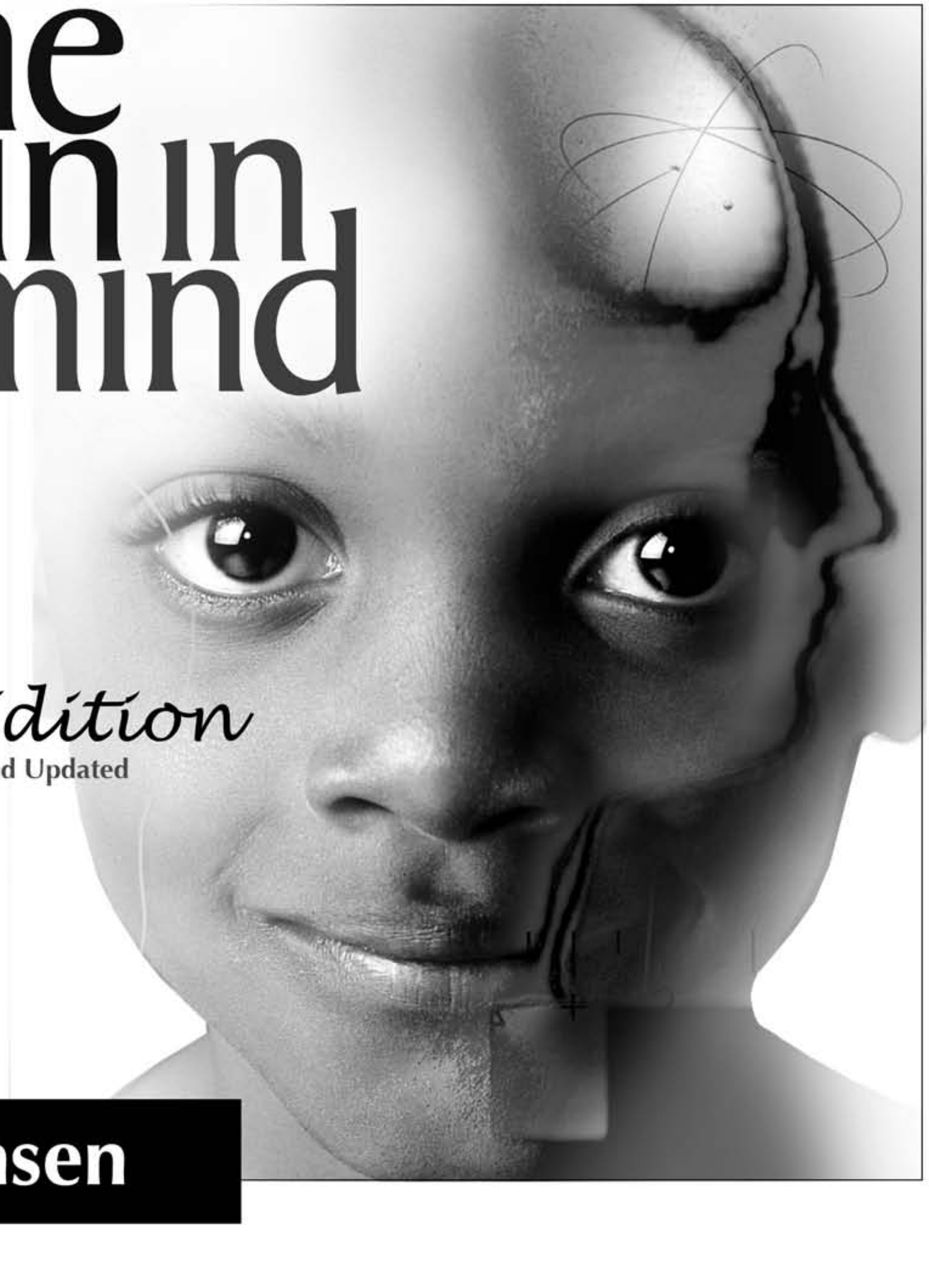
Teaching with the brain in mind



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Introduction

The revolution is being televised. Countless stories on the Discovery Channel and PBS have revealed exciting new insights about the brain. Mainstream broadcast media such as ABC, NBC, CBS, and CNN and publications such as *Time* and *Newsweek* have carried stories about recent brain discoveries. Dozens of books, videos, journals, newsletters, and publishing companies have documented this burgeoning field.

Educators worldwide have taken notice, and models of how we educate are being transformed. With brain-based learning now an established paradigm, if a far from universal one, it makes sense to explore some basic questions. First, how strong and reliable is this field of brain-based learning? Second, how do we know what we know about the brain? Can we apply laboratory findings directly in a classroom? The themes implied by these questions are simple; they are about answering the critics of brain-based education, understanding the sources that underlie it, and reviewing the reliability of evidence.

