Walch Science Literacy Series
Chemistry

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WALCH PUBLISHING

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To the Teacher

As teachers, what do any of us want for students? In addition to wishing them healthy and fruitful lives, we want them to be able to think. We want them to be literate in the fields we teach year after year. We want them to develop the thinking skills that will allow them to be respected and productive. We hope that they will be critical of false claims and weak arguments. We urge them to study so that they may possess that special body of knowledge that will help them to do their jobs better. In addition, we want them to develop habits of mind that characterize good thinkers. In this program we have developed a tool that will help you direct your efforts to a very worthwhile end, namely teaching science literacy.

What Is Science Literacy?

Project 2061, sponsored by the American Association for the Advancement of Science (AAAS), seeks to promote literacy in science in order to help people live interesting, responsible, and productive lives in a society in which science, mathematics, and technology are central.

In the book *Science for All Americans,* Project 2061 defines science literacy as "what every high school graduate should understand about science, mathematics and technology." It recommends that scientific literacy include:

- Being familiar with the natural world and recognizing both its diversity and its unity
- Understanding key concepts and principles of science
- Being aware of some of the important ways in which science, mathematics, and technology depend on one another
- Knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations
- Having a capacity for scientific ways of thinking
- Using scientific knowledge and ways of thinking for individual and social purposes

What Are Habits of Mind?

Science literacy requires ways of understanding and habits of mind that allow people to grasp what science and technology are about, to make some sense of how the natural and designed worlds work, to think critically and independently, and to recognize and weigh alternative explanations of events.

Habits of mind refer to thinking skills, values, and attitudes that, taken together, relate directly to a person's outlook on knowledge and ways of thinking and acting. Habits of mind need to be learned in the context of all scientific content areas. Students need not only to acquire these skills but also to be able to use them in new situations, both in and out of school.

Habits of mind include values and attitudes, computation and estimation skills, manipulation and observation skills, communication skills, and critical response skills.

The *Walch Science Literacy Series* uses a variety of content areas to help students develop the necessary habits of mind needed by a scientifically literate person. The following list of habits of mind describes the science literacy skills included in the series.

Values and Attitudes

- Raise questions and seek answers.
- Make hypotheses.
- Make careful observations.
- Keep honest, clear, accurate records.
- Offer reasons for findings.
- Understand that different explanations can be offered and that it isn't always possible to tell which is correct.
- Value and exhibit curiosity, honesty, openness, and skepticism.
- View science and technology thoughtfully.

Computation and Estimation Skills

- Manipulate numbers mentally.
- Translate from common fractions to decimals.
- Estimate measurements and computations.
- Judge whether measurements and computations are reasonable.
- Understand the purpose of each step in a calculation.
- Determine the units in which an answer should be expressed.
- Estimate probabilities of outcomes.

Manipulation and Observation Skills

- Use common tools.
- Operate common audio equipment.
- Make simple models and equipment.
- Repair things.

- Keep a notebook that describes observations and distinguishes these from speculations.
- Calculate and compare areas and volumes.
- Read analog and digital meters on instruments.
- Disassemble and reassemble simple mechanical devices.
- Understand the purposes of the parts of simple mechanical devices.

Communication Skills

- Describe and compare things in terms of number, shape, texture, size, weight, color, or motion.
- Draw pictures that correctly portray observations.
- Write and illustrate instructions to carry out a procedure.
- Use numerical data in descriptions.
- Organize information in simple tables and graphs.
- Read tables and graphs of all kinds.
- Locate information in reference books, newspapers, magazines, CDs, databases, and the Internet.
- Make and interpret scale drawings.

