Praise for the First Edition of *The Brain-Targeted Teaching Model* by Mariale M. Hardiman

"This book will encourage many educators to teach 21st century students via 21st century policies and practices that are grounded in the dramatic advances occurring in the cognitive neurosciences."

—Robert Sylwester
Author of *A Child's Brain: The Need for Nurture*
Emeritus Professor of Education
University of Oregon, Eugene, OR

"Teachers will find the content valuable and can implement the Brain-Targeting Teaching® concept very easily."

—Steve Hutton
School Improvement Specialist
Villa Hills, KY

"Mariale Hardiman offers a unique model that teachers can use to assess the extent to which they are considering brain-friendly concepts when they plan their lessons."

—David Sousa
Consultant in Educational Neuroscience
Author of *How the Brain Learns*
Palm Beach, FL

"The emphasis on integrating the arts with content areas is timely and welcome. An additional strength are the examples from 'expert teachers' which show how the model can be implemented while addressing curriculum standards."

—Jacqueline LaRose
Assistant Professor of Education
Eastern Michigan University, Ypsilanti, MI

"This book provides a teacher-friendly model that teachers can use to establish student-friendly classroom environments and effective teaching strategies and activities."

—Darla Mallein
Director of Secondary Social Sciences Education
Emporia State University, Emporia, KS

"The Brain-Targeted Teaching Model for 21st Century Schools *has much to offer all educators. The book contains a wealth of knowledge from cognitive and neuroscience and presents it in a way that is accurate and accessible. Hardiman's work creates a vision of education in which scientific discoveries about thinking and learning are taken full advantage of."*

—Jay N. Giedd
Chief of Brain Imaging Unit
Child Psychiatry Branch, NIMH
Bethesda, MD

"Few educators bring Dr. Hardiman's ability, experience, and scholarliness to the increasingly rich exchange between educators and neuroscientists. She has succinctly synthesized a large body of information into a must-read for educators, researchers, and anyone else interested in how neuroscience and cognitive science can make a difference in the classroom."

—Kenneth S. Kosik, MD
Harriman Professor of Neuroscience
University of California, Santa Barbara, CA

"Hardiman's book provides a practical way for educators to operationalize theoretical principles and teach in a way that can effectively engage students on different and meaningful levels. The research and strategies presented in this book emphasize the very important notion of supporting students' personal, social, and academic development and achievement."

—Fay E. Brown
Director of Child and Adolescent Development
Yale School Development Program
Yale University, New Haven, CT

"One of the central components of Hardiman's remarkable book is creativity—the ability to generate something new. Promoting the development of this unique attribute is critically important for the success of our students, and I applaud Dr. Hardiman for showing that neuroscience can and should inform the process of education."

—Charles J. Limb, MD
Associate Professor
Johns Hopkins University Schools of Medicine and Education
Baltimore, MD

"This book is a tour de force, providing not only a comprehensive understanding of cognitive and neuroscience research, but also a well-constructed model providing teachers with the practical tools they need to integrate it into their classrooms. Dr. Hardiman has become a leading authority in the emerging field of neuroeducation."

—Paula Tallal
Board of Governors Professor of Neuroscience
Rutgers University, Cream Ridge, NJ

"Dr. Hardiman provides clear explanations of what is currently known about the functions of the human brain, along with practical examples of ways to apply these understandings in the classroom. With this book she offers a significant contribution to the field of education."

—Dee Dickinson
Founder
New Horizons for Learning
Seattle, WA

"Dr. Hardiman's Brain-Targeted Teaching® Model is one of the most powerful and research-based methods of achieving greater learning retention—its focus on the arts and creative problem-solving moves teaching from traditional 'drill and kill' methods to one that engages students for the demands of 21st century teaching and learning."

—Linda Casto
Advisory Board
Johns Hopkins University Neuro-Education Initiative
Malibu, CA

"The Brain-Targeted Teaching® Model has informed my teaching in so many ways. I love the model's infusion of the arts as the arts lend themselves to creative expression for all children. There is no question that the Brain-Targeted Teaching® Model enhanced the quality of my teaching."

—Andrea Jackson
5th Grade Teacher
Baltimore, MD

"The Brain-Targeted Teaching® Model provides a framework for teaching that makes sense not only in K–12 but also in higher education settings. I hope to continue spreading the word that higher education coursework can be significantly enhanced by using the tenets of Brain-Targeted Teaching®."

—Vicky M. Krug
Assistant Professor
Pittsburgh, PA

The Brain-Targeted Teaching Model

Second Edition

Dedicated with much love to Walker, Bennett, and Molly. May you always seek the joy of learning in all of life's endeavors and adventures.

To family, friends, colleagues, and students who have embraced making a difference in the lives of others through the generous sharing of your knowledge and wisdom.

The Brain-Targeted Teaching Model

A Framework for Joyful Learning and Leading

Second Edition

Mariale M. Hardiman

Forewords by Tracey Tokuhama-Espinosa and Martha Bridge Denckla

CORWIN
A SAGE Publishing Company

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A Sage Company
2455 Teller Road
Thousand Oaks, California 91320
(800) 233-9936
www.corwin.com

Sage Publications Ltd.
1 Oliver's Yard
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London, EC1Y 1SP
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Sage Publications Asia-Pacific Pte. Ltd.
18 Cross Street #10-10/11/12
China Square Central
Singapore 048423

Vice President and Editorial Director: Monica Eckman
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Typesetter: Hurix Digital
Cover Designer: Gail Buschman
Marketing Manager: Olivia Bartlett

Printed in the United States of America.

LCCN 2024057416

This book is printed on acid-free paper.

25 26 27 28 29 10 9 8 7 6 5 4 3 2 1

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Foreword to the Second Edition

Mariale M. Hardiman has been a leader in the learning sciences for longer than most of her graduate students at Johns Hopkins have been alive. *The Brain-Targeted Teaching Model* (2003) and its 2012 follow-up was one of the primary books in the field directed specifically at teachers and teacher educators. Now, nearly a quarter of a century later and with global evidence from different countries around the world showing the applicability of her six core *brain-targeted* goals, she continues to pave the way for teachers interested in leveraging information from neuroscience into real-live classroom settings. The strength of her work is twofold: She was among the first to challenge the neuromyths of *brain-based* popular press books and to leverage the science of learning, and she was the first to remind us how humans can be so uniquely different, yet all share core needs when it comes to learning. These core elements make up her six brain-targeted goals.

Hardiman's book ensures teachers recognize the basic needs of all students in all classrooms to learn and thrive through

1. a positive emotional climate (target one);
2. a neuroaesthetically pleasing learning environment (target two);
3. a holistic and holonic design approach that places learning goals in context (target three);
4. teaching through individual mastery of skills (target four);
5. a real-world application to stimulate creative thinking (target five); and
6. a non-traditional, multifaceted approach to evaluation through alternative forms of evidence presentation, such as the arts (target six).

While there have been dozens of books that have followed her work, all build off of these fundamental concepts. Each of the six goals could be a book on its own (and many authors have approached teaching in this piecemeal way), while Hardiman shows how weaving these elements together builds a tapestry that better frames the whole of the teaching-learning experience.

