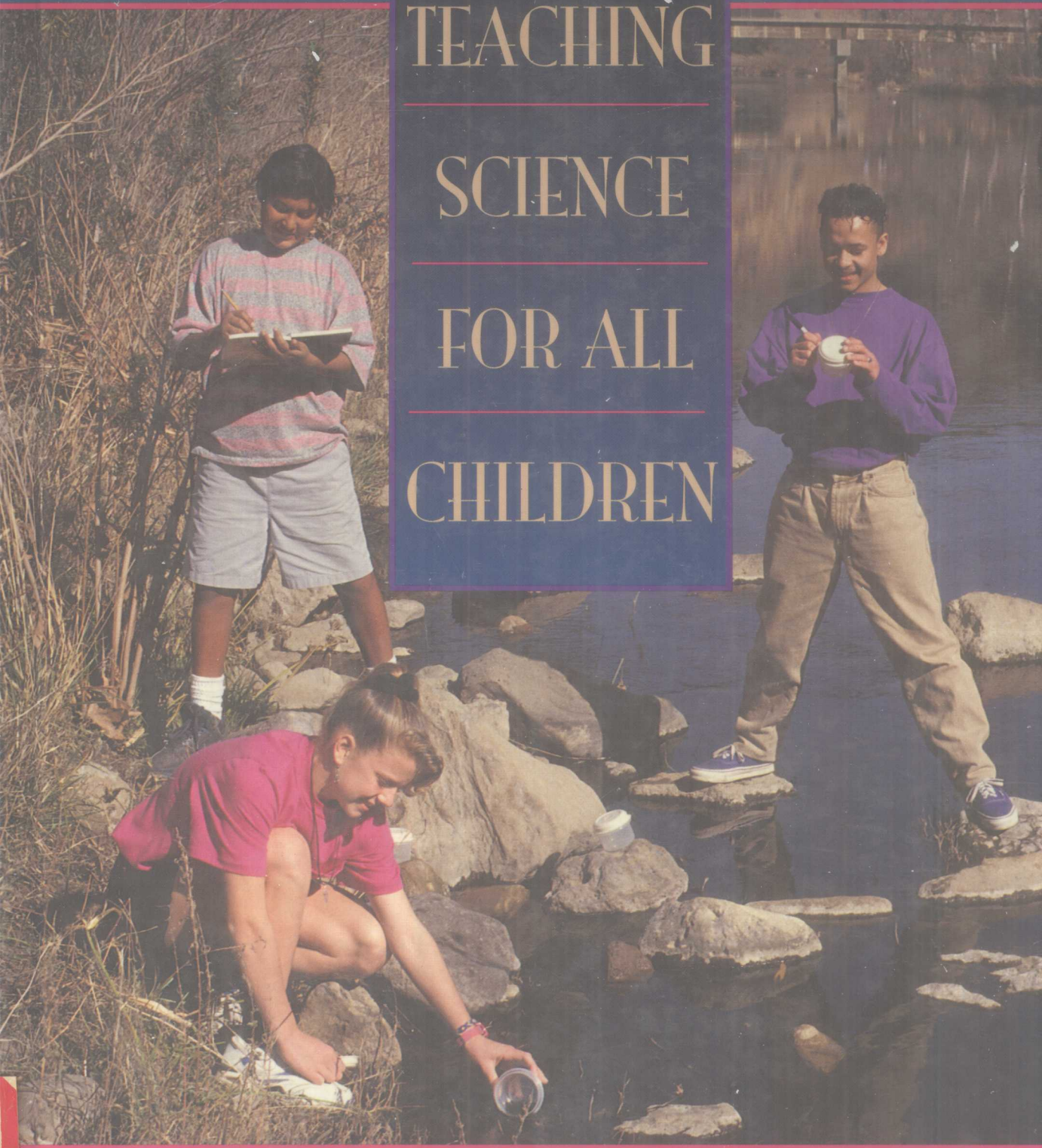
SECOND EDITION

TEACHING SCIENCE FOR ALL CHILDREN



Ralph Martin · Colleen Sexton · Kay Wagner · Jack Gerlovich

Teaching Science for All Children

Second Edition

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with

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DEDICATIONS

Experience and time tend to heighten appreciation for the support, advice, and guidance offered to a developing youngster by benevolent adults. Three people have been most significant in my life and I choose to dedicate my part of this edition to them. Out of respect, Raymond Russell will always remain "Mr. Russell" to me. He was more than just a teacher and coach, and he made the first discovery. I am just now rediscovering his lessons. John Schoby, businessman, would never believe all that he taught me about fairness, compassion, forgiveness, consistency, tenacity, and the fruits of hard labor. Dr. Mary Jo Henning made the later discovery. Were it not for her patience, wisdom, and encouragement, I would not have been able to identify new opportunities, nor would I have dared to experiment with new possibilities. I am grateful to have walked in their shadows.

r.m.

To my former teachers who exemplified effective teaching and inspired me to follow in their footsteps.

c.s.

To my mentor and friend. Ditto.

k.w.