Critical Response Skills

- Support statements with facts from books or other sources, and identify the sources.
- Recognize faulty comparisons.
- Seek evidence for believing something, and discount reasons based on hearsay or speculation.
- Question claims built on vague attributions.
- Compare consumer products.
- Be skeptical of arguments based on very small samples of data, biased samples, or samples not matched with controls.
- Notice and criticize the reasoning of faulty arguments.
- Check graphs to see that they do not misrepresent data.
- Compare probabilities with chance.
- Insist that critical assumptions behind an argument be made explicit.
- Recognize arguments based on selected data.
- Suggest alternative ways of explaining data.

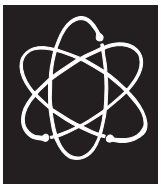
The foregoing list, while long, does not cover every conceivable habit of mind, but it does provide you with the insight and understanding necessary to be able to teach successfully a set of identified and organized thinking skills to your students.

To the Student

How would you like to be one of the best thinkers in your school? Would you like to be able to put pieces of a problem together quickly and thoroughly in order to find a solution? Do you want to be able to spot flaws in weak arguments? Can you develop a strategy for setting up an experiment that will work to give you an answer to a problem?

Most students would like to be able to do all these things. But some of them are not as successful as they could be because they have not developed the skills—the "habits of mind"—of really good thinkers. In this program, you will learn some new thinking skills, and you will know when you are using them. You will become a more effective thinker and problem solver as you work through the science situations in this book.

Our best wishes for good thinking.



Activity 1

The Case of the Missing Skis

The skis were on the porch last night. Now they're gone! Who could have taken them? All that remains are a few footprints in the snow around the porch. Could these footprints provide a clue about the ski thief?

Scientists are often puzzled by mysteries like the Case of the Missing Skis. They know that something has happened because of clues left behind. They have to figure out what the something is with only the clues to work with.

You probably know that scientists think that all matter is made of **atoms.** Atoms are tiny particles, much too small to be seen with the naked eye or even with the best of microscopes. But if it's impossible to see atoms, how do we know they exist?

The first step in answering such questions is to use whatever visible clues are available. Think about what you can learn from the clues left behind when the skis disappeared. What do the footprints in the snow tell about the missing skis? Are they the footprints of a man or a woman? a big person or a small person? a single person or a group of people? Was the person walking or running? Did the person limp or use a cane? It's possible to ask many questions about the footprints. Eventually, it might be possible to construct a picture of the ski thief.

Scientists trying to invent a picture of an atom follow much the same steps. For example, if you fire a stream of atoms through an electric field, the stream breaks into two parts: one charged positively and one charged negatively. This clue suggests that atoms consist of two parts, one positive and one negative. One idea suggested was that an atom was a ball of positive electric charge. Embedded in this positive charge were the negative particles, much like chocolate chips in a cookie. Draw an atom that fits that description. What questions does this picture raise in your mind? What experiments could you perform to answer those questions?

Scientists' pictures of the atom improve step-by-step. New evidence—new clues—suggests better pictures. Better pictures suggest new questions, new experiments, and so on. By this careful process, scientists develop very clear pictures of objects that are impossible to see . . . and young detectives can identify ski thieves they never saw in action.

1. Scientists think that a single atom of oxygen is about a 70 trillionth of a meter (0.000 000 000 070 m) in diameter. Think of a way to describe that size in everyday terms.

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2. In a famous experiment designed to study atoms, Australian-English scientist Lord Ernest Rutherford fired positively charged particles at a thin piece of gold. The particles were about the size of atoms. Most of the particles went right through the gold foil, as shown in Figure 1.1. What information did this experiment provide Rutherford about the gold atoms?

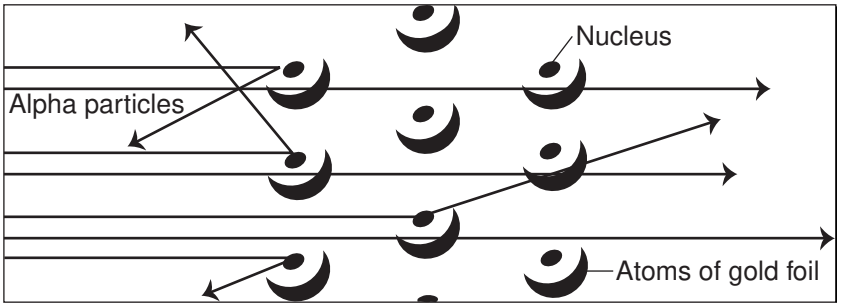

Figure 1.1

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3. A few of the positively charged particles in Rutherford's experiments were reflected backward from the gold foil. What does this result suggest about the structure of atoms?

