Introduction

> *Learning can and often does take place without the benefit of teaching—and sometimes even in spite of it—but there is no such thing as effective teaching in the absence of learning.*
>
> —Angelo and Cross (1993, p. 3)

Speaking of learning in spite of, or because of, visualize the two science classrooms as you read the following scenarios. Ask yourself these questions: *How are these two classrooms alike? How are they different? Which science teacher would you rather have had when you were a middle school student? Which teacher epitomizes the way most teachers teach science today?*

■ SCENARIO I

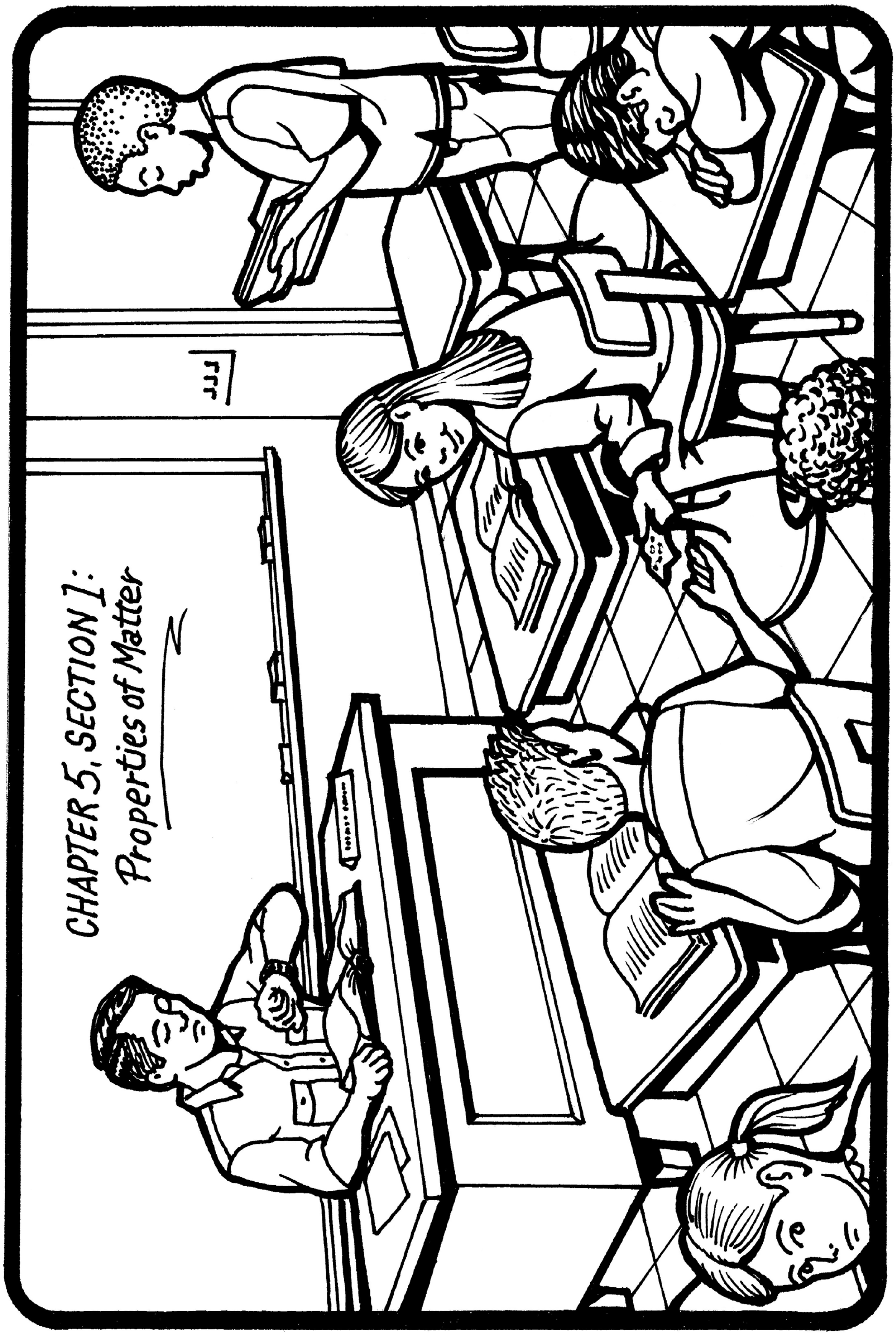
Mr. McIntire teaches science at Pine Lake Middle School. Let's look in on his class. Some of Mr. McIntire's seventh graders are filing into his classroom. Others are standing outside in the hall talking and, after being asked repeatedly, slowly saunter into the classroom. Once the second bell rings, Mr. McIntire checks roll by calling the names of every student in class and listening for the response of *here* or *present.* This goes on for some time, and since students are bored, they begin talking to peers in close proximity, for which they are promptly reprimanded. Six minutes later, class begins with a review of the homework from the night before. Students were assigned to write the answers to all of the questions at the end of the textbook chapter covered on yesterday. Many students come in without their homework, so they have nothing to look at while the remainder of the class listens to Mr. McIntire give the answers orally. Students mark their answers as correct or incorrect. Finally, after about 20 minutes, the lesson for the day begins. The objective addresses the Physical Science Content Standard *properties and changes of properties in matter.* Students are told to open their textbooks to Chapter 5, Section 1, and the lesson begins. Students will be taking turns reading the chapter aloud while the remainder of the class follows along. Mr. McIntire stops periodically to ask questions of volunteers. Nonvolunteers are never called upon, and some tune out completely. This goes on for the remainder of the period. The homework assignment tonight will be to answer the questions at the end of Chapter 5, Section 1, for discussion tomorrow. Since there are a few minutes remaining in class, students are told to begin their homework now and work until the bell rings. When the bell rings, students jump up and run for the door.