To the Elementary Science Methods students at Drake University who have been, and continue to be, inspirations for my science activity ideas, as well as enthusiastic supporters of hands-on, and often electronically delivered, quality science teaching.

j.g.

Preface

Learners may believe what they see, but they actually understand what they do. This second edition of *Teaching Science for All Children* extends our belief beyond the successful features of the original textbook. Understanding is easy to describe in theoretical terms but difficult to achieve with the limits and daily pressures of the classroom. The popular concept-turned-slogan of "hands-on learning" is often supported by teachers but misunderstood or misused. It is important that the children's hands stimulate their senses but perhaps more important that children's minds be strongly connected to what their hands do. Hands-on, minds-on learning can be effective, but only if both occur. This edition helps users learn how to ensure that what children's senses "see" helps them create understanding from what they do. This book expands our original constructivist approach to help you to help students make important learning connections by stimulating and guiding their thinking.

Our mission as science teachers is to find effective ways to help learners construct their own understanding by connecting their many ideas into a fabric of concepts, attitudes, and skills that carries meaning for them personally and academically. Additional goals of this mission are to fulfill the National Science Education Standards (NSES). This edition has been rewritten to apply those content standards in many ways in order to stimulate an awareness in learners of the history and nature of science, to develop skills in using science inquiry processes, and to bring about an understanding of the complex interrelationships among science, technology, and society.

The philosophy that guides our book is one of promoting the concept of *whole science* by making certain that the ideas, skills, and attitudes of science all are included in the experiences that teachers offer learners. Whole science is based on the constructivist belief that knowledge exists only in the minds of learners and that they must create those understandings from their own experiences. This approach was developed in the preservice teachers' courses at our universities several years ago, and the methods were refined and expanded with recent funding from the National Science Foundation during the Lead Teacher Project at Ohio University. The project involved dozens of practicing elementary, middle school, and special education teachers who taught science. The lead teachers tested in their own classrooms and helped to improve the ideas and activities that are included in this book. As leaders in science education reform, they shared these same ideas and methods with hundreds of other teachers. All of the ideas, methods, and activities have been tested extensively; they can and do work if you are willing to accept as evidence significant gains in pupil science achievement, skills, and attitudes.

We have constructed our book to help you connect the important parts of science, first by helping you to understand the holistic nature of science teaching and later by helping you to develop your own impression about how learners construct their understanding. The science goals, planning techniques, and teaching approaches provided in our book support this conception of constructivism. Dorothy Gabel, editor of the *Handbook of Research on Science Teaching and Learning* (Macmillan, 1994), recently identified the most promising and effective research-based teaching strategies and practices for science. Our textbook has incorporated those strategies and practices into its chapters and science lessons. For example, in this edition you learn how to use *wait-time* and the strategies of a *learning cycle* and *cooperative learning*. *Analogies* are used within chapters to assist

conceptual understanding, and the tool of *concept mapping* is illustrated and used as a lesson design, teaching, and assessment tool. Teaching for *conceptual understanding* is emphasized throughout, and *problem solving* is a common technique emphasized in the assessment tools for our science lessons. *Science-technology-society* is included in each lesson, and the technique of using *discrepant events* is featured as a special teaching method. *Real-life situations* and uses are emphasized where they logically fit within lessons.

Each chapter begins with a *scenario,* a story that sets a visual context for the chapter's message. The scenarios, all factual, help to create a vicarious experience through a short story related to the chapter. This experience should give you an advanced *organizer* (a mental framework) for understanding parts of the chapter that may be new or difficult to you. We hope these features will help you to construct your own understanding of the material in our book.

Within each chapter we have added visual aids—figures, tables, exhibits, and photographs—to reinforce the ideas presented. Sometimes we include relevant exercises that you might want to try. The feature *What Research Says* supplements the chapters with a brief authoritative report taken from the recent research. Another feature we have added is *Teachers on Science Teaching.* These supplements are written by teachers to give an applied view on each chapter's topics, with classroom uses described by some of our country's finest teachers. Of course, we close each chapter with a customary summary. *Discussion questions* and ideas for class *projects* are included; many of these are field based to complement any early field experience or internship that instructors may prefer. *Additional readings* contain annotations for further study on the important topics of each chapter.

Experiment with how you use this book—we have written each chapter to stand alone, though we have organized this book in a linear way. In Part I we provide a foundation for science, learning, and literacy in four chapters. Then, in Part II, Chapters 5 through 8, we focus on preparing elementary and middle school lessons. In these chapters we explore constructivist lesson planning and assessment, ways to create and maintain a safe science classroom, the characteristics of effective science materials and programs, and ways to use a variety of resources (including technology) for science teaching. Safe science is featured in Chapter 6, but also integrated throughout our textbook, and included in each lesson.

Part III, Chapters 9 through 11, is devoted to a variety of teaching methods and teacher skills. These chapters include learning cycle and inquiry teaching methods, effective questioning techniques, and effective uses of traditional strategies and materials such as demonstrations and science textbooks.

