale
Go to: *www.scilinks.org*
Code: IO014



Macroinvertebrate

There are several ways to measure pH; the most common methods use pH paper, a chemical test kit, or a pH meter. pH paper usually is packaged as small strips that students dip into the solution being tested; when they observe a color change, they compare it with a key in which different colors represent the values of the pH scale. Chemical kits involve the addition of an *indicator* solution to a sample of water and comparing the color change with a key in which different colors represent the values of the pH scale. A pH meter is a sort of electronic probe that directly measures pH (the hydrogen ion concentration) from the solution.

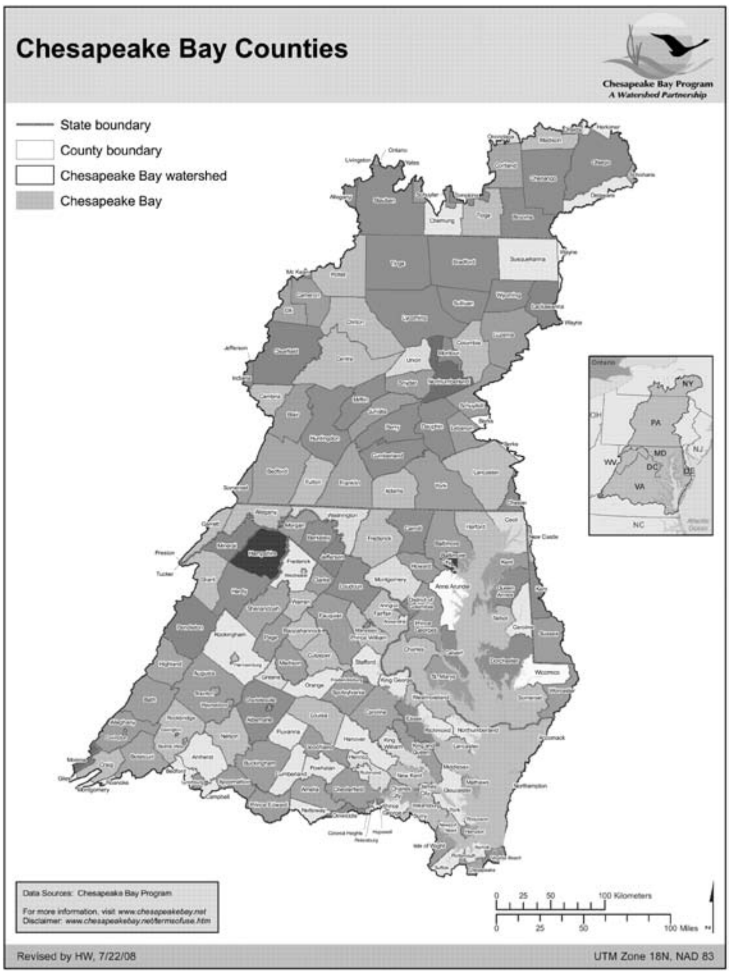
FIGURE 3.3
pH Scale



Salinity in Water

In our locale we are able to study freshwater at a local site and then move downstream into the larger watershed of the Chesapeake Bay, the nation's largest estuary (see Figure 3.4). By moving to the estuary we can add salinity as an additional water quality measurement.

FIGURE 3.4
Chesapeake Bay Map



Source: Chesapeake Bay Program

What Is Salinity?

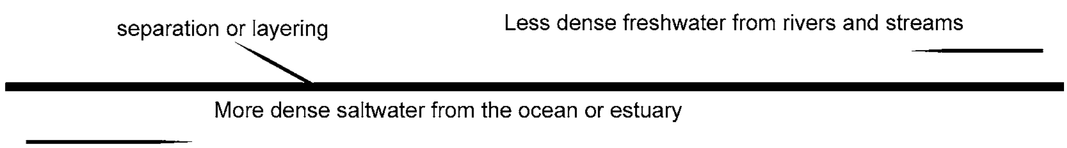
Nearly all water contains dissolved chemicals, even rainwater. We call these dissolved chemicals *salts*. The major dissolved salts (by element) found in seawater are 55.3% chlorine, 30.8% sodium, 3.7% magnesium, 2.6% sulfur, 1.2% calcium, and 1.1% potassium (Windows to the Universe 2002). Salinity is a measure of these dissolved salts in water and is calculated as the amount of salt (in grams) dissolved in 1,000 grams (or 1 liter) of seawater. Salinity, therefore, is represented as parts per thousand (ppt), meaning the number of grams of salt in 1 liter of seawater. For example, the salinity of normal ocean water is about 35 ppt (the range of salinity for ocean water is 32–37 ppt). This means that for every liter of seawater there are 35 grams of salt. In contrast, the salinity of brackish estuarine water is typically 0.5–17 ppt, and that of freshwater is less than 0.5 ppt.

What Causes Salinity?

Salts end up in aquatic ecosystems through relatively simple processes:

1. Rainwater falling on the land weathers and erodes rocks and rock fragments.
2. Rivers carry larger rock fragments as bed load, as they roll along the bottom of the stream. Smaller rock fragments and mineral grains are transported as suspended load (within the water column). Also included are ions or dissolved salts from the chemical weathering of rocks.
3. The weathering of other minerals and rocks also provides salts to the sea. For example, the calcite in limestone dissolves in slightly acidic natural waters, yielding calcium (Ca) and carbonate (CO_3).

FIGURE 3.5
Layering Salinity



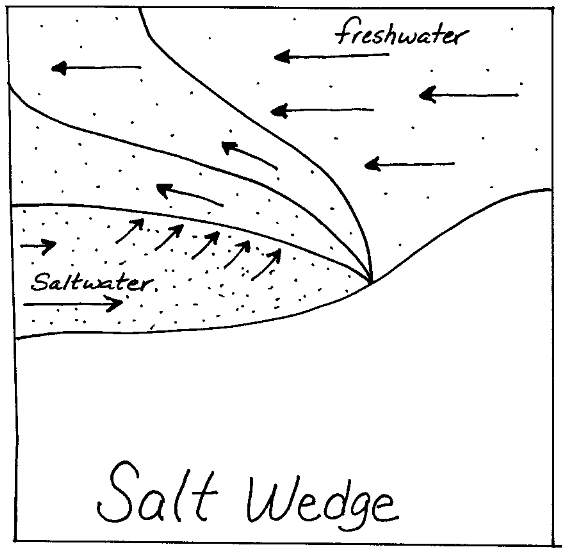
4. Streams and rivers then carry dissolved salts to the seas (an estimated 4 billion tons per year). Some of these dissolved solids will be deposited as sediment, so yearly gains may roughly balance sediment deposition. Salts have become concentrated in the sea from these many small deposits (compared with freshwater) and the Sun's heat causes the evaporation of water, leaving the salts behind. The most abundant mineral in seawater is sodium chloride (NaCl), or common sea salt.