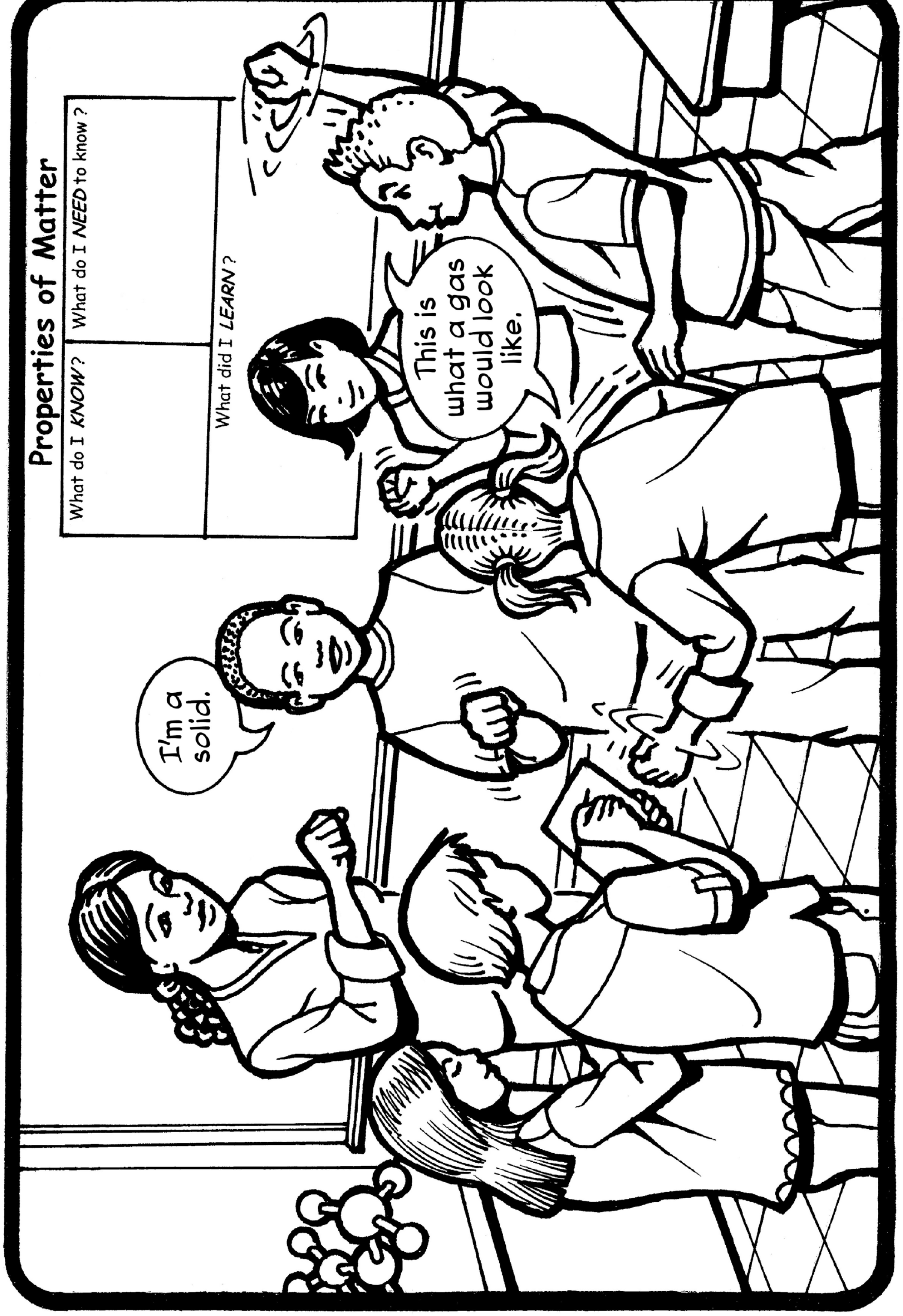
■ SCENARIO II

Mrs. Miller teaches middle school science at Douglas Middle School. Students cannot wait to get to her class since they are never quite sure what novel things will be happening each day. They have nicknamed her *Mrs. Science* and she wears the label well! As students come into class, they automatically know to look for a *sponge activity* on the board. Today the activity asks them to continue work in their cooperative groups on the science projects that they began earlier in the week. Students know exactly how to proceed in their groups since they have worked cooperatively all year. The *materials manager* gathers the supplies and each group's *facilitator* leads a group discussion of the progress on the project while Mrs. Miller checks roll quickly using a seating chart. She then takes turns visiting each group for a progress report of their respective projects.

After about 15 minutes of group activity, Mrs. Miller asks that students put up their materials and get ready for today's lesson, which is on the Physical Science Content Standard *properties and changes of properties in matter.* She begins by drawing a K-N-L chart on the board regarding the four states of matter and has students brainstorm what they already *know* and what they think they will *need* to know. Later, they will summarize by filling in the column on what they have *learned.* She finds that both volunteers and nonvolunteers already know a great deal about the topic.

To reinforce the learning, Mrs. Miller then has students stand up and she demonstrates how to simulate atom movement by having them shake their fists. This is a metaphor for the fact that atoms vibrate and have energy. Then students shake two fists to represent two atoms. If the fists are maintaining relative position, she tells them that they are simulating a solid. If the fists rotate around one another, they simulate a