Over the past two decades, advances in neuroimaging in real classrooms (e.g., Davidesco et al., 2021), the establishment of how emotions impact cognition (e.g., Gotleib et al., 2022), and measurements of neuroplastic changes based on comparative teaching methodologies (e.g., Tymofiyeva & Gaschler, 2021) have added even more credibility to the role that neuroscience can play in shaping educational practices. This newer evidence only serves to strengthen her original model. Few educators have had the vision to both acknowledge these foundational concepts and then take the time to explain the research behind them in a way that inspires.

In 2006 to 2008, Mariale participated as one of the members of my Delphi expert panel to identify standards in Mind, Brain, and Education science, which others called neuroeducation or educational neuroscience. I will never forget her enthusiastic engagement with the process as she willingly accepted invitation after invitation to help shape the field. Kurt Fischer, also on the Delphi panel, mentored Mariale's work and encouraged her efforts to create the Mind, Brain, and Teaching program at Johns Hopkins, which served as a beacon to many teachers, shining light on science-based, evidence-informed ideas to guide their practices as he and Howard Gardner created the Mind, Brain, and Education program at Harvard. Soon, other programs began around the world, following their lead. Their tireless work to encourage teachers to become learning scientists catalyzed a whole generation of educators into action, myself among them. It is now common to see many of the fundamental ideas Mariale promotes in her book in numerous educational programs around the world and her influence on the work of countless other educators.

Mariale's revision to this second editor is focused; she has been careful not to throw the baby out with the bathwater. Rather than a complete rewrite, she offers important updates and newer citations from relevant research. While others have gone from the *lab to the classroom and back* in their work with teachers, Mariale begins with the wisdom from expert teachers themselves, which is refreshing. The supplemental sections on culturally relevant pedagogies and the acknowledgment of more embodied cognition research to explain the vital partnership of the mind and body are also welcome additions. Finally, the new chapters that expand the vie at different kinds of educators and settings, as well as a review of the research on Brain-Targeted Teaching® in multiple global contexts end the book with two important messages, which are both intuitive, but which also require explicit descriptions. First, we are all more alike than we are different. Second, humans around the world share ideal conditions in which they grow, learn, and thrive best, and these conditions can and should be designed by teachers, starting with you.

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Tymofiyeva, O., & Gaschler, R. (2021). Training-induced neural plasticity in youth: A systematic review of structural and functional MRI studies. *Frontiers in Human Neuroscience*, *14*, 497245.

Foreword to the First Edition

The Brain-Targeted Teaching Model for 21st-Century Schools is a welcome update to the 2003 book that introduced educators to Dr. Hardiman's Brain-Targeted Teaching® Model. Both that book and the new edition share the ambitious goal of providing teachers with valuable knowledge from the neuro- and cognitive sciences in a form that can be readily understood and applied in practice. The strength of Dr. Hardiman's approach is that in addition to carefully describing research findings, she frames those findings in terms of an accompanying pedagogical model that educators can use to interpret, organize, and apply the information they are receiving. From the viewpoint of a researcher and clinician, this is exactly what teachers need—a way to connect the information we provide with the kind of practical expertise that can only be gained in real-life school settings.

Too often, efforts to translate scientific research for use by educators run into serious difficulties. One way to go wrong is to water down the science and describe important ideas only colloquially or metaphorically, with little or no documentation of sources. Broad-brush *research-based* recommendations for practice may be offered, but these usually represent little more than common sense, and the support they garner from scientific research tends to be trivial. Allusions to brain science serve to make existing ideas seem *cutting edge*—as though they hold some great new promise for *fixing* education in one fell swoop.

Despite widespread enthusiasm for the idea of joining together the work of scientists and educators, other frameworks like the Brain-Targeted Teaching® Model have not emerged. Instead, there has unfortunately been only a proliferation of pseudoscientific *brain-based* educational products and workshops, many promoted in the media. Though research scientists are wise to steer well clear of these enterprises, this leaves no one to counter the *neuromyths* or misconceptions teachers are left with. In contrast, Dr. Hardiman is unique in her vigilance to avoid overreaching beyond what can be reasonably concluded from scientific research. This is one of the main reasons why scientific researchers are willing to work with her. Though her background is that of an educator—foremost as a long-time, nationally honored urban school principal—she has forged professional relationships with research scientists at her own institution, Johns Hopkins University, as well as others around the country.

She is determined to make sure that her claims are grounded in rigorous scientific research and are well-referenced. This does not mean, however, that research findings relevant to education must be presented as they would be in a scientific journal, without thorough explanations of vocabulary, basic concepts, or logical implications for practice. When educators have to try on their own to understand research conclusions and *translate* them into educational frames of reference, they become vulnerable to the possibility that much is lost in translation; they may misunderstand or overgeneralize. Teachers (like anyone) may go astray when the work of helping them understand and apply scientific ideas is left undone. Teachers do not work in a vacuum, and their success often depends on collaboration with others whose belief in rigorous, evidence-based practices provides the format for practice. A global commitment to the training of all who provide educational services to students at all levels must include a commitment to this scientific approach to understanding learning, the cognitive processes associated with learning from the earliest grades through higher education, and the use of research to promote innovative, creative, and effective teaching.

Whereas many educational researchers exhibit a strong ideological bent and often try to recruit scientific research to support a predetermined agenda, Dr. Hardiman starts with rigorous research and works in a highly pragmatic way to build a pedagogical framework on the foundations of scientific knowledge. She is able to lean on her experience as a long-time practitioner to consider the needs of teachers and schools. Because Dr. Hardiman understands so well how teachers think, she is able to seek out the scientific information that teachers want to know and deliver that information in a way that makes it accessible and useful.

With all of the advances that have come in the neuro- and cognitive sciences since Dr. Hardiman's 2003 book, it is great to have an updated version of the Brain-Targeted Teaching® Model. Many educators are already familiar and comfortable with her framework; they will finish this book and return to the classroom with great new ideas that are based in up-to-date and sound research. For those who may only now be learning about Dr. Hardiman's work, this book will reveal a pedagogical model that resonates with educators' goals and strategies as well as a plethora of useful information from the brain sciences. The collective hope is that this book serves as a road map toward creating ever-better outcomes for your students and better collaborative professional practices in your school.