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Interpreting Indirect Evidence

GOAL

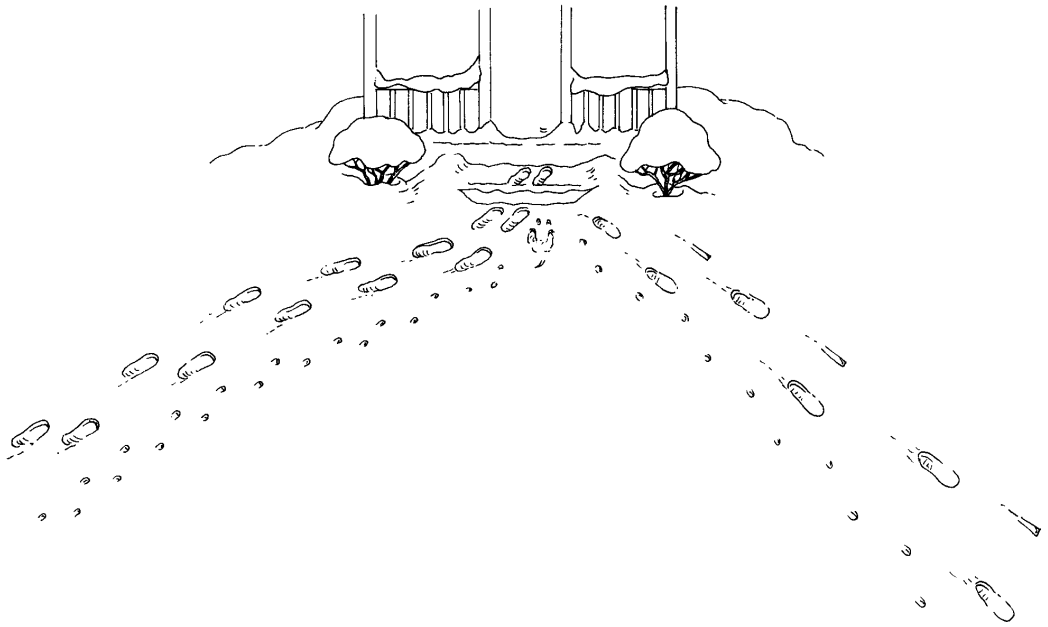
To collect and interpret information about an event that has not actually been observed

MATERIALS

You will need the following sketch.

PROCEDURE

A pair of skis were left on the porch one night. The next morning they were missing. The following sketch shows the footprints in the backyard snow on the morning the skis were discovered missing. Answer the questions about this event. The porch in the drawing is 1.5 meters wide.



1. What information can you obtain about the loss of skis from the back porch just by looking at this drawing?

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(continued)

Interpreting Indirect Evidence (continued)

2. What measurements or other activities can you do to obtain more information about this drawing?

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3. Make a hypothesis as to how the skis disappeared from the porch.

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4. Explain how you could test this hypothesis.

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RECORD KEEPING: Record the answers to the questions on the back of this sheet or on another sheet of paper. Be sure the hypothesis you write for question 3 can be tested.

