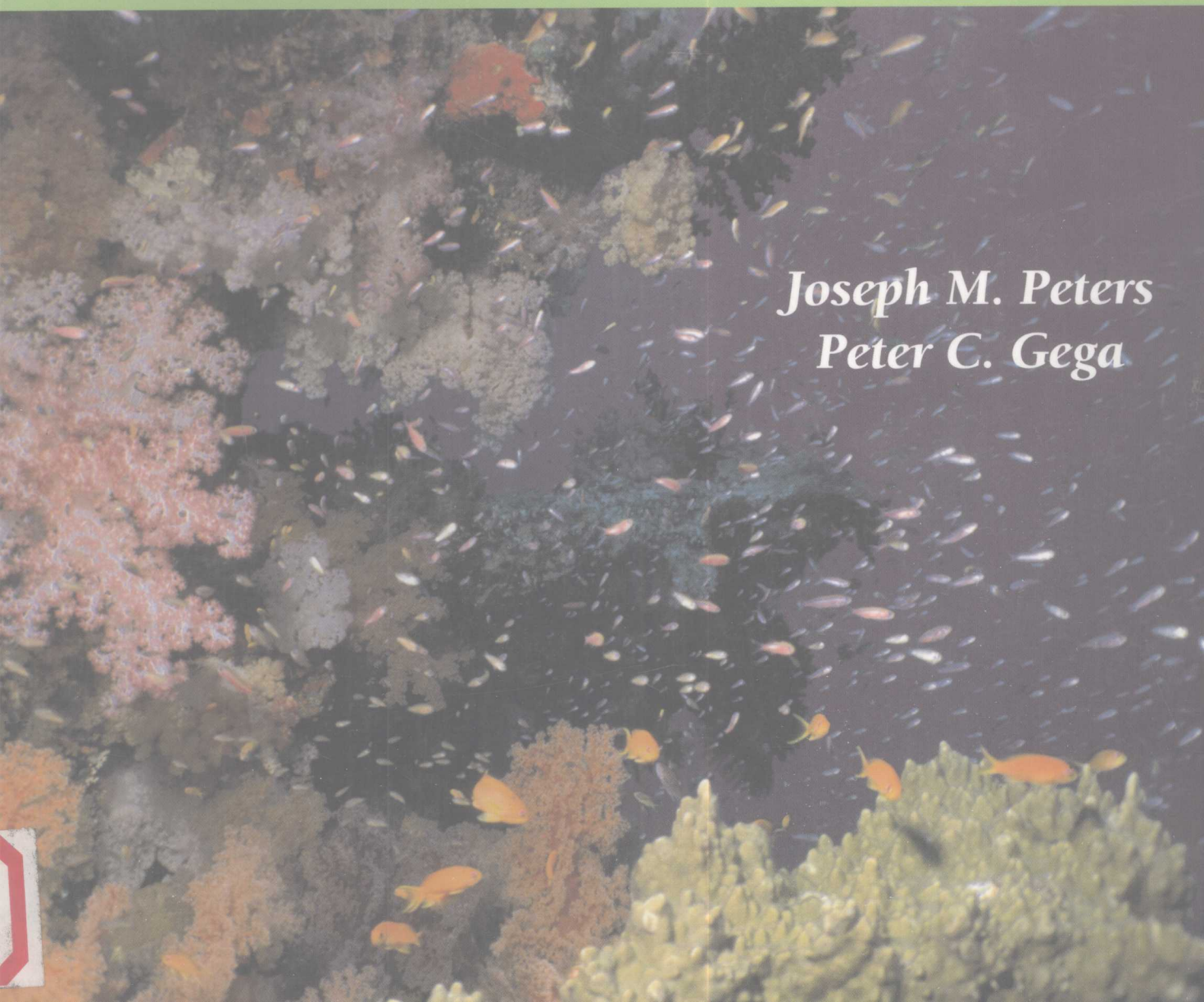
How to Teach Elementary School Science

4th Edition

MULTIMEDIA EDITION
Integrated CD and
Companion Website



Joseph M. Peters
Peter C. Gega

How to Teach Elementary School Science

Fourth Edition

Joseph M. Peters
University of West Florida

Peter C. Gega
Professor Emeritus
San Diego State University

Upper Saddle River, New Jersey
Columbus, Ohio

Library of Congress Cataloging in Publication Data

Peters, Joseph M.
How to teach elementary school science / Joseph M. Peters, Peter C. Gega.—4th ed.
p. cm.
Gega's name appears first on the earlier edition.
Includes bibliographical references and index.
ISBN 0-13-016582-4
1. Science—Study and teaching (Elementary) I. Gega, Peter C. II. Title.