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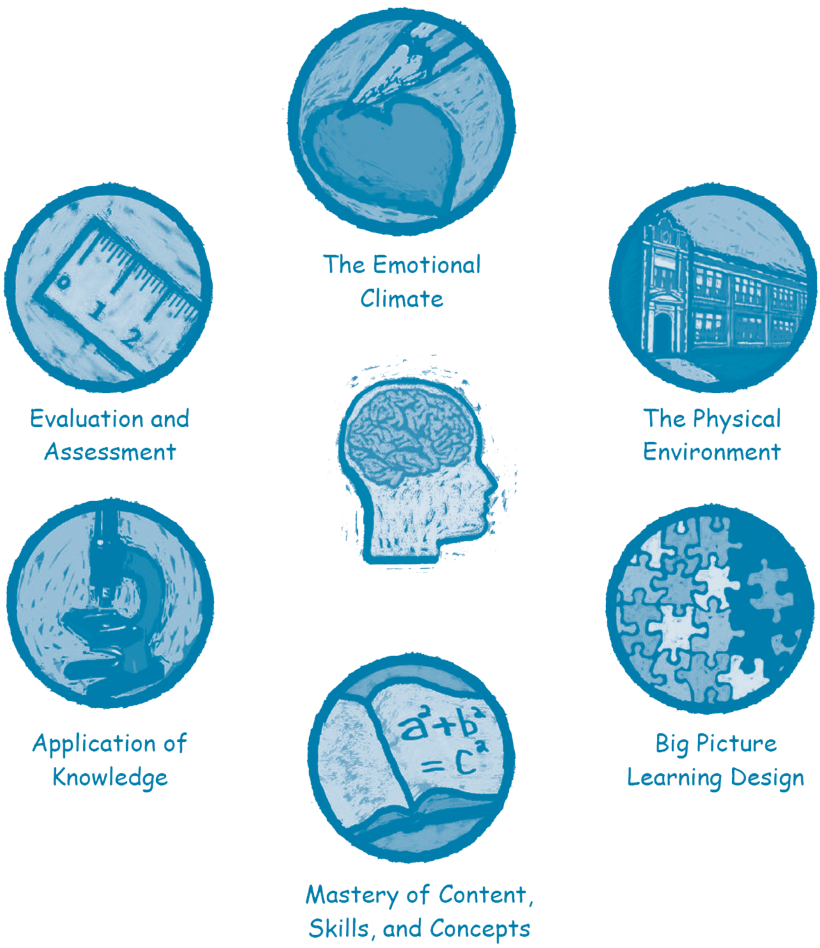
Preface



The Brain-Targeted Teaching Model

I am pleased to present *The Brain-Targeted Teaching Model: A Framework for Joyful Learning and Leading* and offer this book as a new edition of *The Brain-Targeted Teaching Model for 21st-Century Schools*. Since the publication of the first edition in 2012 and my first book in 2003, the field of neuroeducation has continued to evolve, becoming a recognized interdisciplinary approach to education. Research from the learning sciences has produced numerous findings that are increasingly viewed as important to expanding an understanding of how we best acquire and apply knowledge (see Ozernov-Palchik et al., 2024). Like professionals in other emerging *neuro* fields—neurolaw, neuroeconomics, neuroaesthethics, neuroethics—many practitioners seek to not only become familiar with the advancing knowledge of human cognition and learning, but also to understand how this knowledge can inform their work.

Still, research from the scientific community that is *specifically intended* for practitioners must continue and accelerate. Findings from neuro- and cognitive science research in areas such as attention, memory, emotions, creativity, executive function, embodied cognition, sleep, exercise, and more must continue to expand our understanding of cognition and learning. This growing knowledge, however, creates the need for translation of relevant research findings to determine appropriate connections to practical applications within multiple fields (Hardiman et al., 2012).

Who Should Read This Book

This book is intended to serve as a bridge between research and practice by providing any practitioner with a cohesive, usable model of effective instruction informed by education research as well as findings from the learning sciences. The research and instructional strategies presented are designed to be relevant to a wide range of practitioners.

Since the publication of the 2012 edition, I have been amazed at the array of professionals—nationally and internationally—who have used the Brain-Targeted Teaching® (BTT) Model in their work. Some have enrolled in our academic courses at Johns Hopkins University. Others attended professional development sessions, conference presentations, or simply read the book and adopted the model for use in their own context. Many who have used the BTT Model have been educators, from early childhood practitioners to higher education faculty. Others include organizational leaders, corporate trainers, strategic planners, policymakers, athletic coaches, home school practitioners, and parents. Based on their work, feedback, and research, it is a great honor to present this current book on the Brain-Targeted Teaching® Model as a tool to inform teaching, leading, and learning.

For practitioners in any field, it is critical that relevant research on cognition and learning be approached systematically and realistically, rendering a better understanding of the developing child and adult learner, greater precision in instructional techniques, and enhanced educational outcomes.

In my own work as a school principal in an urban school district and now at the university level, I have found that too often practitioners are handed an ever-changing array of initiatives and programs that rapidly come and go. Well-meaning leaders may not understand how this serves only to dilute productivity rather than support it. Practitioners may *wait out* one initiative in hopes that a better one will come along or feel confused as they try to meld a new program with the previous one.

Accordingly, without a cohesive model, practitioners may easily be confused by the plethora of strategies that claim (some appropriately, some not) to be based on research from the learning sciences. Usable knowledge may be confounded with myths that divert time and waste valuable resources.

The Central Purpose of This Book

A Pedagogical Framework—The Brain-Targeted Teaching® Model

The basis of this book is to bring relevant research from the learning sciences to practitioners through a pedagogical framework, the Brain-Targeted Teaching® (BTT) Model (Hardiman, 2003; 2012). The model provides a cohesive structure for interpreting research findings from the learning sciences and applying them to their own practice. The BTT Model is neither a curriculum nor a marketed product. Rather, it is a way to plan effective learning and leading informed by research from the learning sciences and research-based effective instruction. It was designed, in part, from the thinking skills frameworks of Dimensions of Learning (Marzano, 1992), Multiple Intelligences (Gardner, 1983, 1993), and Bloom's Taxonomy (Bloom & Krathwohl, 1956). It aligns with the Universal Design for Learning (Cast, 2011; Rose & Meyer, 2002) with an emphasis on reaching all learners through techniques that honor culturally relevant pedagogy and neurodiversity. At the core of the BTT Model is a focus on activities that tap into creative thinking, problem-solving, and application of content to real-world contexts. Practitioners also have recounted how meaningful integration of the arts into learning activities leads to heightened student engagement and more effective retention of content.

The model presents six important domains, or *brain targets*, of the teaching and learning process. These include the following:

- Brain-Target One—Establishing the emotional climate for learning
- Brain-Target Two—Creating the physical learning environment
- Brain-Target Three—Designing the learning experience for *big-picture* understanding
- Brain-Target Four—Teaching for the mastery of content, skills, and concepts
- Brain-Target Five—Teaching for the extension and creative application of knowledge
- Brain-Target Six—Evaluation *for* learning, not just *of* learning

Special Features of the Second Edition

Similar to the 2012 version, this book reviews research from the learning sciences; discusses how the findings can inform practice; and shares activities from practitioners who have used the model in classrooms, higher education courses, corporate training sessions, strategic planning, and more. It begins with a consideration of current practices and how the emerging field of neuroeducation can promote innovative and creative problem-solving. It then examines themes from the learning sciences that practitioners should know, including discerning the differences between meaningful uses of research and common misapplications of findings, known as *neuromyths*. Next, in order to help with understanding of research in subsequent chapters, the book provides fundamental information of how the brain works, including its structure and function. Chapter 3 provides an overview of the BTT Model, and the chapters that follow focus on each of the six brain targets, including research supporting the target as well as concrete examples of applications from educators and practitioners from related fields. Finally, readers will see how the model can be used as a unifying framework in a school or any organization.

Those familiar with the first edition will note that the components of the BTT Model have not changed. In fact, research that supports each of the brain targets described above has continued to grow. Thus, this edition includes newer studies along with some of the seminal research studies described in the last edition. In addition, I have invited researchers and colleagues to share their knowledge and experiences with the BTT Model, resulting in multiple new "Expert Practitioner" excerpts that appear in each of the chapters describing the six brain targets and offer rich new approaches to learning and leading.