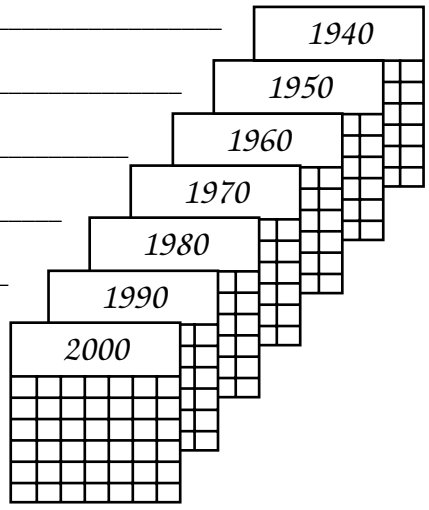
CONCLUSIONS: What conclusions can you make about the missing skis from examining the indirect evidence? Write your conclusions in a paragraph.

APPLICATION: You have already wrapped birthday presents for your twin brother and sister. The packages are the same size, and now you don't know which package is which. Your brother's present is a baseball and your sister's present is a charm bracelet. Using what you have learned about interpreting indirect evidence, explain how you could put name tags on the correct presents without unwrapping either of the packages.

Atomic Structure

Explain how a person can know about events that have occurred in the past without actually having seen those events occur.

Knowledge of Past Events



Activity 1

Swimming Pool Chemistry

It's a perfect summer day. The weather may be hot, but the town swimming pool is open. You can go swimming, be with your friends, and cool off.

But did you ever think about the health hazards of a swimming pool? Every person carries at least some germs on his or her body. And people who have a cold or some other illness carry a lot of germs. Furthermore, the warm water of the pool is an ideal environment for germs to grow in. Without proper precautions, a swimming pool can become a giant breeding ground for disease.

Fortunately, it's fairly easy to make a swimming pool safe for everyone to use. The element **chlorine** and some of its compounds kill germs quickly. The most common chlorine compound used in swimming pools is **hypochlorous acid** (HOCl). By maintaining the proper level of chlorine in a pool, the water can be made safe for all swimmers.

There is, however, one catch to maintaining the proper level of chlorine in a pool. The amount of chlorine released from hypochlorous acid depends on how acidic the pool water is. **Acidity** refers to the property that gives lemons, limes, and grapefruit their sour taste. Chemists use the **pH scale** to measure acidity. The pH scale runs from about 0 (very acidic) to about 14 (not acidic at all) with a pH of 7 being completely neutral (as is pure water).

If the pH of pool water is too low, very little chlorine is released from the hypochlorous acid. Then the germs in the water are not killed. If the pH is too high, very large amounts of chlorine are released. High levels of chlorine cause eye irritations and promote the growth of algae. The pH level has to be at a point where enough chlorine is released to kill germs but not too much or too little to cause other problems in the pool.

Pool workers use test kits to check swimming pool water. With the kit, workers test both the amount of chlorine in the water and the pH of the water. Using a test, they can tell if there is too much, too little, or just the right amount of chlorine in the water by matching the color the water turns with a color on the kit scale.

They use a similar color-matching test to determine the pH of the pool water. If the test indicates the pH is too low (below 7.4), they add sodium carbonate to raise the pH of the water. If the test indicates the pH is too high (above 7.6), they add sodium bisulfate to lower the pH. Public pools should be tested every few days. Regular testing of the pool keeps the water clear and sparkling.

Use references such as library books, encyclopedias, or the Internet to find information to answer the following questions.

1. Describe the properties of the element chlorine.

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2. Why is chlorine itself generally not used to chlorinate home swimming pools?

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3. What is battery acid and what is its pH? What are some other acids and how are they used?

4. Chemicals known as bases are the opposite of acids. Household ammonia is one base. What is its pH? What are some other bases and how are they used?

Graphing pH

GOAL

To make a graph and determine the best pH range for swimming pool water

MATERIALS

You will need graph paper, the data in the following table, and a pencil.