LB1585.G39 2002
373.3'5044—dc21

2001030521

Vice President and Publisher: Jeffery W. Johnston
Editor: Linda Ashe Montgomery
Development Editor: Hope Madden
Editorial Assistant: Lori Jones
Production Editor: Linda Hillis Bayma
Copy Editor: Linda Poderski
Text Design: SettingPace
Design Coordinator: Diane C. Lorenzo
Photo Coordinator: Sandy Lenahan
Cover Designer: Diane Ernsberger
Cover photo: Pictor Uniphoto
Production Manager: Pamela D. Bennett
Director of Marketing: Kevin Flanagan
Marketing Manager: Krista Groshong
Marketing Coordinator: Barbara Koontz

This book was set in Berkeley Book by Carlisle Communications, Ltd. It was printed and bound by Courier Kendallville, Inc. The cover was printed by The Lehigh Press, Inc.

Photo Credits: Alan and Sandy Carey/PhotoDisc, p. 203; Scott Cunningham/Merrill, pp. 114, 184; Kenneth P. Davis/PH College, p. 105; Tim Daniel/ODNR/Division of Wildlife, p. 94; Richard Hoyt/Great Explorations in Math and Science, p. 120; T. Hubbard/Merrill, p. 156; Israel Office of Information, p. 21; Jet Propulsion Laboratory/NASA Headquarters, p. 38; Ken Karp/PH College, p. 30; KS Studios/Merrill, p. 194; James Kudlack and Barb Eldridge/Onekama Elementary School, p. 84; Anthony Magnacca/Merrill, pp. 130, 162, 166, 172, 179; Michael Newman/PhotoEdit, p. 73; Joseph M. Peters, pp. viii, 147; Barbara Schwartz/Merrill, p. 142; Silver Burdett Ginn Needham, p. 7; Cary I. Sneider/Great Explorations in Math and Science, p. 67; Stone/David J. Sams, p. 207; Courtesy of Uncle Milton Industries, Inc., p. 2; Anne Vega/Merrill, p. 48.

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada, Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Prentice-Hall Singapore Pte. Ltd.
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

10 9 8 7 6 5 4 3 2 1
ISBN 0-13-016582-4

This book is dedicated to David "Gus" Thomas, Mercyhurst College, whose desire for teaching inspired a love of science in all those with whom he came in contact.

Preface

Elementary school teaching is a challenging and exciting career. Your future as a professional educator includes the responsibility to meet the future demands and challenges of society, and the elementary classroom is where it all begins. The lifelong science-related attitudes of your elementary students will be shaped, for the most part, before they finish fifth grade. Along with these attitudes comes the desire to seek out new information about the world around them and to apply this knowledge in the form of technology. It is your job to build the skills, content knowledge, and desire for inquiry that will allow your students to function in a society that will be highly scientific and technologically developed. Your future as a teacher will include lifelong learning and research in your own classrooms. This text serves as a guide to start your journey as a professional educator.

New to This Edition

As you initiate your learning of elementary science education through the use of the fourth edition of this text, you will become acquainted with several features that will support you in your science education experiences. To help you think about the applications of what you are learning, you will find

- Vignettes opening each chapter that help introduce the concepts contained in the chapters and focus your thoughts

- Teaching tips for you to consider in your future instruction

- Companion Website references, which provide extensions to the chapter content

- CD-ROM connections, which help illustrate concepts in an actual classroom setting
- An entire chapter devoted to technology and science education

Organization of the Text

You will find that this book contains practical methods covering how to teach science to elementary through middle level learners. A companion paperback text, *Concepts and Inquiries in Elementary School Science,* Fourth Edition, as well as one hardcover text containing the complete content, *Science in Elementary Education,* Ninth Edition, also published by Prentice Hall, are also available.