I present four new chapters for this edition, written or cowritten by colleagues who have used the BTT Model in their work. The new chapters include Chapter 11, which focuses on Culturally Relevant Pedagogy within the BTT Model and how this content informs online and hybrid learning. Chapter 12 addresses how parents and home school entities such as microschools can align strategies with the BTT Model. Cutting-edge technology in the form of Virtual Reality is discussed in Chapter 13 along with more common forms of technology as it is used in educational applications. I am excited to share Chapter 14, which demonstrates ways in which the BTT Model has been examined in research studies nationally and internationally, providing evidence of its effectiveness in programs servicing early childhood to adult learners. Chapter 15, "Last Words," recount the inspiring story of the late Gordon Porterfield and how his graduate students responded to an activity that required them to learn in a way outside of their comfort zone yet triggered a meaningful learning experience. The Appendices include a checklist of instructional strategies to help guide practitioners and leaders in implementing each of the components of the BTT Model. In addition, the two sample learning units that threaded through each of the chapters of the first edition (Hatchett and Genetics & Heredity) are now offered in Appendices II and III.

It is important to note that in many cases, you will see the model shown within teaching and learning environments. To any reader who is not in the field of education, I would like to point out that broadly, educators exist in every walk of life. Beyond the traditional role of classroom teachers, educators include leaders of any organization, corporate trainers, athletic coaches, parents, consultants, and many more and varied professionals. In fact, we are all educators when we impart information to students, colleagues, workers, and our children. As you move through the various chapters of this book, think about how the content applies within your own context.

Finally, it is important that I explain why I find the concept of *brain-targeted teaching* (a description I coined in the last book) to be more useful than the term *brain-based learning*. A number of people have justly criticized the use of the term *brain-based* as an adjective describing learning. The silliness of the term is exemplified by the question, "Doesn't all learning occur in the brain? After all, we don't think with our feet!" I concur that labeling learning as *brain-based* seems uninformative, as learning indeed occurs in the brain and embodied memory systems. In contrast, *all teaching should result in learning*, so while all learning is *brain-based*, all teaching is not. Accordingly, I wanted to focus on how pedagogy can be informed by knowledge of how the brain learns—how people perceive, process, and remember information. Therefore, the term *brain-targeted teaching* seemed particularly apt.

Research from the learning sciences has demonstrated that the essence of learning is about biological changes. In view of that, focusing on the *science of learning* should be as central to discussions about education as the focus on accountability for the *product of learning*. It is time that policy and practices reflect a focus on the way humans think and learn. The emerging field of neuroeducation and the Brain-Targeted Teaching® Model can be the linchpin in this work.

Acknowledgments

It is with great pleasure that I acknowledge those whose contributions have been critical in conceptualizing and writing this book. I begin by recognizing the dedicated work of the team of core professionals who have been constant collaborators and support of the Brain-Targeted Teaching® (BTT) Model from its beginnings in the early 2000s to now. As collaborators, they have been thought partners, researchers, teachers of academic courses and professional development programs, coauthors, editors, and more. While there are many who fit into this group, I want to recognize especially the work of Clare O'Malley Grizzard, Ranjini JohnBull, Joe Meredith, and Rachael Barillari.

The voices of the many Expert Practitioners turn research and theory into rich images of real-world application of the BTT Model. Their excerpts add context to each of the brain targets. I am so grateful for the many ways in which they shared their wisdom and amazing practices to make a difference for others in schools, workplaces, and homes. They are teachers and leaders in public and independent schools, universities, and corporations. In the first pages of this edition, I list their names and the titles of their excerpts in the order they appear throughout the chapters in the book. In particular, much gratitude goes to Clare O'Malley Grizzard, who brings the arts into the BTT Model for the chapters that describe each brain target (Chapters 4 through 9).

I would also like to thank those who authored or coauthored chapters that have been added to this edition. In Chapter 11, Ranjini JohnBull shares her wisdom on Culturally Relevant Pedagogy within the BTT Model in online and hybrid learning environments. Clare O'Malley Grizzard and Jacqueline Renfrow contributed expert advice in Chapter 12 on Implementing the BTT Model at home and out-of-school learning environments. In Chapter 13, David Toia describes Virtual Reality and Katherine Fu technology in education. Chapter 14 reviews research studies showing evidence of the effects of the BTT Model on a variety of interventions nationally and internationally. I am grateful to Katherine Fu for her dedicated work in researching studies to be included in this review.

I am incredibly humbled by the Foreword for this edition written by a giant in the field of Educational Neuroscience, Tracey Tokuhama-Espinosa. Her contributions to the field are enormous at Harvard University, her work in academic organizations, and her many publications. Her generous words are greatly appreciated and valued.

I would also like to thank those who contributed in multiple and varied ways through ideas, edits, images, and supportive suggestions: Melody Huang, Bob Lessick, Thom Grizzard, Clara Fangfang Ma, Carolyn Freeland, Tara Chadwick, Krysta Herring, Don Perry, and Sam Clayton. And, finally, many thanks to all of the educators and professionals in other fields who have used the Brain-Targeted Teaching® Model over the years to enhance their practice and share their work with colleagues and friends.

I also want to recognize those who contributed to the first edition of this book. At the time they were postdoctoral fellows at the Johns Hopkins University School of Education—Emma Gregory, Luke Rinne, and Julia Yarmolinskaya. I also want to recognize Martha Bridge Denckla, who authored the Foreword for the first edition and all of the many researchers and authors who provided reviews of the book from the first edition of this book. I would like to acknowledge the graphic designer, Bennett Grizzard, for the creative graphics that depict each brain target in the icons that appear in the book. The learning units in the Appendices of the book appeared in the first edition. Special thanks again to Clare O'Malley Grizzard and Suzanne McNamara for wonderful examples of how the BTT Model can be used in elementary and high school.

Finally, many thanks to Corwin's Jessica Allan and her team for expert guidance and support of this second edition.

About the Author

Dr. Mariale M. Hardiman is Professor Emeritus at Johns Hopkins University in Baltimore, MD. Her work has contributed to advancing the field of neuroeducation through various roles including professor, researcher, school principal, consultant, and author of books, book chapters, journal articles, and multi-media presentations. She founded the Neuro-Education Initiative and the Mind, Brain, and Teaching programs at the Johns Hopkins University School of Education. Through academic courses and professional development, her work connects research from the learning sciences with teaching and learning strategies for professionals in education and related fields. She has conducted pioneering research on the effects of arts integration on long-term retention of academic content. She also examined how knowledge of the learning sciences influences teaching practices and efficacy beliefs. Her National Science Foundation-funded research investigated teachers' perceptions of creative thinking strategies and creativity assessments. Additionally, Hardiman's administrative roles at the Johns Hopkins School of Education include Department Chair, Vice Dean of Academic Affairs, and two appointments as Interim Dean.

In her time as a school principal in Baltimore City, Hardiman developed a teaching framework, the Brain-Targeted Teaching® Model that promotes arts integration and creative problem-solving. Hardiman presents her work nationally and internationally on topics related to the intersection of research in the learning sciences with effective teaching, leading, and learning. Her research on arts integration has been featured in various popular news outlets including the *New York Times, Forbes, Psychology Today, Pacific Standard*, and *Southern Living*.