Our book contains more than *60 complete science lessons,* found in Part IV, and organized among the disciplines identified by the NSES: life, physical, and earth and space. Each lesson is correlated with the grade levels and concepts urged by the NSES framework. Our lessons contain more than *150 different activities* that are constructed in a very powerful way—a way to encourage the highest level of student hands-on, minds-on activity, and a way to stimulate high levels of concept formation. Our plans are consistent with how children construct their own understanding and with constructivist teaching practices. We use the 4-E learning cycle of *Exploration, Explanation, Expansion, and Evaluation.* The Exploration phase prepares students for science as an inquiry process, while the Explanation phase stimulates learners to construct conceptual understanding. This fundamental understanding is Expanded by addressing the new dimensions of the NSES content standards, such as the history and nature of science, the interrelationships of science and technology, and science in personal and social perspectives. Evaluation embeds assessment in the instruction throughout the cycle and uses performance-based techniques such as pictorial assessment, reflective questioning, and hands-on assessment. The lessons have been classroom tested by our own undergraduate and graduate students and by the lead teachers (practicing teachers) previously mentioned.

All chapters and activities are supported by several unique appendixes. These are written for preservice and inservice teachers who wish to locate effective science resources or entire science curriculum projects, and/or to become involved in networks or alliances of science teachers through state or federal agencies.

Of course, at all times we encourage you to try our book's ideas your own way. If you do, you will be learning about teaching science as we advocate for the students you will teach: by constructing *your own*

understanding. So you see we hope you will believe the ideas and information that you see in this book; more important, we hope that you will try each idea and learn to understand the complexity and rewards of effective science teaching from what you do.

ACKNOWLEDGMENTS

No book is ever written alone. In addition to our author team, many important persons supported the project and turned the dreams and ideas into a reality. Indeed it is an understatement to say we are grateful to those many talented persons.

We are indebted to Nancy Forsyth, Vice President and Editor-in-Chief, Education, whose vision shaped the project into a comprehensive product, and her able assistant, Kate Wagstaffe, who ensured first-class treatment at every stage of the publishing process. Deborah Brown, as Production Administrator, steered us through the complexity of publishing. Anne Rebecca Starr functioned admirably and persistently as Production Editor. Beverly Miller earned the moniker of "Hawkeye" as copyeditor. Glenna Collet and Laurel Aiello delivered the nice touches that readers expect in design and illustration. Lois Oster created an extremely useful and comprehensive index.

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About the Authors

Ralph Martin is Professor of Science Education and Director of the School of Curriculum and Instruction for Ohio University's College of Education. Throughout his years of teaching, he has received more than $1 million in grants for work in science and mathematics. He has served on Ohio commissions in science and vocational education to improve science education. He is an active member of the National Science Teachers Association and the School Science and Mathematics Association, as well as his state science organization, Science Education Council of Ohio (SECO), where he served four terms on the board of directors. Dr. Martin has earned the SECO Service Award in Science Education, Ohio's Outstanding Educator award for Project Learning Tree, and the Project Learning Tree national award. The second edition of *Teaching Science for All Children* is Dr. Martin's fifth book, including *Introduction to Teaching* (1988) with co-authors George Wood and Edward Stevens, also published by Allyn and Bacon.

Colleen Sexton has worked in preparing science teachers and promoting science education in a number of capacities. Dr. Sexton is involved in the Appalachian Distance Learning Project—a project which fiber optically links three third-grade classrooms, separated by over 150 miles. She has worked extensively with classroom teachers in helping them plan science lessons which take advantage of available technology.

For the past three years Dr. Sexton has worked with 43 elementary science teachers from 13 different school districts in southeast Ohio on an NSF-funded Lead Teacher Project. Dr. Sexton is also involved in a research project which is concerned with equity throughout Ohio's school districts.

Kay Wagner has over 26 years of experience in the education and information transfer field, including 18 years of public school teaching, 6 years as Ohio's state science education supervisor, and 12 years in project management related to public information and education programs, public information product development, resource curriculum production, public outreach program planning, and teacher and student activities. While employed as state science supervisor in Ohio, Ms. Wagner devised and implemented a statewide telecommunications network linking all school districts, vocational schools, and colleges and universities that provided teacher training. She served as the director of the Alliance Programs for the Triangle Coalition for Science and Technology Education, as President of the Science Education Council of Ohio, and on the Board of Directors for the National Science Teachers Association.

She currently is employed by Science Applications International Corporation (SAIC) as director of the U.S. Department of Energy's Center for Environmental Management Information, a nationwide information center for the Department's Environmental Management program.

Jack Gerlovich is Associate Professor of Science Education at Drake University. He was the state science consultant for the Iowa Department of Education for 11 years. He is also the president and founder of JaKel, Inc., a science education safety company. His 15 years of science teaching experience include elementary, junior high, high school, and college levels.

Dr. Gerlovich is a fellow at the American Association for the Advancement of Science and the Iowa Academy of Science. He is a member of the National Science Teachers Association (Board of Directors 1985–87), the Council of State Science Supervisors (National President 1985–87), and the National Academy of Applied Sciences (Board of Directors).

Dr. Gerlovich, a nationally renowned safety expert, has authored and coauthored 30 professional journal articles, eight state science publications, and developed books, software, and video products on the subject.

CHAPTER OUTLINE