Mountain spring

Modeling Salinity

Figures 3.5 and 3.6 illustrate how salinity affects the physical properties of water. Figure 3.5 illustrates the limited mixing between the less dense freshwater and the denser salt water of an estuary. In shallow estuaries the influx of ocean water creates a *salt wedge,* where the denser salt water, by tidal action, infiltrates under the less dense freshwater and creates a density gradient from the surface to the bottom (Figure 3.6). In this situation, the amount of freshwater and salt water varies by depth and impacts the types of organisms found.

FIGURE 3.6
Salt Wedge



Source: Peter Cook, *http://omp.gso.uri.edu/ompweb/doee/img/imgindx1.htm*

Depending on a variety of factors, the estuary may be partially or fully mixed (Figures 3.7 and 3.8, p. 50). For example, in relatively shallow (20 feet) water with strong winds you may have complete mixing from the top to the bottom of the water column.

Measuring Salinity

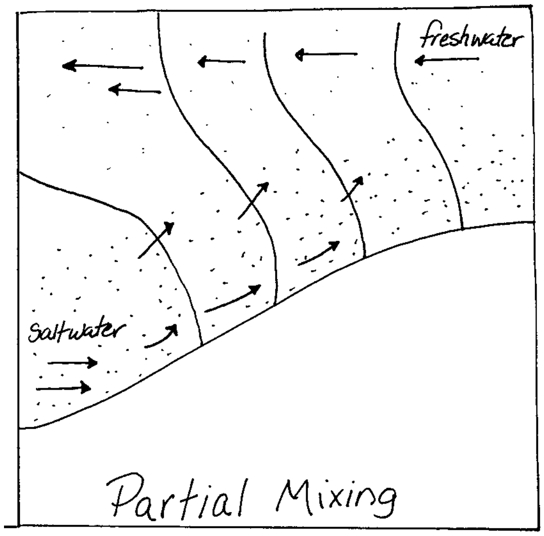
It is important to measure salinity because, as with pH, certain organisms are naturally adapted for a

SCILINKS THE WORLD'S A CLICK AWAY

Topic: Solvation of Solids in Water
Go to: *www.scilinks.org*
Code: IO015

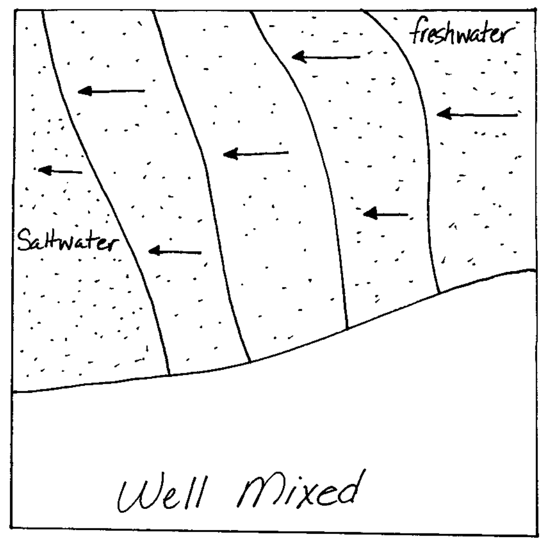
Topic: Freshwater Ecosystems
Go to: *www.scilinks.org*
Code: IO016

FIGURE 3.7
Partially Mixed Estuary



Source: Peter Cook, *http://omp.gso.uri.edu/ompweb/doee/img/imgindx1.htm*

FIGURE 3.8
Fully Mixed Estuary



Source: Peter Cook, *http://omp.gso.uri.edu/ompweb/doee/img/imgindx1.htm*

Jellyfish

specific range of salt tolerance within their environment. Salinity measurements play an important role in understanding water quality and have an impact on the diversity of life in an aquatic ecosystem. By measuring salinity some basic ideas about biodiversity can be predicted and can have an impact on species being studied, whether they are plant, animal, or microbe. For example, in a drought year with very little rainfall (freshwater) an estuary may become more salty (saline), leading to an increase in the appearance of organisms such as jellyfish and salt-tolerant fish. Thus, salinity will not only affect the types of organisms present but also influence the biodiversity of the habitat.

In the early days of ship travel salinity was measured by collecting approximately 1 liter of seawater and allowing it to evaporate, leaving the salts behind. These salts were weighed and used to estimate salinity (thus the parts per thousand). Today salinity can be measured with a number of simple devices, including hydrometers.

Understanding a hydrometer reading requires a general understanding of what the reading indicates. The hydrometer measures the *specific gravity* of a liquid, which is the density of a substance divided by the density of water. For our purposes, the measurement indicates the density of the sample solution. Pure water has a specific gravity of 1 g/cm^3 and is used as our benchmark; ocean water has a specific gravity of about 33–37 g/cm^3. Any sample solution will be compared with the freshwater baseline, and, thus, any water that contains dissolved salts will show an increased density by having a measurement greater than 1 g/cm^3 (Figure 3.9).

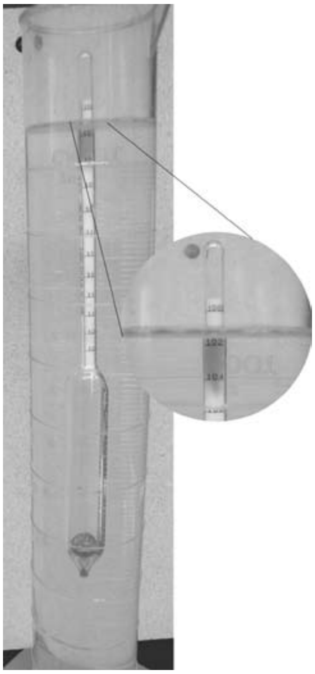
A hydrometer is basically a "bobber" in water. Students can construct their own hydrometer or buy a specific gravity instrument in a local aquarium shop. We have used one similar to the Aquarium Systems Instant Ocean Hydrometer. Instructions on making hydrometers can be found at the following websites:

- *www.csd509j.net/cvhs/berand/Marine/Labs/Making%20Test%20Tube%20Hydrometers%20Student%20Guide.doc*
- *www.ecawa.asn.au/home/jfuller/liquids/hydrometers.htm*

Oxygen in Water

Oxygen accounts for approximately 21% of the gas content of our atmosphere, with the majority consisting of nitrogen gas. We can think of the 21% as parts per hundred (pph), meaning that out of 100 molecules in a sample 21 of them would be oxygen. In lakes, ponds, streams, and oceans, however, *dissolved oxygen* (DO) is measured in parts per million (ppm); generally the range is 5–8 ppm. To convert from pph to ppm we multiply by 10,000 (the difference between 0.01, parts per hundred, and 0.000001, parts per million). Thus we find that the 21% of atmospheric oxygen is about 210,000 ppm, which is an enormous disparity in concentration compared with the value of 8–9 ppm of DO in a pristine freshwater environment with a temperature range of 20–25°C. Understanding this difference (Table 3.1) between oxygen in air and oxygen in water makes us appreciate the adaptability of aquatic creatures, which allows them to survive on scarce amounts of oxygen—something that terrestrial organisms cannot do.