How to Teach Elementary School Science focuses on the methods of teaching elementary school science. It centers on why science education is basic to children's schooling

and explains the foundations that give it form and substance. Each of its eight chapters develops a broad concept or a cluster of related teaching skills through descriptions and the use of many real-life examples. The examples reflect our personal teaching experiences or ongoing, firsthand observations with elementary school children. The chapters and several of the included follow-up exercises should enable you to

- Decide what areas of science are basic, useful, and learnable for children
- Recognize and assess differences in children's thinking
- Use open-ended and closed-ended teaching activities in planning and implementing lessons and units
- Improve children's scientific skills
- Develop technological applications
- Locate and use a variety of resources to teach science
- Arrange and manage learning centers, microcomputer centers, and projects
- Assess science teaching

Each chapter focuses on an overall concept such as learning, assessment, or technology. To help summarize and extend the content, each chapter includes a summary, reflection, and additional readings. In addition, samples of the National Research Council's *National Science Education Standards* are cited throughout the text when applicable.

Supplements

- **CD-ROM**
  Containing classroom footage, this free supplement allows users to view, examine, and manipulate clips of elementary science classroom teaching. The CD is ideal for reflection and developing a deep, lasting understanding of text content.

- **Companion Website**
  A truly text-integrated supplement at **www.prenhall.com/peters** will provide users with access to research, meaningful activities, self-assessments, useful web links, chat areas, and a threaded message board. For the professor, the Syllabus Manager allows online creation and management of course syllabi.
- **Instructor's Manual**
  This useful tool provides additional support for instructors, test questions, and online integration.
- **NSE Standards Sampler**
  This document works in tandem with the text to help prospective teachers learn, fully understand, and apply the National Science Education Standards.

Acknowledgments

I wish to thank the many people who helped with this edition of *How to Teach Elementary School Science*. I especially wish to thank editors Linda Montgomery and Hope Madden of Merrill/Prentice Hall for their insight, encouragement, continued assistance, and constructive comments. I also want to thank those who reviewed the draft manuscripts and provided suggestions for the fourth edition. These include Kristin Devlin, Maro Foster, Tina Howard, Angela Kriner, Robin Loukota, Holly Nelson, and Misty Rawls, students at the

University of West Florida, who reviewed draft manuscripts and provided suggestions for clarifying concepts and improving the text for their colleagues, as well as my students at Mercyhurst College (see photo) who assisted with finalizing the content.

This edition of *How to Teach Elementary School Science* includes many vignettes. I extend my sincere thanks to Norman Lederman, Oregon State University; Ken Tobin, University of Pennsylvania; Jerry Mayernik, Northway Elementary School, North Hills School District, Pennsylvania; George O'Brien, Florida International University and Angela Alexander, Pine Villa Montessori School, Dade County (Florida) School District; Christine Peters, Harborcreek School District, Pennsylvania; Kata McCarville, South Dakota School of Mines and Technology; Pam Northrup and Charlotte Boling, the University of West Florida; and Sue Dale Tunnicliffe, International Council of Associations for Science Education Primary Projects and Homerton College, for sharing their experiences with us and reviewing chapters.

I would also like to acknowledge the external reviewers of this text: Andrea M. Guillaume, California State University–Fullerton; Eileen S. Kelble, The University of Tulsa; William C. Kyle, Jr., University of Missouri–St. Louis; Scott P. Lewis, Florida International University; Michael Meloth, The University of Colorado–Boulder; Brian Murfin, New York University; Michael Odell, University of Idaho; and John Shimkanin, California University of Pennsylvania.

Most important, I would like to show my heartfelt appreciation to my wife, Darlene, and to my children, Joe and Brenda, for their patience and guidance during the revision.

Joseph M. Peters

Discover the Companion Website Accompanying This Book

The Prentice Hall Companion Website: A Virtual Learning Environment

Technology is a constantly growing and changing aspect of our field that is creating a need for content and resources. To address this emerging need, Prentice Hall has developed an online learning environment for students and professors alike—Companion Websites—to support our textbooks.

In creating a Companion Website, our goal is to build on and enhance what the textbook already offers. For this reason, the content for each user-friendly website is organized by chapter and provides the professor and student with a variety of meaningful resources.

