Preface

A NEED FOR CHANGE

Although a challenging, exciting, and relevant science education for all American students is a national goal, quality science programs are missing in many classrooms. Something is very wrong when Americans consult tarot cards and astrologers, believe far-fetched tabloid stories of aliens abducting earthlings, and do not understand how the Earth revolves around the Sun (Hampton & Gallegos, 1994). Sadly, votes cast by these same Americans affect major environmental policies and technological decisions. With society becoming increasingly more dependent on scientific and technological skills, Americans lacking these skills will be severely handicapped for living and working in the twenty-first century.

Science is a creative pursuit that has changed the way teachers view the universe and inspired a need to explore that continually alters the process and quality of human life. Science is an ever-changing process, not simply a collection of facts. Science allows us to experience the excitement and richness of the natural world. In *Science for All Americans,* F. James Rutherford and Andrew Ahlgren (1989) discussed the need for a standard set of recommendations on what understandings and ways of thinking are essential for all citizens in a world shaped by science and technology:

> Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education—meaning education in science, mathematics, and technology—should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. America's future—its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities—depends more than ever on the character and quality of the education that the nation provides for all of its children. (Rutherford & Ahlgren, 1989, p. v)

Today's children will rely on science and technology more than people do today for jobs, communication, food, health care, energy, and the protection of the environment. The future of the world will someday be in the hands of the children.

METAPHORS FOR REFORM IN SCIENCE EDUCATION

Students need constant and rigorous exposure to new ideas and methods of thinking as society continues to move toward a new educational paradigm. Many teaching, learning, and assessing strategies and curriculum frameworks are still rooted in the seventeenth century, the Newtonian Age of machines and precision. Newtonian strategies in schools may need to be reassessed, and perhaps replaced, with more modern strategies, reflecting an infinitely more complicated and nonlinear worldview. This is not to imply the elimination of Newton's teachings from science curricula. On the contrary, Newtonian physics still provides the groundwork for much of modern science, and it will always remain central to the scientific knowledge base. While science educators continue to embrace Newton's scientific contributions, the research in this book suggests that educators need to move beyond the Newtonian paradigm to discover a new paradigm more in keeping with the twenty-first century.

With reform in science education a major goal for educators, *Brain-Compatible Science* is intended to offer a glimpse of where that reform could be headed. The application of chaos theory and new science concepts to construct metaphors of change in science education just might motivate teachers to discover new ways of thinking about teaching, learning, assessing, and designing science curriculum. Chaos theory with its incredible metaphors of order emerging out of chaos brings new vigor into science education, creating a new way of viewing old problems. Looking deeply into the unpredictable randomness of these contemporary theories, science educators may find new patterns, meaning, and direction to revitalize their teaching. A redirected vision for the future, a holistic new framework for brain-compatible science, and a more productive way of viewing the earth and the universe could emerge.

PUTTING BRAIN-BASED LEARNING TO WORK IN THE SCIENCE CLASSROOM

Brain-Compatible Science defines and summarizes essential principles of chaos and new science theory, using them to organize a review of the most recent reform in science education and brain-based learning research. Six chaos and four new science principles are explored to discover their implications for teaching, learning, assessing, and designing curriculum for brain-compatible science education. The book is most appropriate for teachers of grades 3–8, although many of the lesson plans and assessment ideas can be easily adapted for younger or older students.

Also included in the book are numerous lesson plans, science labs, reproducible student handouts, a lesson plan guide, assessment rubrics, checklists, lab reports, and even cooperative group roles for the science classroom. Everything that a science teacher needs to be effective and current can be found within the pages of this book. Best practices in science education are discussed, with topics including:

- Brain-based learning theory
- Gender equity
- Cultural diversity and changing classroom demographics
- Classroom management

- Multiple intelligences theory
- Constructivist learning
- Science inquiry
- Higher-level thinking strategies
- Alternative forms of assessment
- Curriculum integration
- Cooperative learning
- Community in learning
- Guiding principles and values

The Introduction provides an overview of the old and the new science, which creates the impetus for reform in science education. The Introduction also introduces chaos theory and the new sciences, the major reform initiatives in science education, and brain-based learning theory. Following the Introduction, the book is divided into two major sections, Chaos Theory and New Science Principles, and the third section summarizes the implications of chaos theory and new science principles for teaching, learning, assessing, and designing curriculum. At the back of the book is a glossary to define the chaos theory and new science terminology.