PROCEDURE

The following table shows how much of two chemicals are present in swimming pool water at various pH levels. The ideal situation for the pool water is for it to have no more than 55 percent of either hypochlorous acid (HOCl) or chlorous ion (OCl^-). Graph the numbers shown in the table and decide what an acceptable range of pH values is in order to maintain the proper balance of HOCl and OCl^-.

pH	Concentration of HOCl	Concentration of OCl^-
2	100	0
3	100	0
4	100	0
5	98	2
6	95	5
7	70	30
8	20	80
9	5	95
10	1	99
11	0	100
12	0	100

RECORD KEEPING: Make your graph on a sheet of graph paper.

CONCLUSIONS: Between what two pH values are the concentrations of both chemicals at 55 percent? What would you conclude is the ideal pH for a swimming pool using these chemicals to kill bacteria?

APPLICATION: When your family returns from vacation, you notice that there is a green scum forming in your swimming pool. Your sister says, "The pool needs chlorine." She wants to dump a large bottle of chlorine laundry bleach into the water. Is that a good idea? Why or why not?

Activity 1

The Search for Quarks

Scientists never seem to know when to stop. They do experiments to find the answer to some question, often with success. But in most cases, the answer they find suggests new questions which, in turn, require new experiments. This process often goes on over and over again.

Consider the question: What is the smallest particle of matter? In the 1800s, chemists thought the answer to that question was the **atom.** But in the 1890s, scientists discovered **electrons** inside an atom. Then they knew that the atom itself was composed of smaller particles. Later they learned that atoms also contain **protons** and **neutrons.**

So protons, neutrons, and electrons are the smallest particles of matter, right? It seems not. In the 1950s, scientists began to suspect that protons and neutrons themselves (but not electrons) consist of even smaller particles, to which they gave the name **quarks.** The search has become somewhat like opening a Chinese puzzle box, with each box containing yet a smaller box.

Today, scientists have discovered five (and probably six) kinds of quarks that they believe make up all kinds of matter. Quarks are used to build protons and neutrons which, in turn, are used to build atoms. In addition, scientists have found six kinds of **leptons,** of which the electron is one. These six quarks and six leptons are now thought to be the smallest particles of which matter is made.

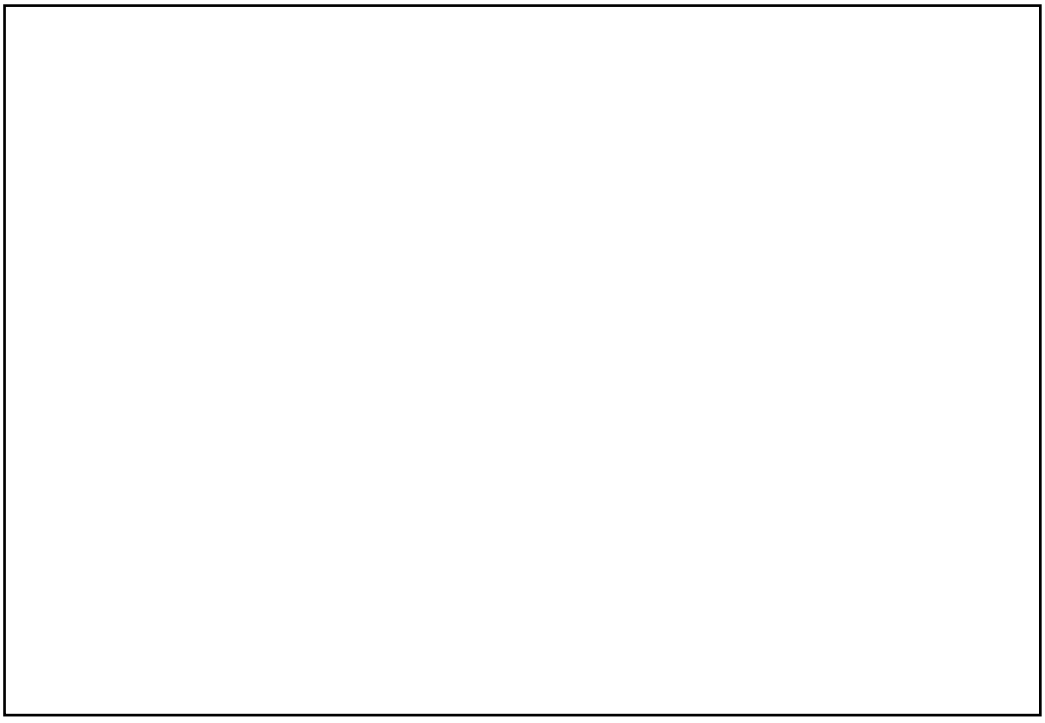
Discovering quarks and leptons has required one of the largest and most expensive research programs ever developed. These particles can be produced only in very large **particle accelerators** (atom smashers) that cost millions and even billions of dollars. Hundreds of scientists are involved in each study on fundamental particles.