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Visit her website www.braintargetedteaching.org

Introduction

The Emerging Field of Neuroeducation

> *Because of its broad implications for individual and social well-being, there is now a consensus in the scientific community that the biology of mind will be to the twenty-first century what the biology of the gene was to the twentieth century.*
>
> —Eric Kandel, *In Search of Memory*, p. xiii

How do we prepare our learners, from young children to adults, for a rapidly changing world? How do we ensure the effective transfer and creative application of knowledge for learners at all levels and in multiple contexts from education to the world of work and general life endeavors? As technology has enabled a global, interconnected world, how do we prepare for greater cultural awareness? How do we support the well-being and mental health of our students and workers? How can we address the inequities in opportunities and accessibility to quality education? All of these issues and more have clearly come to light, especially in the wake of the pandemic, which has changed how we think about schooling, employment, and lifestyles.

There are no simplistic answers to addressing these questions. Yet with the resolve and collaboration of educators, leaders, policymakers, parents, and all related constituents, no challenge is beyond our knowledge and wisdom. But we must be open to conducting our work in different ways. In education, for example, despite the calls for greater emphasis on critical and creative learning, traditional approaches to curriculum and instruction still dominate what happens in our nation's schools. While higher pay and working conditions may address the teacher shortage, my experience with practicing professionals points to their desire for more agency in what and how they teach. And in increasing numbers, educators are pursuing professional learning experiences to increase their knowledge of how the human mind thinks and learns, focusing on the needs of the learner rather than how they score on standardized tests (Privitera, 2021).

Indeed, efforts to reform American schools should begin by changing the very notion of how to measure educational success, driven by the movement of 21st century learning, and ultimately informed by new knowledge from the learning sciences. At present, with no national consensus on what makes an effective school, policies have largely reduced the notion of measuring successful schooling to merely tracking achievement scores in reading and mathematics.

Clearly, educators must not shrink from accountability for student performance. The current practices that measure educational effectiveness, however, are driving school policies and practices and have resulted in a well-documented narrowing of the curriculum, reducing time spent on the social studies and the sciences and—at the same time—diminishing opportunities for many children to participate in the visual and performing arts, physical education, and even recess. This is especially true in under-resourced schools, where budgets are tight and many educators believe that children require more time to work in the tested subject areas. Narrow accountability measures fail to give the public, from parents to policymakers, the broad measures of school effectiveness they want and deserve.

While the practice of high-stakes accountability helps identify expectations of student learning, it also cuts down on the time they have to provide students with deeper and more engaging learning experiences (Guggino & Brint, 2010). Practices that support narrow, *spoon-fed* thinking are incompatible with our nation's need for workers capable of collaboration, innovation, and creative problem-solving—the hallmark of 21st century skills. Educating the citizens of tomorrow will require the redesign of school policies and practices so that students do not merely acquire information, but also are provided with opportunities to apply what they have learned in novel, creative ways.

As we redefine American education, the emerging field of neuroeducation can play an important role by focusing educators on *how students learn* rather than on merely *what they learn*. As neuro- and cognitive science researchers continue to accrue knowledge about the science of learning, it is important that relevant findings reach educators in a manner that allows them to incorporate this knowledge into policies and practices. As is the norm in medicine, neuroeducation can bring to educators the *bench to bedside* approach through which research informs practice and the needs of practitioners drive research questions.

Interest and research into the field of neuroeducation has continued to grow internationally. Examples include the Organization for Economic Co-Operation and Development (OECD) panel on how the learning sciences can change the nature of teaching (Guerriero, 2017), and two Delphi panels of scientists and educators address how the learning sciences should shape education practices and policies (Tokuhama-Espinosa, 2017). Other reviews examined the impact of neuroeducation training on teachers' beliefs and pedagogical practices. For example, Privitera (2021) reviewed existing research on how neuroscience training influenced instruction. He found that teachers who received training in topics related to neuroeducation were more likely to adopt pedagogical practices that reflected students' cognitive development and diverse learning needs. Moreover, teachers' general and personal self-efficacy beliefs—the power of education to reach all children—significantly improved after they participated in professional development in the learning sciences (JohnBull & Hardiman, 2023). It is clear that a growing number of educators see the potential of the science of learning to inform the field of education. During the last fifteen years, teacher attendance at national, regional, and local conferences related to learning and the brain has grown significantly (Privitera, 2021), and teachers report that information from the learning sciences is highly relevant to their work (Howard-Jones et al., 2007).

As professional development programs, books, and journal articles have proliferated, however, there has emerged a strong need for some way to separate the wheat from the chaff when it comes to commercial products and textbooks that increasingly tout the use of *brain-based* strategies to improve student achievement (Sylvan & Christodoulou, 2010). Practitioners must have ongoing information that helps them become informed consumers of research claims and a cohesive way to apply relevant research to effective practice.

The BTT Model is presented as a tool for applying the learning sciences to educational practice that is consistent with the skills associated with 21st century learning—preparing all students to become the creative and innovative thinkers and learners of tomorrow.

1

Information From the Neuro- and Cognitive Sciences That Educators Should Know

Separating Neuromyth From Neuroscience

The field of neuroeducation continues to produce a solid literature base and a growing number of research findings and can and indeed should inform the teaching and learning process. Unfortunately—and for a variety of reasons—these worthwhile findings are sometimes oversimplified or misinterpreted when attempts are made to apply them to pedagogy. In this chapter, I begin by identifying some of these erroneous constructs of the science, often referred to as neuromyths. Next, this chapter highlights some general themes from the learning sciences that can give educators a broader perspective of child development and learning. Many of these general themes (and associated neuromyths) will be revisited in subsequent chapters as we explore the Brain-Targeted Teaching® Model.

> There exists a solid literature base and a growing number of research findings from the neuro- and cognitive sciences that can and indeed should inform the teaching and learning process.

Neuromyth in Education

Despite more than two decades of research and commentaries, beliefs in neuromyths on the part of the general public and educators in particular continue to proliferate (e.g., Dekker et al., 2012;

Grospietsch & Lins, 2021; Howard-Jones, P. A., 2014; Rousseau, L., 2021; Tokuhama-Espinosa, 2018). In considering neuromyths, we must be aware of not only why they are incorrect but also how they came to be widely believed, especially among educators. Although the media and manufacturers and marketers of commercial educational products improperly sensationalize findings, teachers are the ones who are blamed for incorrectly applying those findings (Goswami, 2006). After interviewing educators on the use of neuroscience in education, Howard-Jones et al. (2007) reported that teachers felt a sense of embarrassment and even betrayal when they discovered that programs they thought were grounded in neuroscience research actually lacked scientific support. Teachers have been encouraged, for example, to teach to the left or right side of the brain, or to inventory their students' learning styles (see section below for explanation)—activities that, while perhaps alluring, lack scientific support. Teachers' time and school resources are wasted when they are duped by false advertising or forced by policymakers to use products or methods that are not supported by research. To illustrate, I will highlight some popular neuromyths so that we can see why it is important for teachers to become more savvy consumers of research.

> Teachers felt a sense of embarrassment and even betrayal when they discovered that programs they thought were grounded in neuroscience research actually lacked scientific support.