liquid. A gas is made by taking the fists and extending them out far away from each other. Plasma is simulated when students are moving their arms wildly and opening their fists to extend fingers, implying that light is released. Tomorrow, students will use these movements in conjunction with the song "The States of Matter," written by Warren Phillips and found on his website at www.wphillips.com. The homework assignment tonight is to find things in their homes that represent each state of matter and bring the list back tomorrow. The bell rings and students reluctantly file out of class. However, several gather around and are engaged in friendly conversations with Mrs. Miller on their way out of the room.


CHAPTER 5, SECTION 1:
Properties of Matter


Properties of Matter
What do I KNOW?
What do I NEED to know?
What did I LEARN?
This is what a gas would look like.
I'm a solid.

BRAIN-COMPATIBLE INSTRUCTION

I am often asked to conduct model lessons in schools around the world. I will take a teacher's class and teach them while other teachers observe the lesson. Following are two letters from students in a second-grade class that I taught some years ago. I taught a science lesson on the planets and their order from the sun. Notice that this lesson was taught before we lost Pluto as a planet. Once I left, the teacher asked the class to write letters telling me what they had learned, and she mailed those letters to my house. The letters were wonderful, and I share several in my classes when I teach adults. Note that second graders still use invented spelling.

> Mrs. Tate tot me my planets in oder. She told us to say My verey educated mother just served us nine pizzas. I know it by heart. We drew the nine planets. I didn't have a nuff roon so I had to write on the side. We listened to music. When she hit the chimes that ment be qiet. We colored planets. I learnt the closest to the sun and the farthest from the sun.