For the Professor

Every Companion Website integrates **Syllabus Manager™**, an online syllabus creation and management utility.

- **Syllabus Manager™** provides you, the instructor, with an easy, step-by-step process to create and revise syllabi, with direct links into the Companion Website and other online content without having to learn HTML.
- Students may log on to your syllabus during any study session. All they need to know is the web address for the Companion Website and the password you've assigned to your syllabus.
- After you have created a syllabus using **Syllabus Manager™**, students may enter the syllabus for their course section from any point in the Companion Website.
- Clicking on a date, the student is shown the list of activities for the assignment. The activities for each assignment are linked directly to actual content, saving time for students.
- Adding assignments consists of clicking on the desired due date, then filling in the details of the assignment—name of the assignment, instructions, and whether or not it is a one-time or repeating assignment.
- In addition, links to other activities can be created easily. If the activity is online, a URL can be entered in the space provided, and it will be linked automatically in the final syllabus.
- Your completed syllabus is hosted on our servers, allowing convenient updates from any computer on the Internet. Changes you make to your syllabus are immediately available to your students at their next logon.

Common Companion Website features for students include:

For the Student

- **Chapter Objectives**—outline key concepts from the text
- **Interactive Self-quizzes**—complete with hints and automatic grading that provide immediate feedback for students

  After students submit their answers for the interactive self-quizzes, the Companion Website **Results Reporter** computes a percentage grade, provides a graphic representation of how many questions were answered correctly and incorrectly, and gives a question-by-question analysis of the quiz. Students are given the option to send their quiz to up to four email addresses (professor, teaching assistant, study partner, etc.).

- **Web Destinations**—links to www sites that relate to chapter content
- **Message Board**—serves as a virtual bulletin board to post—or respond to—questions or comments to/from a national audience
- **Chat**—real-time chat with anyone who is using the text anywhere in the country—ideal for discussion and study groups, class projects, etc.

To take advantage of the many available resources, please visit the text's Companion Website at

www.prenhall.com/peters

Brief Contents

CHAPTER 1
Science Inquiry and the Nature of Science 3

CHAPTER 2
Constructing Science Experiences 31

CHAPTER 3
Planning for Inquiry 49

CHAPTER 4
Developing Inquiry Skills 85

CHAPTER 5
Assessment 115

CHAPTER 6
Science Experiences for All Students 143

CHAPTER 7
Constructing Technological Understandings 167

CHAPTER 8
Science Learning Opportunities 195

APPENDICES AP-1

INDEX IN-1

Contents

CHAPTER 1
Science Inquiry and the Nature of Science 3

Vignette 1-1: The Nature of Science 3
The Nature of Science 5
Grade 3 Examples • Comparing Classrooms • Grade 5 Examples • Classroom Comparisons • Questions as an Invitation to Learn
Vignette 1-2: How Can You Teach the Nature of Science? 10
Scientific Concepts and Generalizations 12
Generalizations • Science Concepts • Parsimony • The Spiral Approach
Science Process and the Process Skills 17
Evidence • Science Processes and Objectivity • The Importance of Working with Data • The Interactive Nature of Process, Knowledge, and the Nature of Science
Teaching Children 21
Guiding Documents for Science Education • Societal Considerations
Teacher as Researcher 25
Metaphors

Summary • Reflection • References • Suggested Readings

CHAPTER 2
Constructing Science Experiences 31

Vignette 2-1: Children's Learning 31
Paradigms 32
Understanding Paradigms • Paradigms of Science Education • Children's Learning and Your Classroom
Constructivism 34
A General Constructivist Approach to Teaching • Piaget and Constructivism • Vygotsky and Social Constructivism • A Constructivist Model • The Constructivist Learning Model

Summary • Reflection • References • Suggested Readings

CHAPTER 3
Planning for Inquiry 49

Vignette 3-1: Open-Ended Divergent Thinking Unit 49
National Standards and Planning 50
Planning for Inquiry 52
Teacher-Directed Example • Learner-Directed Example • Closed and Open Problems
Closed- and Open-Ended Activities 53
Closed-Ended Activities • Open-Ended Activities
Learning with an Integrated Approach 64
Planning Integrated Lessons with Children's Literature
Planning Units 72
Determining Generalizations • Finding Activities • Determining Bridges or Introductions
A Sample Unit 74