Although much of the current thinking in chaos theory and the new sciences, as well as the latest knowledge of brain-based learning, parallels the recurrent themes found in the science education reform literature, no scientific evidence and very few studies exist to date to determine if there is a one-to-one correlation between the dynamics at an atomic level and human dynamics. Many of the images and metaphors discussed in *Brain-Compatible Science* are based on complicated, nonlinear equations and scientific principles that are beyond the scope of the research purpose.

Each chapter in the first two sections includes the following:

- Background information to introduce, define, and discuss the chaos or new science principle
- Implications of chaos or new science principle for brain-compatible science featuring best practices in science education
- A detailed science lesson featuring chaos and new science theory
- Additional lessons, assessments, and surprises
- Concept Web, which includes a summary of the implications for science education and additional lesson ideas
- Navigating the Road to Change in Science Education chart comparing three paradigms for science education:
  - Too Much Order: a traditional, conservative view
  - On the Edge: the preferred view fostering creativity, growth, and renewal
  - Too Much Chaos: an unstructured, liberal view

The 10 featured lessons include the following components:

- Grade level appropriateness (grades 3–8, adaptable for others)
- Chaos or New Science Connection providing background
- Curriculum Connection
- Targeted National Science Education Standards
- Objectives
- Materials needed for the activity
- Preactivity discussion to prepare students for the activity

- Procedure providing step-by-step instructions for the teacher
- Closure to appropriately wrap up the lesson
- Questions and extensions to pursue the topic in greater depth
- Technology Connection suggesting possible Web sites to visit

The 10 featured lesson plans, along with other ideas presented in this book, are designed to incite a paradigm shift in science education. The lesson plans are suitable for integration into existing science curricula, and although they contain references to chaos theory and the new sciences, the intent is not to teach chaos theory directly or to imply that chaos theory principles belong in science curricula. Certain elements of the principles may be appropriate, however, and certainly could be offered as enrichment alternatives for interested students, or the principles could simply be viewed metaphorically as a means of motivating educators to embrace changes in their vision of what embodies quality science education.

A PARADIGM SHIFT

The paradigm shift from a textbook-driven program to a process-oriented science curriculum has been a gradual evolution, disquieting for some, energizing for others, and not without the usual frustrations that accompany change. During my years in the science classroom, a growing number of teachers have plunged wholeheartedly into the new science education paradigm. Although I see a significant change overall, many teachers, especially those in elementary classrooms, still prefer the old way.

Too little preparation and collaboration time, difficulties obtaining supplies, lack of confidence, not enough ongoing staff development in science, and the school structure itself hinder many teachers' ability to initiate a more expeditious change. Pulled in many directions, teachers must compact lessons for gifted students; individualize instruction for learning disabled (LD) students; integrate technology into their teaching; and work around gym, art, and music schedules. Add in their regular correcting, planning, grading, disciplining, and conferencing, and today's teachers never have enough time! As teachers continue to learn and evolve together, I hope that new ideas for science teaching, learning, assessing, and designing curriculum will emerge, and that somehow the process will simplify.

Moving into the twenty-first century, the wondrous images of chaos theory may provide science educators with fresh insights and offer a new sense of direction for science education. As we search for contemporary strategies to rejuvenate curriculum and inspire learning, and as we invent new ways of teaching and assessing our children, I believe that we have much to learn from chaos theory principles. The haunting metaphors and computer-generated fractals have already changed the way I think about the world and my role as a science educator. I hope that my insights, serving as a "strange attractor," will inspire others to do the same.