Let's begin with two fundamental facts. First, students who attend school from kindergarten through secondary school typically spend more than 13,000 hours of their developing brain's time in the presence of teachers. Second, their brains are highly susceptible to environmental influences—social, physical, cognitive, and emotional. And, more important, their brains *will be altered* by the experiences they have in school. As educators, we *must*—ethically, morally, and opportunistically—pay attention to how we ask students to spend time with us. These concepts are fundamental to education, yet we often take them for granted.

Answering the Critics

Despite the mounting evidence that supports brain-based learning, some critics say, "It's no big deal; there's nothing new" or, "We don't know enough to do anything." Some even say, "Nothing will change." I wonder if those same critics would have had similar things to say at Kitty Hawk in 1903, when the Wright brothers flew the first airplane only 100 yards: "It's no big deal," "It won't change anything." We are now at the doorstep of the same kind of revolution. Instead of a mechanical one fueled by new modes of transportation, it's one of neurons, chemicals, networks, and wonderful, truly historic discoveries. For the first time in human history, we are beginning to understand how our brain works. Yes, maybe we are just at the stage of the Wright brothers' first flight. But it's a great time to be alive.

Shortly after new "brain-based" thinking began to make its way into the mainstream, critics began finding fault. For example, John Bruer, president of the James S. McDonnell Foundation, noted that "well-founded educational applications of brain science may come eventually, but right now, brain science has little to offer education practice or policy" (1998, p. 14). Armed with selected willing scientists and selective studies, the critics (Bruer, 1998, 1999; Bailey, Bruer, Symons, & Lichtman, 2001) have attempted to invalidate the integration of brain-based understandings into schools. Some claim that it's still too early and we don't know enough for sure. But if we waited for irrefutable evidence on *everything* we did in education, we'd need to stay at home.

Some people are simply "early adapters," and others, more skeptical, are "late adapters." By nature, critics are typically late adapters. There are also those who have more personal agendas to protect, such as a pet program, an institution, or a foundation that they fear is being threatened. Having said this, some critics have raised valid points; others have raised what I see as unwarranted objections. Here are some of the criticisms and my responses.

Criticism: Many "pop" writers were not scrutinizing the sources of their information about the brain.

Response: I agree. The general news media are not always reputable sources of information about the brain. Nor is one scientist, one critic, one famous person, or a single study; anyone seeking reliable information must consider multiple credible sources. For example, I first consider material from the basic neuroscience sources, then look at clinical studies if they're available, and finally locate reports of educational practices or action research to confirm the practical applications. Readers of research on the brain should look for significant sample sizes, blind studies, well-designed experiments, and plausible conclusions. For every source that appears in the References section of this book, there are a half dozen that I left out, just to keep the length of the list reasonable. In short, what I state in this book is solid information.

Criticism: There's nothing new here—all this brain-based stuff is a bunch of hype.

Response: I strongly disagree. Whenever someone claims there's nothing new, I reply with this abbreviated list of "Top 10 New Discoveries About the Brain," all of which have come to light during the past 10 years:

1. We have discovered that the human brain can and does grow new neurons, that these neurons become functional and are highly correlated with memory, and that this process can be regulated.

2. We have discovered that there is no stable baseline for stress. Unlike other systems of the body, which usually revert to a prior, healthy state after suffering trauma (a process called homeostasis), the brain responds to extended periods of stress by developing a new, less healthy baseline. These "allostatic"—or adjusted—stress loads are becoming increasingly common and are associated with serious health, learning, and behaviorial risks.

3. We have discovered that aggressive behavioral therapies, new drugs, and revolutionary stem-cell implantation can be used to influence, regulate, and even repair brain-based disorders, including fetal alcohol syndrome, autism, retardation, strokes, and spinal cord injury.

4. We have discovered that "teenage behavior" may result from a complex array of fast-changing factors—not just hormones.

5. We have discovered that genes are not fixed. Evidence suggests that both gene expression and genetic makeup can be altered.

6. We have assembled tomes of evidence to support the delicate interplay between emotional states and cognition.

7. We have confirmed that music can affect cognition.

8. We have confirmed that software programs that use brain plasticity to retrain the visual and auditory systems really can improve attention, hearing, and reading ability.

9. We have discovered that exercise is strongly correlated with increased brain mass, better cognition, mood regulation, and new cell growth.

10. We have discovered that humans with implanted "brain chips" can operate thought-controlled mechanical interfaces; in other words, they can guide a robotic arm merely by thinking. The implications of these findings could revolutionize life for the physically disabled.

Anyone who says there's nothing new in brain research must have been living in a cave. The past 10 years have been the most explosive and hopeful in the entire history of neuroscience.

Criticism: Research findings are being misinterpreted; unwarranted leaps are being made.