> Dear Mrs. Tate,
>
> Thank you! For teaching us about the plants. And how to put them in orber. Also for letting us act it out. I was wonding can you be a teacher one day. You'll be a great teacher. You prodleley teach 2nd gread. Thank you Mrs. Tate for comeing to our school!
>
> **Plantes**
>
> 1. Merkey
> 2. Vens
> 3. Earth
> 4. Mars
> 5. Jupeter
> 6. Saturn
> 7. Uranes
> 8. Nursen
> 9. Pluto

This is such an exciting time to be a teacher! While the brain remains a mystery, we know more today than ever about how brains acquire and retain information. The formula is quite simple. Take the research of learning-style theorists (Gardner, 1983; Sternberg & Grigorenko, 2000), combine it with the work of educational consultants (Jensen, E., 2009; Sousa, 2006; Sylwester, 2003), and add a dash of classroom observation regarding the use of best practices. There you have it! The recipe for effective teaching or 20 strategies that take advantage of how all brains learn. These strategies work for elementary, middle school, high school, and college students, as well as adults, in any learning situation. They work for students in special education programs, regular education programs, and gifted programs; students who are learning a second language; and students who have attention deficit disorder. In other words, they work for all students and adults. While these ways are not new—your most effective teachers have used them for generations—what is new is that brain researchers have given us a reason as to why these strategies work better than others. If you really examine the letters from the second graders, you will see that I used at least five of the strategies as I taught them about the planets in order: mnemonic devices, drawing, writing, music, and role play. Whether I am teaching students from kindergarten through 12th grade or adult audiences, I teach absolutely nothing without the 20 strategies. I am challenging you to do the same.

The 20 brain-compatible strategies are as follows:

1. Brainstorming and discussion
2. Drawing and artwork
3. Field trips
4. Games
5. Graphic organizers, semantic maps, and word webs
6. Humor
7. Manipulatives, experiments, labs, and models
8. Metaphors, analogies, and similes
9. Mnemonic devices
10. Movement
11. Music, rhythm, rhyme, and rap
12. Project-based and problem-based instruction
13. Reciprocal teaching and cooperative learning
14. Role plays, drama, pantomimes, and charades
15. Storytelling
16. Technology
17. Visualization and guided imagery
18. Visuals
19. Work study and apprenticeships
20. Writing and journals

By the time teachers have incorporated these strategies into their lessons, they have addressed all of Howard Gardner's (1983) multiple intelligences as well as all four of the major modalities: visual, auditory, kinesthetic, and tactile. Refer to Figure 0.1 for a chart that shows this correlation.

OVERVIEW OF THE NATIONAL SCIENCE EDUCATION STANDARDS

The 20 strategies answer the question of how to teach; however, one of the foremost questions any science teacher should be asking is "What am I supposed to teach?" While there are district curricula and state standards, the National Research Council (NRC, 1996) has written a 261-page document called the *National Science Education Standards.* The document is available from the National Academies Press at www.nap.edu/openbook.php?record_id=4962 and contains eight categories of content standards for science. They are as follows:

Unifying concepts and processes in science
Science as inquiry
Physical science
Life science
Earth and space science
Science and technology
Science in personal and social perspectives
History and nature of science

These broad categories are further delineated into the grade-level knowledge and skills required to be proficient in the content area of science and should serve as the major *chunks* to be addressed during instruction. This book contains over 250 activities for teaching science in brain-compatible ways. Every activity is correlated to one or more of the grade-level categories that follow:

6.0. Unifying Concepts and Processes Standards

Levels K–12

Systems, order, and organization

Evidence, models, and explanation

Change, constancy, and measurement

Evolution and equilibrium

Form and function

6.1. Science as Inquiry Standards

Levels K–12

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

6.2. Physical Science Standards

Levels K–4

Properties of objects and materials

Position and motion of objects

Light, heat, electricity, and magnetism

Levels 5–8

Properties and changes of properties in matter

Motions and forces

Transfer of energy

Levels 9–12

Structure of atoms

Structure and properties of matter

Chemical reactions

Motions and forces

Conservation of energy and increase in disorder

Interactions of energy and matter

6.3. Life Science Standards

Levels K–4

Characteristics of organisms

Life cycles of organisms

Organisms and environments

Levels 5–8

Structure and function in living systems

Reproduction and heredity

Regulation and behavior

Populations and ecosystems

Diversity and adaptations of organisms

Levels 9–12

The cell

Molecular basis of heredity

Biological evolution

Interdependence of organisms

Matter, energy, and organization in living systems

Behavior of organisms

6.4. Earth and Space Science Standards

Levels K–4

Properties of earth materials

Objects in the sky

Changes in earth and sky

Levels 5–8

Structure of the earth system

Earth's history

Earth in the solar system

Levels 9–12

Energy in the earth system

Geochemical cycles

Origin and evolution of the earth system

Origin and evolution of the universe

6.5. Science and Technology Standards

Levels K–4

Abilities to distinguish between natural objects and objects made by humans

Abilities of technological design

Understanding about science and technology

Levels 5–8

Abilities of technological design

Understanding about science and technology

Levels 9–12

Abilities of technological design

Understanding about science and technology

6.6. Science in Personal and Social Perspectives Standards

Levels K–4

Personal health

Characteristics and changes in populations

Types of resources

Changes in environments

Science and technology in local challenges

Levels 5–8

Personal health

Populations, resources, and environments

Natural hazards

Risks and benefits

Science and technology in society

Levels 9–12

Personal and community health

Population growth

Natural resources

Environmental quality

Natural and human-induced hazards

Science and technology in local, national, and global challenges

6.7. History and Nature of Science Standards

Levels K–4

Science as a human endeavor

Levels 5–8

Science as a human endeavor

Nature of science

History of science

Levels 9–12

Science as a human endeavor

Nature of scientific knowledge

Historical perspectives

The remainder of this book provides an explanation of each strategy and more than 200 pieces of research as to why these particular strategies work better than others. It will also provide you with more than 250 activities to incorporate in your lessons to ensure that brain-compatible instruction is taking place. Each activity is correlated to a content standard and a recommended grade level or levels. Many of the activities can be used to address any content standard and at any grade level. A recommendation is also provided as to whether this activity fits best before, during, or after instruction. The advantage of having activities for multiple grade levels in one book is that they can be used as is or adapted for students performing below, on, or above grade level. At the end of each chapter there is a reflection and application page on which you can take your personal curriculum objectives and correlate them to specific activities in the chapter or create original activities based on the strategy.

This book attempts to accomplish the following six major objectives:

1. Introduce you to 20 strategies that take advantage of ways in which the brain learns best
2. Supply over 200 research rationales from experts in the field as to why these strategies work better than others
3. Provide more than 250 activities of how to incorporate the 20 strategies into a K–12 science classroom
4. Correlate the science content standards to each activity
5. Allow time and space at the end of each chapter for the reader to reflect on the application of the strategies as they apply directly to the reader's specific objectives
6. Ask and answer the five questions that every teacher ought to be asking when planning and teaching a brain-compatible science lesson

Enjoy the wide variety of K–12 activities that can make science come alive in your classroom. The most important consideration as you teach science is to take advantage of the natural inclination of human beings to want to solve problems and find answers to questions that present themselves in the real world and to have fun while doing it! Keep these words from our initial quote in mind:

There is no such thing as effective teaching in the absence of learning.

—Angelo and Cross (1993, p. 3)

Comparison of Brain-Compatible Instructional Strategies to Learning Theory		
Brain-Compatible Strategies	*Multiple Intelligences*	*Visual, Auditory, Kinesthetic, Tactile (VAKT)*
Brainstorming and discussion	Verbal-linguistic	Auditory
Drawing and artwork	Spatial	Kinesthetic/tactile
Field trips	Naturalist	Kinesthetic/tactile
Games	Interpersonal	Kinesthetic/tactile
Graphic organizers, semantic maps, and word webs	Logical-mathematical/spatial	Visual/tactile
Humor	Verbal-linguistic	Auditory
Manipulatives, experiments, labs, and models	Logical-mathematical	Tactile
Metaphors, analogies, and similes	Spatial	Visual/auditory
Mnemonic devices	Musical-rhythmic	Visual/auditory
Movement	Bodily-kinesthetic	Kinesthetic
Music, rhythm, rhyme, and rap	Musical-rhythmic	Auditory
Project-based and problem-based instruction	Logical-mathematical	Visual/tactile
Reciprocal teaching and cooperative learning	Verbal-linguistic	Auditory
Role plays, drama, pantomimes, charades	Bodily-kinesthetic	Kinesthetic
Storytelling	Verbal-linguistic	Auditory
Technology	Spatial	Visual/tactile
Visualization and guided imagery	Spatial	Visual
Visuals	Spatial	Visual
Work study and apprenticeships	Interpersonal	Kinesthetic
Writing and journals	Intrapersonal	Visual/tactile

Figure 0.1