Summary • Reflection • References • Suggested Readings

CHAPTER 4
Developing Inquiry Skills 85

Vignette 4-1: Scientific Skill Development 85
Using the Learning Cycle 89
Exploration Phase • Concept Introduction or Invention Phase • Concept Application Phase
Observing 93
Classifying 95

A Primary-Level Example • Middle- and Upper-Level Examples
Measuring 96
Concrete Referents and Improvised Tools • Measurement and the Metric System
Communicating 98
Defining Operationally • Recording Activities
Inferring 101
Inferring as Explaining
Predicting 103
Experimenting 103
Hypothesizing • Controlling Variables
Scientific Attitudes 108
Curiosity • Inventiveness • Critical Thinking • Persistence • Uncertainty • Developing Attitudes

Summary • Reflection • References • Suggested Readings

CHAPTER 5
Assessment 115

Vignette 5-1: Portfolio Assessment 115
Assessment Today 117
Assessment of Science Learning • Changing Emphasis
Authentic Assessment 121
Characteristics of Good Assessment
Types of Authentic Assessment 123
Essay Items • Performance-Based Assessment • Project-Based Science • Peer or Individual Assessments • Interviews • Journals • Portfolios • Concept Maps • Teacher Observations • Open-Ended Questions
Assessing Attitudes 138
Attitudes and Stereotypes Related to Scientists

Summary • Reflection • References • Suggested Readings

CHAPTER 6
Science Experiences for All Students 143

Vignette 6-1: Careers for Women in Science 143
Mandy's Science Fair 145
Historical Perspective 146
Science Learning Centers 146
Deciding the Purpose of a Learning Center • Developing Activity Cards and Record Sheets • Materials • Record Keeping and Evaluation • Arranging the Physical Setup • Managing the Science Learning Center • Live Animal Centers
Science Projects 153
Using Investigations and Activities for Projects • Curriculum Projects
Science Fairs 154
General Guidelines for Science Fairs • Invention Conventions
Teaching Students with Special Needs 156
Inclusive Classrooms • Assisting Students with Disabilities • Resources for Science Teaching • Working with Limited English Proficiency Students • Working with Gifted Students

Summary • Reflection • References • Suggested Readings

CHAPTER 7
Constructing Technological Understandings 167

Vignette 7-1: Where the Wildflowers Are 167
Educational Technology and Elementary Science 169
The Uses of Computers • Types of Software • Research Tools • Software Evaluation • Computer Accessories • Microcomputer Advantages, Disadvantages, and Resources • Software Sources and Reviews • Other Technological Devices
Science Technology Society 179
STS in the Classroom • Benchmarks, Standards, and Technology • Students and Technology
Technology Education and Elementary Science 181
Vignette 7-2: Experiencing Technology Education for the First Time: The Early Elementary Years 181
Energy Technology • Materials Technology • Manufacturing Technology • Communication Technology • Bio-Related Technology • Construction Technology • Transportation Technology • Technology and Career Awareness • Gender Issues and Technology • Technology and the Curriculum

Summary • Reflection • References • Suggested Readings

CHAPTER 8
Science Learning Opportunities 195

Vignette 8-1: Using the Zoo as a Science Education Resource 195
Mrs. Blackwelder's Class Trip 198
Science Learning Opportunities in Support of the Formal Curriculum
Science Learning Resources 202
Museums and Science Centers • Zoos • Horticultural Resources • Industrial-Based Resources • Media Providers • Other Resources
Individual Partners in Education 208
Scientists as Professional Development Partners • Parents as Partners • Family Science Festivals