Some of Us Are Left-Brained; Some of Us Are Right-Brained

Fueled by popular media and commercial products, the notion that we can label ourselves and our students as left- or right-brained thinkers has essentially become common knowledge in many educational circles. The idea arose from research on hemispheric specialization in studies of *split-brain* patients, as researchers were able to isolate processing primarily happening in one hemisphere or the other. Scientists demonstrated that the left brain is associated with language processing, logical or *linear* thinking, and memory for facts, while the right side deals with spatial information, forms, and patterns in a more *holistic* fashion (Goswami, 2006). While each hemisphere *does have specializations*—(for example, Broca's area in the left hemisphere controls much of speech production), the two hemispheres are more similar in function than they are different. This explains why those with lesions on one side of the brain still have remarkable capacity for functioning despite damage to critical brain structures (see Immordino-Yang &

Damasio, 2007). In reality, unless one has actually had his or her corpus callosum (i.e., the bundle of fibers that connect the two hemispheres) severed, both sides of the brain are critically involved in most tasks. The idea that one hemisphere can *dominate* the other—that people who are better at some kinds of tasks than others must have better functioning in one hemisphere—has no basis in fact. There is simply no scientific evidence that would justify identifying learners as either *left-brained* or *right-brained* and gearing instruction toward one side of the brain or the other.

> Unless one has actually had his or her corpus callosum (i.e., the bundle of fibers that connect the two hemispheres) severed, both sides of the brain are critically involved in most tasks.

Listening to Mozart Will Make Your Baby Smarter

The idea that listening to Mozart will increase IQ scores and help babies become smarter was endorsed by articles in such reputable sources as the *New York Times* and the *Boston Globe* as well as by books and commercial products that touted increases in mental development when infants listened to Mozart piano concertos (Campbell, 1997). This misconception was derived from a study by Rauscher et al. (1993) who investigated the effects of listening to Mozart's concertos on spatial reasoning. The researchers found that listening to Mozart produced only short-term (i.e., fifteen-minute) enhancement of spatial reasoning on a subtest of the Stanford-Binet IQ test, compared with subjects who listened to relaxation music or experienced silence. In other words, Rauscher and colleagues (1993) did indeed find an effect of listening to Mozart on one's score on an IQ test, but that effect was fleeting and was only seen for a specific subtest associated with a particular cognitive capacity and not intelligence in general. Although the researchers claim that their work was misrepresented, the impact of the study went beyond mere commercialization. In 1998, the governor of Georgia approved funding in the state budget to provide every child born in the state with a recording of classical music.

Mozart lovers need not despair. Jenkins (2001) reported impressive results in reducing epileptic attacks after patients listened to Mozart for ten-minute intervals each hour. Thompson et al. (2001) suggest that temporary changes resulting from listening to Mozart or any music may be attributed to differences in mood and arousal. Moreover, any effects from listening to Mozart are again quite narrow as the authors claim that only music perceived by the listener as enjoyable produces any effect. We will explore in subsequent chapters how the arts, including music, enhances engagement and learning.

After Critical Periods of Development, Learning Shuts Down

Often used interchangeably, the terms *critical period* and *sensitive period* (a deliberate softening of the former) refer to a time during development when children best acquire knowledge or skills in some domain. The notion is that if appropriate stimulation during this period does not occur, the *window of opportunity* for learning closes and the particular skill will never be developed. Although there is certainly evidence of critical and sensitive periods for certain aspects of development, it is important not to overgeneralize this idea to domains for which there is no evidence. And further, for domains in which a critical or sensitive period can be demonstrated, it appears that in most cases the window may narrow somewhat, but only rarely does it completely close. We could certainly learn to play a musical instrument at sixty, but we might want to think twice about booking Carnegie Hall.

Language acquisition is a key area in which researchers have proposed the existence of a critical period. Much of this work is based on studies of feral children who, due to abandonment or abuse, were not exposed to language and failed to ever develop language skills fully. Jean Itard's work with Victor of Aveyron in the early 1800s and the case of Genie, who was discovered in 1970, led to the theory that language exposure must occur early in life or language fails to develop. Additional evidence of a critical period for language is based on studies of individuals with brain damage; ensuing language impairments tend to be more severe when the incident occurs in adulthood compared with in childhood. Perhaps the most compelling evidence for a critical period for language acquisition (where the lack of linguistic input is not confounded with extreme social deprivation) comes from deaf children of hearing parents. Some of these children are often deprived of good sign language input until elementary school or later. Unlike children exposed to sign language early in life, children exposed later will not learn sign language in a native-like way (Grimshaw et al., 1998).

> Language acquisition is a particularly key area in which researchers have proposed the existence of a critical period.

Second language learning is another, much more controversial area in the study of critical periods. Younger children seem to be advantaged in ultimate attainment of a second language. Even though native-like pronunciation is almost never observed in late learners, adolescents and adults can master a second language, especially with respect to vocabulary and syntax (Robertson, 2002). So although some kind of specialized *critical period* for second language acquisition could exist especially in phonology, there is evidence for high ultimate achievement even among late second language learners.

Although the window of opportunity for language learning seems only to narrow, the same cannot be said of the development of vision. Based on the work of Nobel Prize winners David Hubel and Torsten Wiesel (1970), a kitten temporarily blinded in one eye at an early developmental stage would never recover sight in that eye after the blindfold was removed, thus demonstrating that there is a critical period for the development of the visual cortex.

Research in the area of sensitive periods continues to advance, particularly in the area of adolescent development. Studies reveal changes in brain structure and function at the onset of puberty and into early adulthood (Dahl, 2004; Giedd, 2010). Although this, along with the examples described previously, may provide evidence in favor of the existence of critical or sensitive periods in certain domains, the idea that this is characteristic of all or even most areas of learning is not supported by scientific research. Similarly unfounded is the idea that it is pointless to try to learn new information after a demonstrable critical or sensitive period has ended. This appears to be true only in rare or extreme cases. So for anyone so inclined, do sign up for those tuba lessons!

> Recent studies reveal changes in brain structure and function at the onset of puberty and into early adulthood.

We Only Use 10% of Our Brain

With all of the attention about the workings of the human brain, it is amazing that this myth still perpetuates and appears to be one of the most prevalent myths coming from the popular press (Takuhama-Espinosa, 2018). Indeed, many believe that 90% of the brain is inactive. There are multiple explanations for how this myth came about. For example, University of Washington neuroscientist Eric Chudler (2010) offers several sources for this myth, including the work of Karl Lashley in the 1930s. Lashley found that rats were still able to perform certain tasks even after having large areas of the cerebral cortex removed.

This may be one of several studies where results were misrepresented or exaggerated in a way that contributed to the false conclusion that large areas of the brain were inactive.

In fact, we use all of our brain. Findings from neuroimaging studies demonstrate activity throughout the brain during many different tasks. Chudler (2010) points out that studies involving functional neuroimaging generally only highlight *differences* in brain activity that arise due to the performance of specific tasks. The areas of the brain that appear dark on the scan are likely still active; they simply do not change in response to the task being studied. Thus, when a graphical representation shows only a tiny island of activation, this is in no way indicative of the amount of activity taking place in the brain as a whole. It is clearly established that brain networks work together as we engage in activities that require motor control, sensory processing, and cognitive tasks like language processing, problem-solving, and decision-making.

> Cognition and learning involve multiple networks of the brain and bodily movements.

Teachers Should Assess and Teach to Each Child's Learning Style

A recently debunked neuromyth in educational literature concerns the concept of *learning styles*. Learning style theory assumes that some children learn best through visual, auditory, or kinesthetic methods. According to the theory, teachers should inventory each child's preferred style and adjust instructional strategies to meet each child's assessed style of learning.