FIGURE 3.9
A Hydrometer in a Sample of Water With Salt Added



How Does Oxygen Get Into Water?

Oxygen gets into water from the atmosphere through the process of diffusion, moving from a place of higher concentration (in the air) to one of lower concentration (in the water). Other things that can help oxygen become dissolved in water include waves or wind, which disturbs the surface and allows for easier diffusion. Living aquatic organisms—namely, plants and algae—produce oxygen through photosynthesis and also add a considerable amount of DO to the aquatic system.

TABLE 3.1. Oxygen Values in Air Versus Water

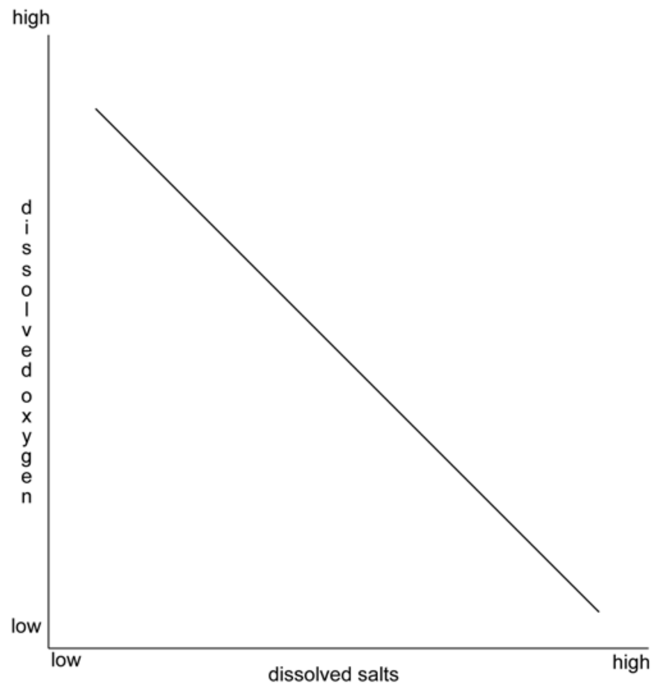
	Oxygen in Air	Oxygen in Water*
Common values described	Constant, approximately 21% of air	Ranges from about 0 to 12 parts per million (ppm)
Comparison of parts per million values	210,000 ppm	0–12 ppm

* There are slight variations between freshwater and salt water—freshwater has a higher DO value at the same temperature as salt water because salt water has dissolved solids that take up space.

Temperature can also have an immense impact on DO levels. As the temperature of water rises, the gases that are dissolved in the water escape more easily because of increased molecular movement; as the temperature of water decreases, gases dissolved in the water are able to remain longer because there is less movement of the water molecules. Therefore, a general statement can be made that warmer water "holds" less oxygen than colder water.

Atmospheric pressure also has an impact on the DO concentration of water. In high pressure (at sea level or relatively close to sea level) oxygen can stay in the water more easily. An increase in elevation results in a decrease in pressure or the amount of "weight" on the water, allowing more gas to escape by diffusion.

FIGURE 3.10
Relationship of Dissolved Salts to Dissolved Oxygen



Finally, the amount of dissolved solids in water has an impact on DO concentrations. As the salinity increases, these dissolved solids take up more space and leave less space for the dissolved gases such as oxygen (Figure 3.10). Living in salt water therefore requires an organism to be highly adaptable to low DO levels, whereas living in freshwater, where there are fewer dissolved solids, does not require this degree of adaptability.

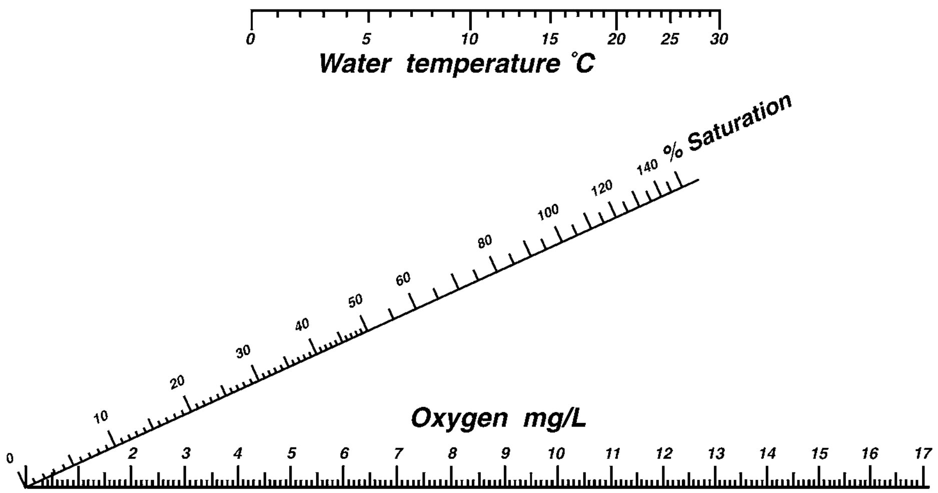
Measuring Dissolved Oxygen in Water

Because of the influences that temperature and pressure have on the amount of DO in water, getting an accurate DO reading can be difficult. Sophisticated measuring devices can compensate for both of these factors, but for many of us the cost is prohibitive.

When measuring the DO of a water sample, you must take the temperature into consideration and record it when the water is tested. (Remember that DO fluctuates with changing temperature.) Once these two values are recorded you can estimate the percent saturation of oxygen in water. It may be easier for students to understand percent saturation using the analogy of a sponge being full or partially full of water instead of referring to parts per million. Percent saturation is, thus, another means to represent the amount of available oxygen in water. With a percent saturation chart (Figure 3.11) students can estimate the percent saturation using the determined DO value and recorded temperature. The procedure is as follows:

1. Collect the water sample and immediately record the temperature.
2. Use a DO test kit (available from CHEMetrics, *www.chemetrics.com*) and determine the ppm value of that sample.

FIGURE 3.11
Percent Saturation of Oxygen



Source: Water on the Web, *http://waterontheweb.org/under/waterquality/oxygen.html*

3. Use a straightedge to connect a line on the diagram between the two points (°C and ppm). For example, a 23°C sample of water with a DO value of 5 mg/L (ppm) has about 62% oxygen saturated in solution.

The University of Wisconsin Extension website has more resources on DO and percent saturation: *http://watermonitoring.uwex.edu/wav/monitoring/oxygen.html*. When performing DO tests, use indirectly vented chemical splash goggles and gloves. Maker sure there is appropriate ventilation. Review MSDS prior to using DO kit chemicals. Washi hands with soap and water after completing tests.