Summary • Reflection • References • Suggested Readings

APPENDICES

A: Professional Bibliography AP-1

B: Science Curriculum Projects AP-4

C: Commercial Science Suppliers AP-7

D: Environments and Nutrition for Classroom Animals AP-8

E: Summary of Children's Thinking AP-9

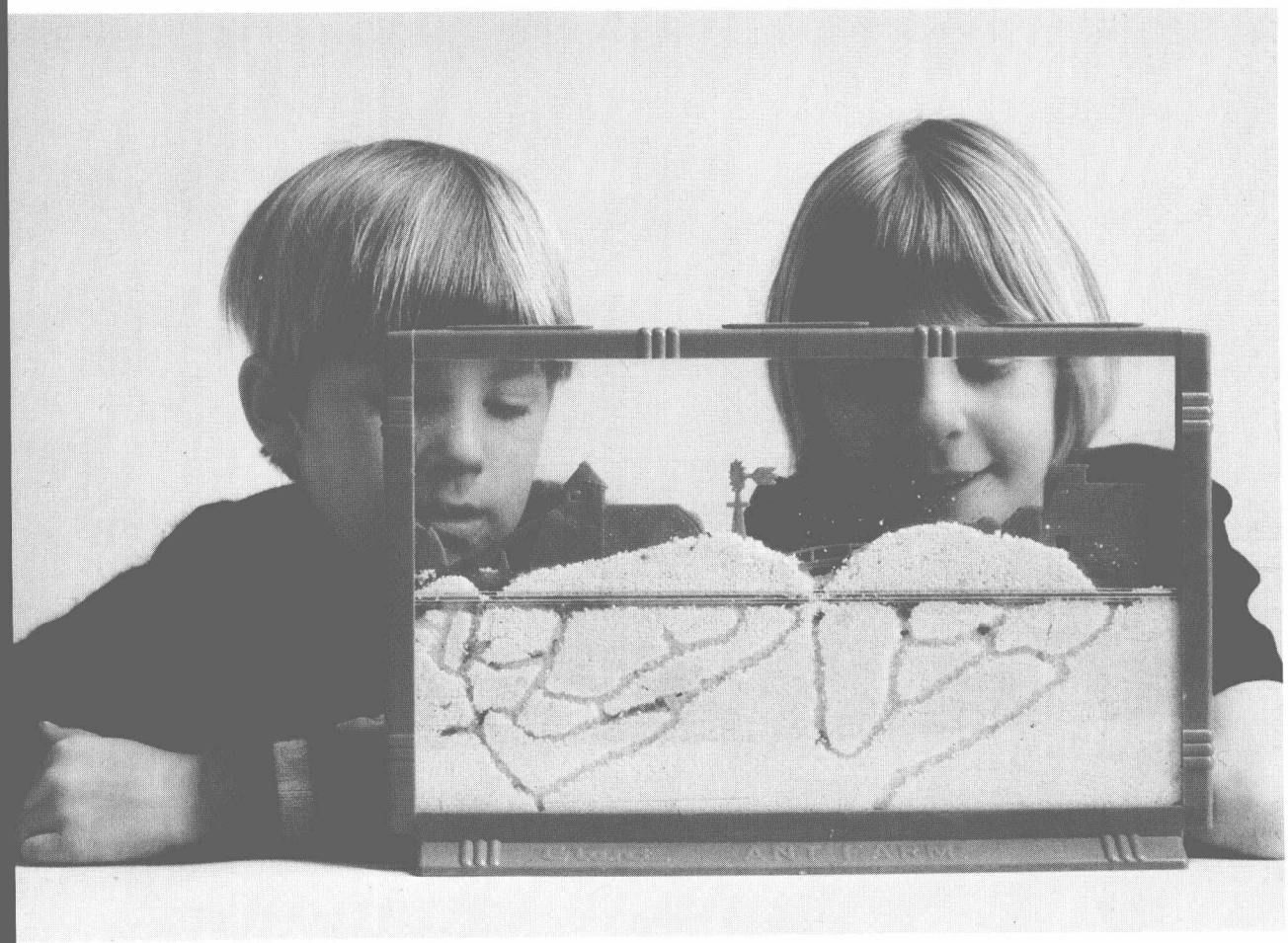
F: State Education Agencies AP-10

INDEX IN-1

NOTE: Every effort has been made to provide accurate and current Internet information in this book. However, the Internet and information posted on it are constantly changing, so it is inevitable that some of the Internet addresses listed in this textbook will change.