This neuromyth is certainly widespread: About 90% of people surveyed reported a belief that everyone has a preferred style of learning (Willingham, 2009). Willingham (2009) argues that this misunderstanding likely comes from popular notions of multiple intelligences and left/right brain processing theories. Unfortunately, the learning style theory as applied to classroom instruction has been aggressively perpetrated by vendors of educational products that promote learning style assessments and strategies for tailoring instruction to specific groups of students. Specifically, learning style theory has been promoted as a way for educators to differentiate instruction based on the *needs* of particular learners. Despite the pervasiveness of learning style theory in educational settings, in an extensive review of the literature, Pashler et al. (2008) found no evidence that children taught in their preferred learning style performed any better than if they were taught through a nonpreferred style. In studies conducted by Rogowsky et al. (2020), findings clearly showed that instruction matched to students' perceived learning styles did not produce better learning. Teachers and trainers should be encouraged to differentiate instruction based on a number of metrics available. Matching instruction to a particular modality is not an effective way to differentiate learning activities.

With regard to meeting individual needs, there are potentially more efficient means of differentiation, such as considering prior knowledge, background in the content, level of mastery of skills, interest level, or learning differences and goals identified in individualized educational programs.

We Can Effectively Work on Tasks Simultaneously Through a Process Known as Multitasking

Multitasking is actually not a good way to get work done. The brain's attentional system requires focusing on concepts and thoughts sequentially, one after the other. This may seem confusing because we are able to do two things at once like walking and talking at the same time. But in that example, we see that walking and talking don't necessarily require focused attention. The brain's attentional network requires us to switch focus every time we move from one mental task to another. We may think that we are doing two mental tasks at the same time, however, there is a cost in loss of working memory when we switch tasks. If you have a good working memory, you may not notice the memory cost; however, for some, switching tasks may require going back to figure out where you were in the first task before you switched to a different one. Given what we now know about multitasking, using a cell phone or texting while driving is a serious safety threat (see Różańska & Gruszka, 2020). Moreover, findings from a review of research on media multitasking—using two or more medias at the same time—revealed that dividing attention has significant negative effects on students' academic performance (May & Elder, 2018).

We Are Born With All the Brain Cells We Will Ever Have

Many of us believe that the brain is a static organ incapable of any significant changes. This is one of the most important myths to dispel for educators as it may influence teachers' attitudes and perceptions about children's capacity to learn (Hardiman & Denckla, 2010). As we will see from the discussion of plasticity and neurogenesis below, the brain is an amazing organ capable of tremendous change throughout life.

> The brain is an amazing organ capable of tremendous change throughout life.

Important Themes From the Neuro- and Cognitive Sciences That Educators Should Know

Now that we have dispelled a number of the most insidious neuromyths, I turn to areas from the learning sciences that can and should inform beliefs as well as practices at all levels and in any context. Each of these topics will also be considered in discussing the related components of the Brain-Targeted Teaching® Model in subsequent chapters.

Plasticity

Plasticity is the term used to explain how the brain is modified with experience. Learning involves changes in the strength between neural synapses after a sensory input or motor activity. Neurons branch new dendrites, grow new axons, develop new synapses, and modify or eliminate established neural connections over the lifespan of the human being. Genetic makeup and environmental interactions set the course for the brain to change with experience (Shonkoff & Phillips, 2000). Just as muscles are strengthened with repeated exercise, brain networks are strengthened with repeated use. Knowledge that the brain continues to change based on experiences is important for all practitioners. Understanding that the brain continues to develop throughout one's lifetime promotes the mindset that the capacity for learning is not fixed—an important concept that we all must embrace as we work with children and adult learners.

> Just as muscles are strengthened with repeated exercise, brain networks are strengthened with repeated use.

Neurogenesis

Neurogenesis refers to the growth of new brain cells. Neurogenesis is critical in the developing embryo, but researchers have found that the brain continues to grow new cells in certain brain regions after birth and throughout our lifespan. Only about twenty years ago, scientists knew that the brain changed when neurons connected and formed neural networks (plasticity), but the common belief was that the brain did not grow new cells. Now we know that the brain has the capacity in certain circumstances to grow new cells at any age.

Researchers have demonstrated the genesis of new brain cells in the cerebellum and in other important regions such as the hippocampus, an area associated with memory (Alonso et al., 2024; Denoth-Lippuner & Jessberger, 2021; Hussain et al., 2024). In addition, it appears that neurogenesis can be enhanced through exercise, nutrition, and stress reduction (Kempermann et al., 2004). Like the concept of plasticity, knowing that the brain is constantly growing and changing helps to promote a *growth mindset* with the profound understanding that experiences can produce not only behavioral changes but biological changes as well.

> The discovery of neurogenesis, the production of new cells in certain brain regions, represented an enormous breakthrough in understanding the human brain.

Emotion and Stress

Study of brain structure and function reveals the intricate interplay between cognition and emotion. Perhaps the words of Jill Bolte Taylor, a neuroscientist recovering from a severe stroke, best express this interplay. Taylor explains a major breakthrough in her thinking about brain function as she chronicles her brain's healing process. She states, "Although many of us may think of ourselves as *thinking creatures that feel,* biologically we are *feeling creatures that think*" (Taylor, 2008, p. 19).

Many of us were trained in our teacher preparation programs to believe that rational and emotional processing should not mix. We believed that educators must focus on developing cognitive processes; emotion must be shut down for learning to take place. Now we know that it is impossible to separate emotions and learning. We will explore this topic in more depth in the chapter on Brain-Target One, Establishing the Emotional Climate for Learning.

The Role of Attention in Learning

Attention is clearly critical for learning. The more attention the brain pays to a stimulus, the more elaborately the information will be retained. The brain is constantly bombarded with sensory stimuli; that which is attended to will encode into the short-term and working memory system. Events that carry emotional arousal are more likely to attract attention than neutral events. These events then stay longer in our memory systems and are later recalled with greater accuracy.

New and ongoing research in the area of attention is showing that it can be enhanced through specific training and by introducing novelty and visual images into the physical learning environment.

Posner and Rothbart (2007) identify three neural networks—or systems of interconnected brain regions—involved in attending behaviors: the alerting network, which allows us to maintain an alert state; the orienting network, which helps us attend to sensory events; and the executive network, which sustains attention to an event. They point out that effortful control of attention develops from early childhood into adolescence. Their studies have shown changes in patterns of neural activity underlying attentional processes and improvement in behavioral measures of attention after subjects received specific training in tasks requiring effortful control of attention. The chapter on Brain-Target Two will address how the classroom environment can be shaped to maximize attending behaviors in children.

> Effortful control of attention develops from early childhood into adolescence.

Executive Function

The term *executive function* is used to describe basic cognitive processes that underlie ongoing, goal-directed behaviors and higher order thinking skills. These basic functions, which are often associated with neural processing in the frontal lobe, include holding information in working memory, initiating as well as inhibiting an action, and shifting perspective or the focus of attention. Together these functions allow us to carry out complex actions such as planning future events, organizing processes, self-monitoring, and regulating emotional response. Far from becoming active all at once, executive function skills develop over time. Scientists believe that some competencies such as emotional regulation are not fully developed until the mid-to-late twenties or even later.