Soil in Water

Transparency and Turbidity

Simply defined, *turbidity* is the relative measure of the transparency (or cloudiness) of a body of water due to an increase in suspended substances in the water column. Suspended substances can be abiotic in origin (e.g., soil) or biotic (e.g., zooplankton and phytoplankton). The "cloudiness" determines the depth at which light can penetrate. *Transparency* is a term that describes how far light can penetrate into a water column before it completely dissipates. The reason turbidity and transparency are important for understanding the biotic nature of the aquatic habitat is because the depth of light penetration is directly linked to important features of the aquatic environment, such as supporting the growth of submerged aquatic vegetation. Our goal here is to focus on the basic concept of transparency as it is related to the cloudiness of water (see also *http://watermonitoring.uwex.edu/wav/monitoring/transparency.html*).

Measuring Transparency

You can use a Secchi disk to measure transparency of slow-moving, deep bodies of water such as ponds, lakes, or bays. A Secchi disk is a black-and-white plate, 20 cm in diameter, that is lowered into the water column (see Figures 3.12 and 3.13, p. 54).

FIGURE 3.12
Secchi Disk

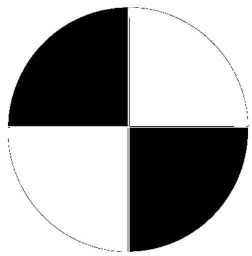


FIGURE 3.13
Using a Secchi Disk to Measure Transparency

FIGURE 3.14
Turbidity Tube With Water Sample

FIGURE 3.15
Turbidity Tube Showing Visible Secchi Disk at Bottom of Tube

The depth in meters at which the dish just disappears is called the Secchi depth and is a relative measure of the water's transparency.

For stream measurements, you can use a *turbidity tube*, which consists of a long plastic tube containing a small Secchi disk at its bottom. Water is added to the tube, which acts as the water column, and the transparency is determined by the height of the water in the tube when the Secchi disk is no longer visible (see Figures 3.14 and 3.15). This measurement gives a relative value of transparency of the water, with a greater value signifying higher transparency and a lower value signifying lower transparency.

Water Activities

You will notice that a number of these activities are initially conducted inside the classroom. Our reasoning is to have the students practice the procedures before using them in the field and to allow students to gain a better understanding of the fundamental content and concepts involved.

Activity 1. Modeling the Water Cycle

This activity uses basic materials to demonstrate condensation and precipitation of the water cycle as well as phase changes of water. The setup is simple yet can lead to other inquiry activities.

Driving Question

What stages of the water cycle are demonstrated by water of different temperatures?

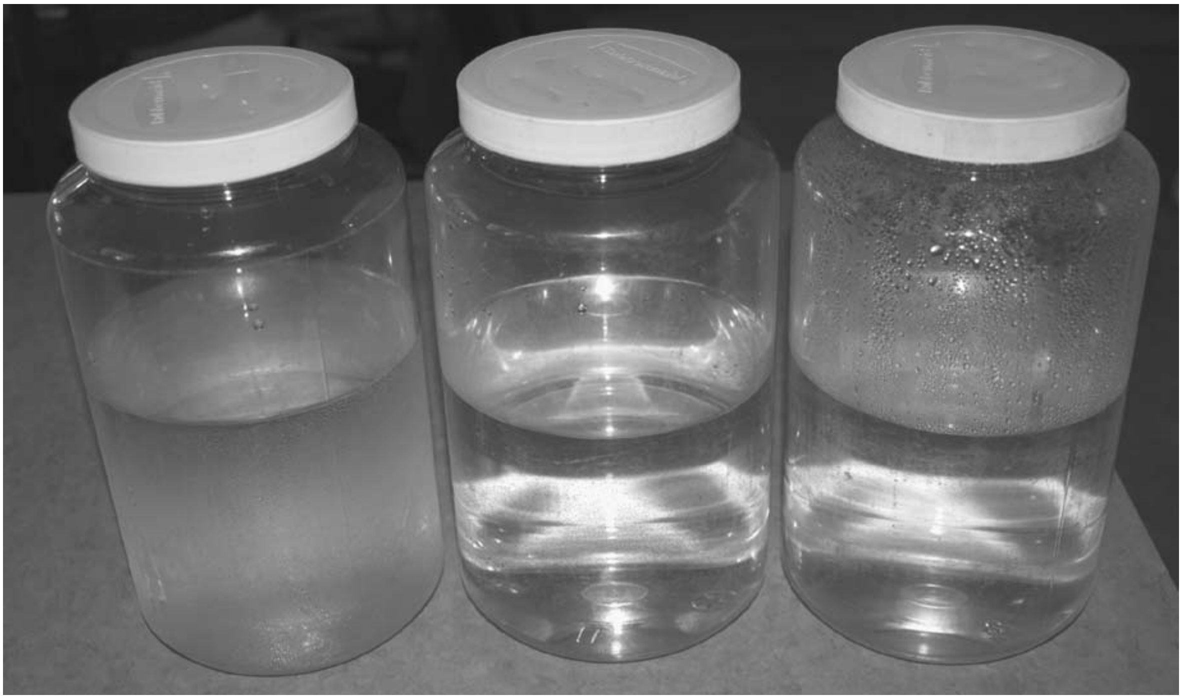
Materials

- Three containers, each half-full of water (good containers are clear plastic 2-liter bottles or clear plastic storage containers or jars with a screw cap lid; see Figure 3.16):
    1. One has room temperature water (approx. 20°C).
    2. One has hot water from the tap (approx. 40°C). (Use caution when working with hot water from the tap, as it can cause skin burns.)
    3. One has cold water (add a few ice cubes and let them melt, approx. 10°C).
- Indirectly vented chemical splash goggles

Procedure

1. Divide the class into groups of no more than three and ask the group to write down

FIGURE 3.16
Water Cycle Model



Water Cycle Data Sheet

Water Temperature	Cold (with some ice cubes melted)	Room Temperature	Hot (hot water from the tap)
Observation after 5 minutes			
Observation after 10 minutes			
Observation after 20 minutes			

observations about changes in the three containers over time on their data sheet.

2. To help them make connections to what they see, ask groups to make illustrations.
3. Have each group share their observations with another group and develop some conclusions about how the containers are different (e.g., one jar has hot water, one jar has condensation on the outside).

Think About

1. Share observations and illustrations with the whole class and develop some consensus about the containers, their contents, and how the observations relate to the phases of the water cycle.
2. Predict what you would observe if we left these water containers on the table over the weekend.
3. How would your predictions change if we left the water containers outside over the weekend?
4. Think about your car windows in the winter, or the mirror in the bathroom after you take a shower. Think about how you can draw pictures on the window or the mirror. Describe what parts of the water cycle this demonstrates.

Activity 2. Preparing pH Indicators From Red Cabbage

Red cabbage juice (RCJ) makes an excellent pH indicator, is easy to prepare, and is a fun introduction for students to the concepts of acids, bases, and pH. There are a couple of standard ways to extract RCJ and the key pigment anthocyanin.

