Walch Science Literacy Series
Chemistry

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WALCH
PUBLISHER
Portland, Maine

Contents

(R) denotes reproducible activity

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 each other.
- 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 understandings 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 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 J. Weston 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.

Communications 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, and databases.
- 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 successfully teach a set of identified and organized thinking skills to your students.

Lesson 7

Tracking Down the Cause

SCIENCE LITERACY SKILLS

- Read graphs and tables
- Suggest alternative ways of explaining data

VOCABULARY

cause and effect **variables**
correlational

Background: Correlations Between Variables

One of the most difficult problems in analyzing scientific data is knowing when the correlation between two **variables** also suggests a **cause-and-effect** relationship. It is this difficulty that is responsible for the rule in experimental science that one tests for one, and only one, variable at a time. In nutritional studies, for example, an experimental animal is given a diet exactly like that given to a control animal except for a single factor. Differences observed between experimental and control, then, can be attributed with some degree of confidence to cause and effect: The single factor by which the two diets differed *caused* the observed effect.

Real-life questions cannot be studied in such neat experiments. In fact, questions involving humans usually cannot be studied by experiments at all. Instead, one must draw such conclusions as one can from historical data or data that can be collected on some topic. Those data may or may not show a correlation between two variables and, if they do, that correlation may or may not represent a cause-and-effect relationship.

The problem is that the correlation between two variables can be explained in many ways other than cause and effect. For example, as in the minister/rum case on the student page, the correlation is probably purely coincidental. Often, a correlation can be explained by some third factor, such as the growth of a new nation in the minister/rum example. In the case of smoking and respiratory disease, cigarette manufacturers have long argued that health problems are caused not by smoking, but by some other characteristic (such as stress) that is common among smokers.

Probably the most important point of this lesson is to warn students that correlational relationships are not *automatically* cause-and-effect relationships, and that further research and analysis may be necessary to discover in any particular instance if correlation does mean cause and effect.

FOR DISCUSSION

Both **correlational** and cause-and-effect relationships are common in students' everyday lives. Ask students to think of examples of both and to explain how they know the difference between correlation and cause and effect in each example.

ENCOURAGING SKILL DEVELOPMENT

Discuss with students the importance of cause and effect as a concept in science. Point out how humans almost inherently look for a cause for any given effect (Why does the sun rise? Why are the trees in my yard dying?) and how science has provided an objective method for identifying cause-and-effect relationships.

Name ______________________________

Date ______________________________

Tracking Down the Cause

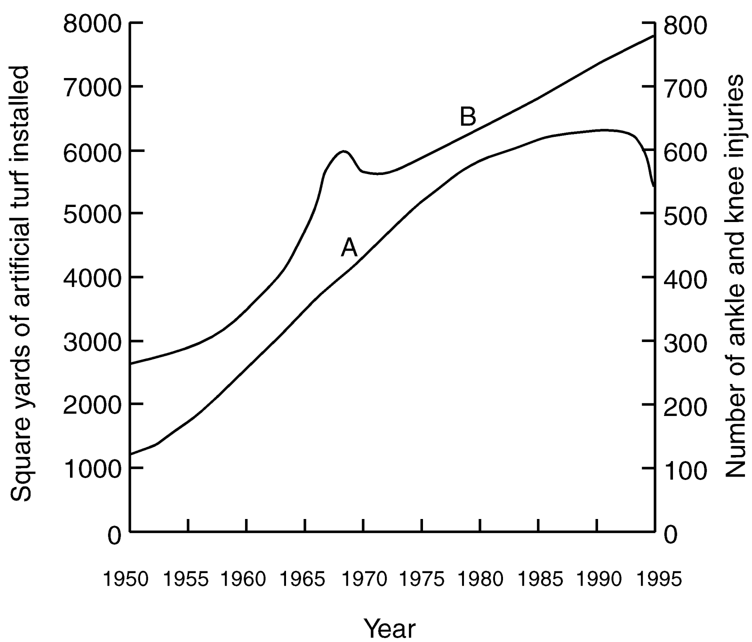
GOAL	MATERIALS
To interpret graphs for cause-and-effect relationships	None

PROCEDURE

Beginning in the 1950's, many owners of football stadiums began to replace the natural grass, or turf, in their facilities with a grasslike plastic substitute called artificial turf. Builders of domed stadiums, such as Houston's Astrodome, had no choice in the matter, since grass could not grow in the artificial light of the stadium. Line A in the following graph represents the number of square yards of artificial turf installed in football stadiums each year since 1950.

Shortly after stadiums began installing artificial turf, sports physicians began to see an increase in the number of knee and ankle injuries experienced by football players. Line B on the graph shows the number of such injuries reported each year since 1950.

Examine the graph and use it to answer the questions.



(continued)

Name ______________________________ Lesson 7

Date ______________________________ Cause-and-Effect Relationships Activity

Tracking Down the Cause (continued)

RECORD KEEPING: Record your answers to the questions in a notebook.

1. This graph shows a correlation between variables A and B. How do you know?

2. Is the correlation between A and B perfect? How do you know?

3. Is there any possible cause-and-effect relationship between A and B? If so, what is it?

4. How else can you explain the correlation between A and B other than as a cause-and-effect relationship?

5. How could you test to see if the correlation between A and B is also a cause-and-effect relationship?

CONCLUSIONS: What conclusions can you make about the relationship between the use of artificial turf and knee and ankle injuries? Write them in a paragraph.

APPLICATION: Your town notices that every time there is a heavy rain and extra water runs through the storm drains into the local creek, dead fish are found downstream. How could your town find out if there is a cause-and-effect relationship between the events?

Lesson 18
The Search for Quarks

Science Literacy Skills

- Recognize differences and values in pure and applied research
- Support statements with facts
- Raise questions and seek answers

Vocabulary

atom	**leptons**
basic research	**neutrons**
electrons	**quarks**
particle accelerators	**protons**

Background: The Superconducting Supercollider (SSC) Project

Research on the fundamental nature of matter posed one of the two greatest controversies (the other being space research) over basic research in the last third of the twentieth century. **Quarks** and **leptons** can be observed only at very high energy levels. These energy levels can be produced on the earth only by the most powerful **particle accelerators.**

In the 1970's, scientists in the United States began designing the most powerful particle accelerator ever to be built, the Superconducting Supercollider (SSC). The SSC was planned to be an enormous machine 82.944 kilometers (51.539 miles) in circumference, capable of producing energies of 20 TeV (20 teraelectron volts or 20 trillion electron volts). These energies would be adequate, scientists felt certain, to answer all or most of the important questions about quarks and leptons.

The U.S. Congress approved initial funding for the SSC in 1987, and construction began on the site in Waxahachie, Texas, a year later. Over the next few years, Congress waffled back and forth on whether to continue its support of the machine. Lawmakers were worried about both its rising costs and its lack of any likely contribution to the solution of practical problems. Finally, in 1994, Congress decided to end its support for the SSC, and that project was brought to a conclusion.

For Discussion

Find out how much students know about particle accelerators in general, and about the SSC in particular. Review briefly with them the history of the SSC project and its current status.

Encouraging Skill Development

In a class discussion, have students clarify the meaning of basic research and the difference between it and *applied research* and *technology.* Ask students to list some arguments for supporting each type of activity.

Library Research
Quarks and Leptons

(Individual)

Ask students to read about quarks and leptons in the library, with the goal of learning which ones have been discovered, what their names are, and how they got their names.

Extension

As a class project, have students construct a time line of the SSC project on a long sheet of kraft or butcher paper. The time line should include important events such as initial concept, congressional actions, President Ronald Reagan's approval, site selection, and cancellation of the project.