Some researchers posit that executive function skills can be enhanced through certain training programs that range from commercial brain-training programs to mindfulness initiatives (Diamond & Ling, 2016). Much research is needed to determine how to best develop specific skills associated with executive function. For example, self-regulation training is an area of great interest in the research community.

In short, executive function skills are critical for effective learning and are more predictive of academic success than IQ or socioeconomic status

(Diamond & Ling, 2016). These skills allow the learner to draw novel associations and flexibly use information in different contexts. It is important to note that newer notions of behavior and learning posit that not all behaviors are consciously controlled but arise from more of a *whole brain* process. We next look at how the brain and body are both critical for cognition and learning.

> Executive function is especially critical for effective learning as it requires being able to draw novel associations and flexibly use information in different contexts.

Embodied Cognition: The Importance of Movement and Learning

Cognition is defined as the process of acquiring knowledge and understanding. *Top-down* processing is a term often used to refer to effortful control of cognitive thoughts and actions, whereas *bottom-up* refers to the processing of an array of sensory-motor information in real time and not driven by effortful cognitive thought; researchers think that both ways of processing information operate together.

The term, embodied cognition, is based on the notion that human cognition is originally rooted in sensory-motor processes and thus determined by bodily experiences. This relatively new approach to cognition challenges traditional theories that the body is *passive* as the brain processes information. The theories suggest that learning is grounded in the learners' sensory-motor system that interacts with the environment and culture (Shapiro & Stolz, 2019). In other words, thought and movement are not separate neurological systems. Cognitive neuroscience research suggests that acquiring academic skills is linked to areas of the brain responsible for body movement in space.

Long recognizing the importance of movement in cognition and learning, Maria Montessori (1967) noted that "one of the greatest mistakes of our day is to think of movement by itself, as something apart from the higher functions . . . . Mental development must be connected with movement and be dependent on it" (pp. 141–142).

Consistent with Montessori's idea, in his book, *Spark,* John Ratey (2008) explains that movement and exercise do more than just produce chemicals that make us feel good; physical activity actually affects cognitive development by accelerating the production of specific chemicals necessary for memory consolidation and spurring the development of new neurons from the hippocampus. Within the Brain-Targeted Teaching® Model we will see the critical role of movement on attention in Brain-Target Two as well as in content acquisition and retention when we consider Brain-Target Four, which emphasizes active learning and arts integration.

Arts and Learning

Although the number of arts programs seems to be shrinking in our nations' schools, a growing body of research maintains that there are important positive effects of arts engagement in educational settings. Besides serving as a creative and enriching experience for children, the arts have been shown to have benefits on learning, student engagement, and self-efficacy. For instance, heading the Dana Foundation Arts and Cognition Consortium, Michael Gazzaniga (2008) reports a tight correlation between the study of the arts and improvement in attention and various cognitive abilities. In addition, researchers report significant differences in academic achievement and social behaviors between youth highly involved in arts programs compared with those with no arts engagement (e.g., Bowen & Kisida, 2019; Caterall, 2009; National Endowment for the Arts, 2024). What is more, researchers have shown changes in brain structure even with relatively small amounts of music training (Hyde et al., 2009). Hyde and colleagues found that students who were given just fifteen months of music training showed significant changes in specific brain regions that were also correlated with improvements in musically relevant motor and auditory skills. Numerous studies over the last twenty years have shown academic and social benefits when students engaged in various art forms including theater, dance, visual arts, instrumental music, and creative writing. Building from these connections between the arts and learning, the chapter on Brain-Target Four (Chapter 7) explores how integrating the arts into content instruction may play a role in long-term retention of information and more robust habits of mind that transfer to all tasks. In Chapter 7, we share our research on the effects of arts integration, in which we found clear advantages for memory of science content when students were given arts-integrated lessons compared to traditional instruction (Hardiman et al., 2014, 2019).

> Researchers have shown changes in brain structure even with relatively small amounts of music training.

Adolescents, Sleep, and Learning

Research in the neuro- and cognitive sciences sheds light on the way the brain changes during adolescence as well as on what patterns of neural activity may accompany at least some of those changes. National

Institutes of Health researcher Jay Giedd (2009, 2010), for example, points out that the onset in puberty brings dramatic brain changes. Compared with prepubescent children, children entering puberty exhibit greater connectivity among various brain regions during task completion, reduction in grey matter volume, and changing balance between connections in the limbic and frontal executive function systems. Research has demonstrated significant brain plasticity during the teen years evidenced by both biological and behavioral measures. Ramsden and colleagues (2011) found changes in verbal and nonverbal IQ scores (both higher and lower) during the teen years compared to earlier testing. These scores correlated with changes in associated local brain structures involved with verbal and nonverbal processing.

In addition to changes in neural and cognitive processing, sleep patterns also typically show significant changes. The circadian rhythms of adolescents point to a tendency for later sleep onset in the evening and later arousal in the morning (Dahl, 2004). This finding suggests that a school day that begins later in the morning may be more consistent with the sleep patterns of adolescents. In general, studies have shown how sleep optimizes the consolidation of newly acquired information in our memory systems in all individuals including children, adolescents and adults (Diekelman & Born, 2010; Saraji et al., 2024; Zahran et al., 2024).

> Circadian rhythms of adolescents point to a tendency for later sleep onset in the evening and later arousal in the morning.

Brain changes may also account for the tendency of adolescents to shift from seeking approval from adults to seeking approval from same-age peers as well as for adolescents having a greater propensity toward thrill-seeking behaviors (Giedd, 2009). Promising new research in this area could be used to assist educators and caregivers in understanding and preventing the increase of morbidity and mortality that comes with this sensitive time in human development. We will examine adolescent emotional development in discussions of Brain-Target One.

Creativity

As a hallmark of *21st century skills*, creativity in teaching and learning has become a topic of conversation and heightened interest in both academic literature and popular media. The World Economic Forum (2023) continues to cite creativity as a critical skill for successful employment. Thus, the demands of the world marketplace challenge educational institutions to prepare students to be creative thinkers who will shape our future world.

However, Bronson and Merryman (2010) point out that although IQ scores for children over the last thirty years have improved, creativity indices have declined. They cite analyses that examined the declining scores of more than three hundred thousand children and adults on the Torrance test, a popular measure of creative thinking. The late Sir Ken Robinson observed that concentrating on high stakes testing in relation to an ever-increasing multitude of content standards is squeezing creativity out of our schools and classrooms (Tabor, 2024).

> Concentrating on high stakes testing in relation to an ever-increasing multitude of content standards is squeezing creativity out of our schools and classrooms.

While educators grapple with how to build more creative activities into overcrowded curricula, scientists have continued to demonstrate differences in how the brain processes information when people are engaged in creative, spontaneous tasks, as opposed to ordinary activities that depend on rote knowledge (see Beaty et al., 2023). In our discussion of Brain-Target Five, we will examine this research on creativity, considering neuroimaging studies as well as behavioral studies. We will explore how teachers might be able to teach content in greater depth to move children beyond the acquisition of information to creative thinking and problem-solving tasks.

The next chapter provides a basic overview of brain structure and function, information that is important as we discuss research that supports the components of the Brain-Targeted Teaching® Model.