Driving Question

How can cabbage juice be turned into a tool to measure pH?

The Boiling Method Materials

- One small head of red cabbage
- Small pot half-filled with distilled water (available at grocery stores)
- Heat source (if electrical hot plate, use a GFI-protected circuit)
- A 500 ml beaker or flask (available from any science education supplier [e.g., Science Kit & Boreal Laboratories, *http://sciencekit.com/Default.asp?bhcd2=1257261644*])
- Indirectly vented chemical splash goggles, heat gloves, and aprons

Procedure

1. Chop up the red cabbage and place it in a pan with enough distilled water to cover it.

2. Boil until the water turns a dark red-purple color. Use caution, as the splashing of hot liquid can burn skin.
3. Pour off the liquid once it cools. Strain using cheesecloth if needed to remove large particles.

The "Juicer" Method Materials

- One small head of red cabbage
- Small pot half-filled with distilled water
- Juicer (obtained in kitchen supply section of department store)
- A 500 ml beaker or flask
- Indirectly vented chemical splash goggles

Procedure

1. Chop up the red cabbage and run it through a juicer.
2. Take the extracted juice and dilute it with distilled water (2 parts juice to 1 part water) so that it thins out a bit and is more translucent. Strain using cheesecloth if needed to remove large particles.

Activity 3. Red Cabbage Juice as a pH Indicator: Developing pH Standards

Once the RCJ solution is prepared, it can be added to a variety of household products to "indicate" what the pH may be. Changes in the color of the RCJ are due to the behavior of the pigment anthocyanin at different pH levels. For example, pink-orange colors indicate acidic solutions, blue colors (royal blue to purple) indicate neutral pH, and blue-green colors indicate alkaline (basic). This activity will use three household solutions (vinegar, water, and baking soda) to prepare the standards used for testing in Activity 4.

Driving Questions

1. How will different household solutions (vinegar, water, and baking soda) react with a homemade pH indicator?
2. How will the pH of different household solutions (vinegar, water, and baking soda) compare with each other?

Materials

- Prepared RCJ extract
- Three small, clear containers (test tubes [available from any science education supplier] or baby food jars)
- Eyedropper (available from any science education supplier)
- Standard test solutions (vinegar, water, and baking soda)
- Indirectly vented chemical splash goggles and aprons

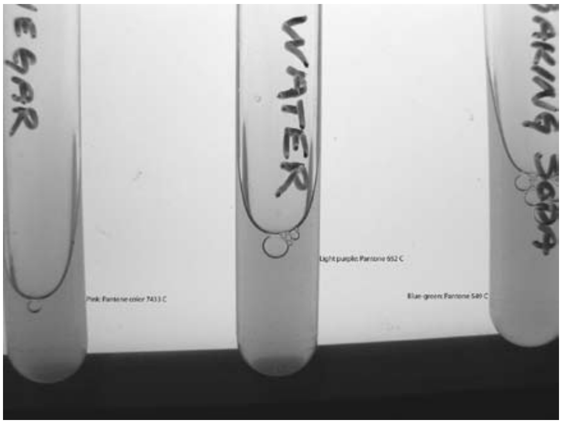
Procedure

1. Add two teaspoons of vinegar, water, and baking soda solution to each of the three small containers (test tubes or baby food jars).

Standard Indicators for Red Cabbage Juice

	Acid	Neutral	Base
	Vinegar	Water	Baking soda
Color of RCJ with test sample	Pink-orange	Blue (royal to purple)	Blue-green

FIGURE 3.17
The Three pH Standards After the Addition of Red Cabbage Juice



These containers will serve as the standard indicators for the pH exploration.

2. Using the eyedropper add drops of RCJ into each container until there is a color change that remains constant.
3. Record the results on the data sheet.
4. Keep the three standards on display (Figure 3.17) so that they can be used as references for the other tests that will be conducted.

Think About

1. Based on the results from this experiment, what color would you expect the RCJ indicator to turn in bleach? Explain why.
2. Based on the results from this experiment, what color would you expect the RCJ indicator to turn in milk? Explain why.

Standard Indicators Data Sheet

	Acid	Neutral	Base
	Vinegar	Water	Baking soda
Color of RCJ with test sample			

3. If you were to use the RCJ indicator to determine if water from a local stream was healthy, what color would you expect the indicator to change to in that sample?

Activity 4. Using Red Cabbage Juice and pH Paper to Determine the pH of Household Products

Another exploratory pH lab can use the RCJ and pH paper to determine the pH of a variety of household products and compare them with samples from the environment.

Driving Question

How accurate is a homemade pH indicator (such as the RCJ indicator) when compared with other tools for measuring pH (like pH paper)?

Materials

- Prepared RCJ extract (color images of RCJ can be viewed at *www.chemistryland.com/CHM107Lab/Lab1/Lab1PreparingCabbageExtract.htm*)
- Household products such as powdered milk solution, soda, borax solution, hand soap solution, hydrogen peroxide, mouthwash, shampoo, and orange juice
- Three water samples from different ecosystems
- Eyedropper (available from any science education supplier)
- Eight test tubes (available from any science education supplier)
- pH test strips (available from any science education supplier, pool supply store, or home improvement store)
- Indirectly vented chemical splash goggles and aprons

Safety

Wear indirectly vented chemical splash goggles and aprons. Wash hands with soap and water upon completing the lab.

Procedure

1. Observe the colors of the standard indicators from Activity 3 and record these colors on the Standard Indicators Data Sheet. This will be used as a reference.
2. Predict whether the household products to be tested will be acid (pink-orange), neutral (blue), or base (green-yellow), and record your predictions on the pH Data Sheet.
3. Add approximately 2 teaspoons of the household products into eight labeled test tubes.
4. Add drops of RCJ into the test tubes.
5. Observe and record the colors of the solutions on the pH Data Sheet.
6. Compare the colors of the products with the RCJ with the colors from the Standard Indicators table and determine the approximate pH of your household products.
7. Test the pH of each of the household products using pH paper and record the results on the pH Data Sheet.
8. Collect three water samples from different aquatic ecosystems (pond, stream, lake) and test the pH with RCJ and pH paper. Record the results on the pH Data Sheet.

Think About

1. What are the advantages of using an acid-base indicator such as RCJ to test the pH of household products?
2. What are the limitations of using an acid-base indicator such as RCJ to test the pH of household products?
3. How do the pH values obtained from the RCJ compare with the one obtained from the pH test strips? Explain any differences.
4. Draw a pH scale (1–14) and place the substances tested at the appropriate pH.

pH Data Sheet

Substance Tested	Predicted Color	Result With RCJ	pH Paper Results	Acid, Base, or Neutral?
Powdered milk solution				
Soda				
Baking soda solution				
Hand soap solution				
Hydrogen peroxide				
Mouthwash				
Shampoo				
Orange juice				
Water source A				
Water source B				
Water source C				

5. Which household products are acidic? Basic? Neutral? Explain your reasoning.
6. Which product contains the highest concentration of hydrogen ions? Which contains the lowest? Explain your reasoning.
7. Many commercial products are advertised as pH balanced. Explain what is meant by the term *pH balanced*.
8. Describe the observations and measurements you made about the three water samples from the environment. How did these samples compare with the household products that were tested?