How to Teach Elementary School Science

Chapter 1



Science Inquiry and the Nature of Science

VIGNETTE 1-1

The Nature of Science

Dr. Norman Lederman
Oregon State University

Shedding Some Light on the Situation

The year is 1971, and Peter is a typically self-conscious high school sophomore. Like several of his friends, Peter has a slight acne problem. After trying several creams and ointments available at the local drugstore, he convinces his parents that the problem requires the help of the family physician. The physician tells Peter and his parents that the cause of his problem is an abundance of oil production by the glands on his face and that this extra oil provides a good nutritional source for common bacteria. She also tells Peter that eating less chocolate, among other things, might solve the problem but that there is a more reliable approach. Naturally, Peter and his parents are anxious to listen further. The physician recommends that Peter's parents purchase a sunlamp. The U.V. rays emitted by the sunlamp do an excellent job of "drying" the skin and eliminating acne problems. In fact, the physician adds, sunlamps are generally good for most people's skin regardless of whether they have an acne problem. Peter would only have to use the sunlamp about 10 minutes per day and, in addition to relieving his acne problems, he can have a desirable tanned look year-round. So, Peter, with his parents' permission, did what thousands of Americans did in the 1970s.

Thirty years later, the medical profession has recognized the possible carcinogenic effects of ultraviolet radiation. Acne patients are no longer advised to use sunlamp therapy. Indeed, the current advice regarding U.V. rays is to avoid them as much as possible. Consequently, the availability of sunscreen lotions and sunglasses designed to protect both the skin and the eyes from harmful light rays has increased significantly. The physician's advice to Peter and his parents in the 2000s would be much different from what it was in 1971.

How does the general public react to this "change of heart" by the scientific community? Although we have seen a proliferation of ointments and creams designed to block the harmful rays of the sun, tanning is as popular as ever in the United States and, indeed, around the world. A significant number of individuals have decided to ignore the advice of the scientific community. It is not uncommon to hear people say, "Why can't scientists make up their minds? One day something is good for you, and next day you hear that it causes cancer. It seems that everything causes cancer. I'm not going to do anything different until they decide once and for all."

The case of U.V. rays is not unique. "Flip-flops" in the opinions of scientists and physicians have occurred with respect to aspirin, alcohol, cold fusion, and Vitamin C. Indeed, such changes have become the object of jokes.

What does this have to do with teaching elementary-level students about the nature of science? These flip-flops we so often see are really not weaknesses of science. They are not reasons for the general public to disregard scientific knowledge or to lose faith in the scientific way of thinking. These flip-flops constitute one of the most important strengths of science—in fact, they *are* science. That is, scientific knowledge is self-correcting on the basis of new empirical evidence or new ways of interpreting data. The knowledge, though tentative, is based on volumes of data and should not be disregarded. Disregarding scientific knowledge severely limits the quality of decisions that we each make about our lives.

What is the nature of science? There are as many answers to this question as there are books; however, at the level of generality that will be useful to you as an elementary teacher there is a strong consensus. Strictly speaking, *science* can be defined as a body of knowledge, a process, and a way of knowing or constructing reality. *The nature of science* refers to those characteristics of scientific knowledge that derive directly from how the knowledge is developed. Of importance to you as an elementary science teacher are the following characteristics:

- There is no single set or sequence of steps in a scientific investigation (there is no such thing as the scientific method).
- Scientific knowledge (both theories and laws) is subject to change (all scientific knowledge is tentative).
- Scientific knowledge must be at least partially supported by empirical evidence (scientific knowledge must involve the collection of data, be consistent with what we "know" about the world, and be testable).
- Scientific knowledge is partially the product of the creative imagination of the scientist (all scientific knowledge combines both empirical evidence and the creative interpretation of data by scientists).
- Given the importance of scientists' individual creativity, scientific knowledge is necessarily subjective to some degree (scientific knowledge is not totally objective as is commonly believed).
- Scientific knowledge is a product of both observation and inference.

By carefully addressing these characteristics of scientific knowledge and by keeping in mind the developmental level of your students, you can help your students develop understandings that will help them in making decisions for the rest of their lives. In particular, your students will begin to develop a more balanced view of the "truth" of scientific knowledge. They will take "the truth" of science with an informed "grain of salt." This means your students will heed the notion that the sun's rays can cause cancer, and it also means they will not disregard all future knowledge about the effects of the sun's rays if the scientific community alters its current position.