Is the information gained worth all that time, money, and effort? After all, knowing about fundamental particles may be an exciting **basic research** project and will surely add to the world's storehouse of knowledge. But it won't help solve crucial social problems, such as feeding the hungry or housing the homeless.

Besides, quark hunting is so expensive that it can normally be financed only by national governments. How do *you* feel about spending your tax dollars on that kind of research? Would you be willing to pay $1 a year, $10 a year, $100 a year so that scientists could find out more about quarks, to see if quarks themselves may be made of even smaller particles?

Use reference sources such as library books and magazines or the Internet to find information to help you answer the following questions.

1. Make a simple diagram showing where protons, neutrons, and electrons are found in an atom.



2. What does it mean to say that an atom is *smashed* when it is placed inside a particle accelerator or atom smasher?

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3. Hypothesize a reason that particle accelerators can also tell about the composition of protons and neutrons.

4. Quark hunting is an example of basic research. Basic research is not conducted to solve any specific practical problem. Why, then, is it done?

Staging a Mock Congressional Debate

GOAL

To stage a mock congressional debate on refunding the SCC project

MATERIALS

You will need reference materials, such as magazine and newspaper articles on the Superconducting Supercollider (SSC) and a notebook.

PROCEDURE

Read the following imaginary scenario and the instructions that follow.

Scenario

Congressman Sam Adams has long had a special interest in the search for quarks and leptons. He was very disappointed when the U.S. Congress decided in 1994 to cancel its support of the SSC project. He now believes that Congress should reverse its decision and begin supporting quark research once more. He has submitted a bill in the House of Representatives, HR3912, that would allocate $100 million to restarting the SSC construction project, with additional funding of $250 million, $500 million, and $1 billion in the next three years.

You serve on the House Energy Committee, which must support or oppose Congressman Adams's bill. Read as much as you can about the SSC to decide whether you support or oppose restarting the project. Organize the information you find into arguments for and against the SSC.

INSTRUCTIONS: Your teacher will set up a mock hearing on Congressman Adams's bill. Ten students will be asked to play the role of representatives at the hearing, five in favor of and five opposed to the bill. One student will be asked to chair the meeting. At the end of the meeting, class members *not* on the committee will be asked to vote for or against Congressman Adams's bill based on the arguments presented at the hearing.

RECORD KEEPING: In a notebook, indicate arguments on both sides of the debate. Organize your information using the titles: "Arguments in Favor of the Bill" and "Arguments Opposed to the Bill."

CONCLUSIONS: Based on the arguments presented at the hearing, do you think the bill should be passed or not? Explain your reasoning.

APPLICATION: Suppose you found out that from their basic research with devices like the SSC, scientists learned information that helped them design new materials that could improve transportation systems and medical equipment. How would this information influence your support for funding the SSC?

Value of Basic Research

Your cousin has read about the Superconducting Super Collider in a local newspaper and wants to talk to you about the project. "What a waste of money," she says. "The SSC will never produce better television sets, improved medicines, long-lasting fibers, or any other product useful to humans. It would be better just to give that money to homeless people and let them find a place to live." What could you say to defend the value of the SSC project?