Activity 5. Modeling the Impact of Salinity in Water

This activity is a simple exploratory demonstration about salinity using an egg and a beaker of water.

Driving Question

How will an egg placed in water behave differently when salt is added to water?

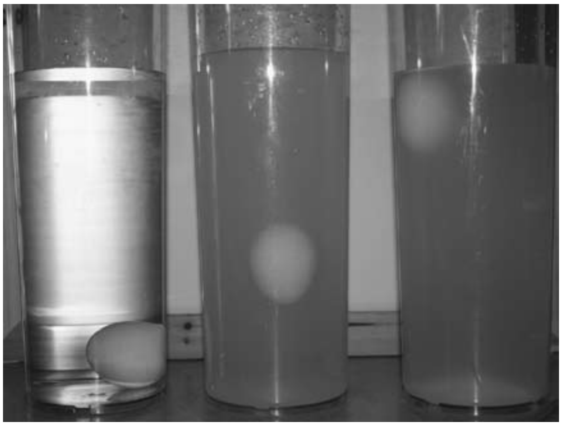
Materials

- Egg (raw or hard-boiled)
- Clear container
- Tablespoon
- Stirring rod (available from any science education supplier)
- Table salt
- Indirectly vented chemical splash goggles and aprons

Procedure

1. Fill container three-quarters full with water.

FIGURE 3.18
Eggs in Water



2. Have students predict what the egg will do when placed in water (see Figure 3.18).
3. Add salt to the water (one heaping tablespoon at a time) and ask them to predict what will happen to the egg.

Think About

1. Explain why the egg behaved the way it did in freshwater.
2. Explain why the egg behaved the way it did when salt was added to the freshwater.
3. Describe the differences between water without salt and water with salt.
4. The Dead Sea is one of the world's saltiest bodies of water, with a salinity of 33.7%. Think of a time you tried to float in your neighborhood pool. Compare this experience with what you think it would be like to try to float in the Dead Sea.

Activity 6. Exploring the Impact of Temperature and Salinity on Water Density

Another activity that provides a concrete example of salinity and water involves placing low- and high-salinity water into the same container. This activity will be conducted in three parts. For Part III refer to the "Modeling Salinity" section earlier in this chapter for a review of the properties of the interaction of freshwater and salt water.

Driving Question

How is the mixing of water affected by temperature and salinity?

Materials

(for each part)

- Clear containers (beakers, pasta storage containers, etc.)
- Hot (40°C) and cold (10°C) tap water
- Table salt (mixed as 1 liter of water with 35 g of salt)
- Measuring cups for pouring (8 oz)
- Blue and yellow food coloring (available in the baking aisle of the supermarket)
- Indirectly vented chemical splash goggles

Procedure

Part I. Room Temperature Samples

1. Pour water into one container so it is about one-third full. Add 5 drops of blue food coloring and mix thoroughly.
2. In separate container repeat the same procedure using yellow food coloring.
3. Tilt the blue container and slowly pour yellow water along the inside of the blue container so as not to splash or disturb blue water.
4. Describe and diagram the results.
5. Explain what happened and why.

Part II. Cold Versus Hot Water Samples

1. Color cold water blue. Repeat sequence of pouring as outlined in Part I.
2. Describe and diagram the results.
3. Explain what happened and why.

Part III. Salt and Non-Salt Samples

1. Use two room temperature samples.
2. Color the salt solution blue.
3. Color the non-salt solution yellow.
4. Repeat sequence of pouring as outlined in Part I.
5. Describe and diagram the results.
6. Explain what happened and why.

Think About

1. What happened when the cold water and hot water samples were combined? Using your understanding of density, explain why this happened.
2. What happened when the salt solution and non-salt solution samples were combined? Using your understanding of density, explain why this happened.

Expected Results

- Room temperature samples mix completely and water turns green.
- Careful pouring will improve separation of cold and hot water samples, with cold (blue) staying at the bottom because of greater density than hot (yellow).
- Salt and non-salt samples separate, with salt staying at the bottom because of greater

FIGURE 3.19
Layered Solution of Samples With Differing Salinities

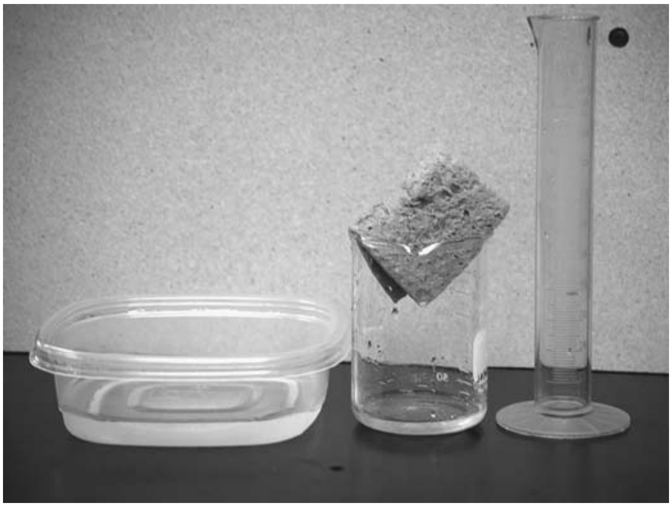
density than non-salt. In Figure 3.19 layers of water with varying salinities are displayed (higher salinity on the bottom).

Ideal results illustrate the impact that temperature and salinity have on the density of water and its ability to mix or not mix (form layers).

Activity 7. Sponging Up the Dissolved Oxygen

This activity models the concept of percent saturation using simple materials and practice. Teachers and students can use the percent saturation chart to gain a better understanding of the relationship among percent saturation, DO measurements, and temperature. For the purpose of this activity the sponge (Figure 3.20) equates to the aquatic ecosystem and the water represents the DO.

FIGURE 3.20
Use of Sponge to Demonstrate Percent Saturation



Sponges can be used to investigate the concept of percent saturation and dissolved oxygen and provide a good method for practicing estimation and math concepts.

Driving Questions

1. How do fish and aquatic organisms get the oxygen they need to breathe?
2. How can you determine the amount of oxygen in water?

Materials

(per team)

- One small kitchen sponge
- One 250–500 ml graduated cylinder (available from any science education supplier)
- One shallow pan
- One 16 oz cup
- Stick thermometer in °C (available from Science Kit & Boreal Laboratories, *http://sciencekit.com/Default.asp?bhcd2=1257261644*)
- Water
- Percent saturation chart (Figure 3.11, p. 53)
- Safety glasses or goggles and aprons

Procedure

Part I. Determining 100% Saturation

1. Add water to the shallow pan so it is about half-full and let the sponge soak until completely saturated.
2. Remove the sponge and carefully squeeze as much water as possible from the sponge into the cup.
3. Pour water from the cup into the graduated cylinder and record the volume. This is the 100% saturation value.

4. Pour water from the graduated cylinder back into the pan so it is ready for the next measurement.

Part II. Target Saturation Levels

The goal of Part II is to attain a better understanding of percent saturation and not necessarily to attain a perfect result (i.e., getting the exact target value). Students should attempt to attain saturation levels of 50% and 25%.

1. Place the sponge in the shallow pan until approximately 50% saturated. (This may happen quickly. Encourage students to experiment with different methods of getting 50% saturation.)
2. Remove the sponge and carefully squeeze water from the sponge into the cup.
3. Pour water from the cup into the graduated cylinder and record the volume.
4. Using the volume from Part I as 100% saturation, calculate the percent saturation of this sample. Repeat the procedure and attempt to attain a 50% saturation level. Sample calculation:

$$\textit{Percent Saturation} = \frac{\textit{volume of water from Part II}}{\textit{volume of water from Part I}} \times 100$$

5. Repeat the procedure and attempt to attain a 25% saturation level.

Part III. Estimating the Amount (in ppm) of Dissolved Oxygen

Once Part II is completed use the percent saturation chart (Figure 3.11, p. 53) to estimate the amount of DO (ppm) at each value of percent saturation for the given temperature. Record these amounts on the data sheet.

Think About

1. Why would we use a sponge to help us model percent saturation?
2. Describe the differences between your measurements for volume in 25% saturation and 50% saturation.
3. How do the results described in question 2 compare with the differences you see between your measurements for volume in 50% and 100% saturation?

SCILINKS THE WORLD'S A CLICK AWAY
Topic: Solubility
Go to: *www.scilinks.org*
Code: IO017

Activity 8. Testing Solubility of Oxygen in Water Over Time

Dissolved oxygen can be the basis of simple exploration activities that incorporate testing samples over time. This is an open-ended activity related to understanding the influence of factors on DO. The basic idea is to collect a sample of water, immediately test it using a DO test kit, and then explore different factors that will affect the ability of the oxygen to remain dissolved.

Percent (%) Saturation and Estimated ppm of Dissolved Oxygen (DO) Data Sheet

% Saturation Target Value	Volume (ml)	Temperature (°C)	Estimated ppm DO
100			
50			
25			

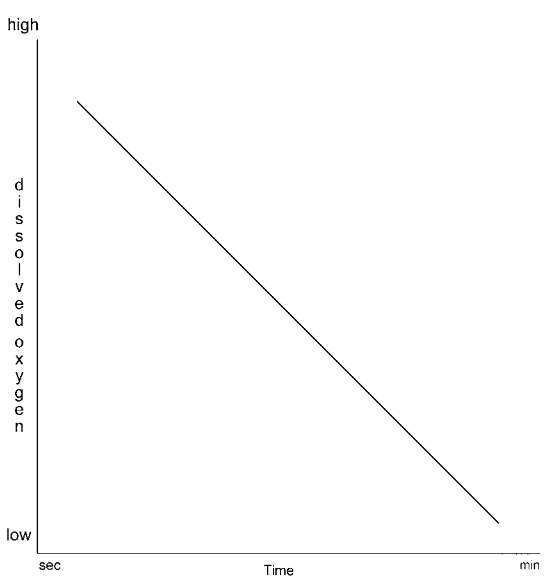
Driving Questions

1. How does the temperature of water affect the percent DO in a water sample?
2. How does the percent DO change in a water sample over time?

Materials

- DO test kit (available from CHEMetrics [*www.chemetrics.com*] and LaMotte Company [*www.lamotte.com*]—the latter has the Earth Force Elementary Education Watershed Field Trip kit and the Pondwater Tour kit)
- A 2-liter sample of tap water or aquarium water
- Indirectly vented chemical splash goggles, gloves, and aprons

FIGURE 3.21
Changes in Dissolved Oxygen Over Time



SciLinks THE WORLD'S A CLICK AWAY
Topic: Soil Erosion
Go to: *www.scilinks.org*
Code: IO018

- Stick thermometer (available from Science Kit & Boreal Laboratories, *http://sciencekit.com/Default.asp?bhcd2=1257261644*)
- Indirectly vented chemical splash goggles, gloves, and aprons

Procedure

1. Use appropriate ventilation. Obtain a sample of water.
2. Test DO immediately, and measure the temperature.
3. Set the sample aside and repeat the test at 15-minute intervals (see Figure 3.21).

Think About

1. What patterns did you notice in measure of percent DO over time?
2. How do you think the results would be different if we started with boiling water and monitored changes over time?
3. How do you think the results would be different if we started with ice water and monitored changes over time?
4. How do you think the results would be different if we started with salt water and monitored changes over time?

This activity can be extended by incorporating different variables, such as a change in temperature (heating or cooling), agitation by manual stirring or other means, exposure to light and dark, and any other factors proposed by the students. The fundamental concept for students to understand is that DO levels fluctuate in water and that this change can be influenced by any number of factors (temperature, salinity, agitation).

Activity 9. Modeling Turbidity

This activity can be used to help students understand how to (1) model the cause of turbidity in water and (2) identify soil composition by sedimentation (see Chapter 4, Soil: It's Not Dirt).

Driving Question

What materials can be found in water, and how can you separate them?

Materials

- Clear jar with lid (Mason jars or canning jars work well)
- Tap water
- Soil sample
- Safety glasses or goggles, aprons, gloves

Procedure

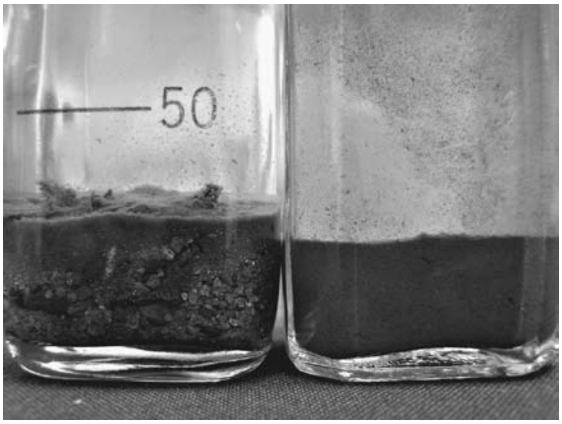
1. Fill approximately one-third of the jar with soil.
2. Fill jar with water, leaving 1 inch of space at top.
3. Put lid on and shake vigorously for five minutes.
4. Stop shaking and observe the particles in the soil (see Figure 3.22).
5. Once observations are complete, set the jar aside for use in Chapter 4 and the activity on soil composition. Wash hands with soap and water.

Think About

1. Describe your observations of the water immediately after shaking.
   a. Have you ever seen water like this in a river or stream? What caused it to look like this?
   b. Describe at least one way water in this condition could affect aquatic life.
2. Describe your observations of the water after the particles have settled. Do you notice anything unique about how the particles have settled?

Have students compare and contrast the particles that settle to the bottom first and those that remain suspended. Challenge them to use their observations to discuss the following question: Do you think that the differences in the sizes of these particles affect which ones take longer to settle? (See Figure 3.23 as an example.)

FIGURE 3.22
Two Soil Samples



Two sediment samples illustrating components of soil texture: On the left is a sample from a mountain spring, and on the right is a sample from a river.

FIGURE 3.23
Sedimentator

Activity 10. Measuring Turbidity With a Turbidity Tube

Initial use of the turbidity tube can be conducted in the classroom using prepared samples. The purpose of this activity is to have students practice using the tube so they become efficient when using one in the field.

Driving Question

How does the turbidity of water change as the amount of soil in the water increases?

Part I. Making a Turbidity Tube

For Part I of this activity we refer you to the GLOBE (**G**lobal **L**earning and **O**bservations to **B**enefit the **E**nvironment) Program and their instructions on making this tool (*http://cartt.4j.lane.edu/ve/globe/globedata/Turbidity.pdf*). See also Figure 3.14, earlier in this chapter (p. 54).

Part II. Preparing Water and Soil Samples Materials

- Four gallons of water
- Soil
- Indirectly vented chemical splash goggles, gloves, aprons (use also for Part III)

Procedure

1. Make four samples of water and soil. Begin with one gallon of water for each sample and add the following amounts of soil:
    - Sample 1: ¼ cup of soil
    - Sample 2: ½ cup of soil
    - Sample 3: ¾ cup of soil
    - Sample 4: 1 cup of soil
2. Shake vigorously and set aside for 15–20 minutes, until all large particles have settled out.

Part III. Measuring Turbidity Materials

- Turbidity tube
- Water and soil samples prepared in Part II

Procedure

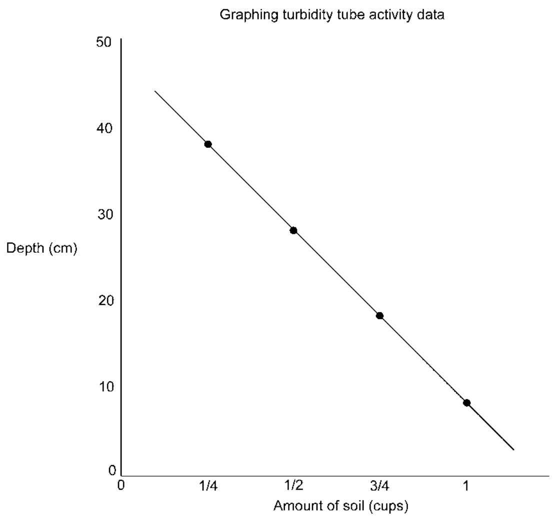
1. Pour first water sample into the turbidity tube until the Secchi disk is no longer visible when viewing the contents of the tube from the opening in the top.
2. Record the depth of water to the nearest 1 cm on the data sheet.
3. Repeat steps 1 and 2 with the remaining water samples. Wash hands with soap and water.

Have students create a line graph (y axis = depth of water to see Secchi disk in centimeters, x axis = amount of soil [e.g., ¼ cup, ½ cup, ¾ cup, and 1 cup], p. 67) to organize their data on the four water samples. Encourage them to review the data and draw conclusions about the impact the soil content of a water sample has on its turbidity reading. Use the data sheet for comparing

Turbidity Reading Data Sheet

	¼ cup soil	½ cup soil	¾ soil	1 cup soil
Turbidity reading (depth reading in cm)				

differing amounts of soil and sediment and the effect of these differing amounts on a turbidity reading.

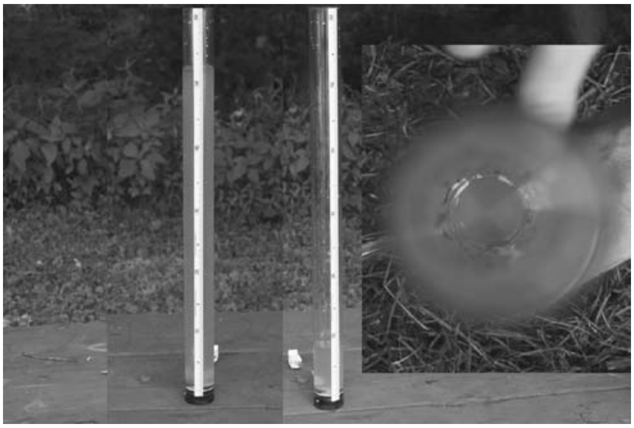


Turbidity tube graph

Think About

1. Review the data from the data sheet and the line graph you constructed to organize your turbidity data. What impact did the soil content of a water sample have on its turbidity reading?
2. Use your data and observations to predict what the turbidity reading might be in a mixture of 1 gallon of water and ⅛ cup of soil. Explain your prediction.
3. Use your data and observations to predict what the turbidity reading might be in a mixture of 1 gallon of water and 2 cups of soil. Explain your prediction.
4. Looking at the samples in Figure 3.24, what can you conclude about the turbidity of this body of water?

FIGURE 3.24
Turbidity Tube Sequence From Monocacy River, Frederick, MD



Wrap-Up

Our goal in this chapter was to provide enough varied activities to help students gain a keener understanding of the role that water plays in the living world. While not an exhaustive list, these experiences will engage students in the purposeful study of the components that affect water and ways to go about measuring them. All of these activities have a direct application to field-based studies, and it is our hope that students will be encouraged to study the local aquatic ecosystems.

Resource List

Websites

CHEMetrics
www.chemetrics.com

GLOBE (Global Learning and Observations to Benefit the Environment)
http://cartt.4j.lane.edu/ve/globe/globedata/Turbidity.pdf

Hydrometers
www.csd509j.net/cvhs/berand/Marine/Labs/Making%20Test%20Tube%20Hydrometers%20Student%20Guide.doc
www.ecawa.asn.au/home/jfuller/liquids/hydrometers.htm

LaMotte Company water quality testing products
www.lamotte.com

Red cabbage chemistry
www.chemistryland.com/CHM107Lab/Lab1/Lab1PreparingCabbageExtract.htm

Ship Mates ("Ocean Salinity")
www.bigelow.org/shipmates/salinity.html

University of Wisconsin Extension
"Dissolved Oxygen": *http://watermonitoring.uwex.edu/wav/monitoring/oxygen.html*
"Transparency": *http://watermonitoring.uwex.edu/wav/monitoring/transparency.html*

Windows to the Universe, University Corporation for Atmospheric Research
www.windows.ucar.edu/tour/link=/earth/Water/dissolved_salts.html&edu=high

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