Response: This criticism is often valid. The best-known example of this kind of extrapolation is hearing about the Mozart effect and then concluding, for example, that all music makes you smarter or all music is good for all students. Another is making an unwarranted leap from the understanding that new learning creates new synapses to the conclusion that more synapses must necessarily be a good thing. Untrue. Children with Fragile X syndrome actually have too many synapses. The best advice here is to read the studies and *wait for corroborating studies* before hopping onto a bandwagon. In addition, just because a study suggests that a certain instructional strategy may work well, the possibility remains that other strategies also work as well or better.

Mysteriously, most brain-based education books have not addressed the kinds of revolutionary discoveries found in my Top 10 list. Books on everything from "brain-based math" to "brain-based leadership" focus on the trivial, not the fundamental, and unfortunately, some of these books are embarrassing to the critical reader and educator. Having said that, I'll add that an author *is warranted* in drawing practical conclusions when there's little or no downside risk and the conclusions are reasonable.

Criticism: Some of the brain studies cited involved animals, not humans.

Response: This is true, but not a definitive reason to discount those studies' findings. Animal studies *do* offer much that we can transfer and learn from. Lab experiments with rats or primates are clearly more credible than those with sea slugs or fruit flies. Some studies may never be done on humans for ethical reasons. And although obvious differences distinguish humans and rats, science tells us that there are more similarities than differences (Cenci, Whishaw, & Schallert, 2002).

Overman & Bachevalier (2001) have studied the question of animal models versus human models, designing and testing learning trials in which humans and animals negotiated comparable mazes. They concluded, "In most instances . . . the procedures of animal testing can be directly applied to children . . ." (p. 120). This is not a blanket justification for applying the results of all animal studies to human situations. But neuroscientists study Norway rats and macaque monkeys for a reason—these animals have significant neuroanatomical similarities compared to humans. Yes, whenever possible, human studies are ideal, ensuring greater reliability and confidence in the results. But, as noted, for ethical reasons, it's not always possible to conduct human studies.

Criticism: The field of brain-based education is not "brain based" enough; many ideas are actually from psychology, sociology, or psychiatry.

Response: The error in thinking that it's not "brain based" *enough* is simple: it's *all* about the brain. The disciplines of psychology, biology, sociology, psychiatry, and pedagogy are all concerned, to some degree, with understanding human behavior. And, increasingly, those looking to understand human behavior are looking at the brain. Most of the newer books in these fields include chapters on brain function, anatomy, or processes. We cannot explore learning and the brain without having our inquiry overlap those of these other disciplines. Besides, where's the wisdom in studying ways to improve student learning without considering issues that affect it, such as nutrition, racism, poverty, trauma, and stress?

A slightly different problem occurs when some "brain-based education" presenters simply recycle their favorite pedagogy—such as that of Dewey, Piaget, Montessori, Kolb, Hunter, Lozanov, McCarthy, or Gardner—with a brain-based spin. "Brain-based" rightfully means that the actual work and conclusions were based on recent findings about the brain. Dewey, Piaget, and Montessori have much to offer, but their models might more correctly be called "brain compatible," meaning that the work and conclusions are *aligned with* or *compatible with* recent brain research. Besides, if the work of these giants was valid before, it's still valid now; we don't need to look for proof in the latest brain scan.

For the critics of brain-based learning, my message is this: you are fighting a losing battle. Thousands of neuroscience studies are being produced every year, and some of them *do* apply to the classroom. In the classroom are millions of teachers who need real-world solutions today, not 50 years from now. Educators are practical; they will try out almost any reasonable, ethical strategy, but they will keep using it only if *it works*. And thousands of educators are already using brain-based strategies with great success. To the critics in an office or a laboratory I say, "Get out in the real world—and teach for a week!"

One developmental neuroscientist recently stated, "If the likely risk-reward ratio is good, I see nothing wrong with classroom teachers trying out new ideas straight from neuroscience" (Jernigan, 2003). Sufficient studies support the things that I argue for in this book, and the references are solid. Many teachers are already doing action research to find out for themselves what works and what doesn't. They know brain-based teaching works.

I believe that over time the ideas and approaches I advocate in this book will become the standard. Why? Because when we teach in ways that make sense for the brain, that match how we were designed to learn, everyone wins.

Making Sense of Brain Research

A new breed of science of the brain is developing: educational neuroscience. No current journal carries that title, but one will probably appear soon. How else will we be able to integrate fields like psychiatry, sociology, nutrition, learning, emotions, and memory into a single social construct? Today dozens of new disciplines serve as examples of things to come. They have multiplied within the thriving biological community and find expression in journals such as *Social Neuroscience, Biological Psychiatry,* and *Nutritional Neuroscience.* Education will soon be part of this trend. The key to introducing and integrating these new fields is visionary researchers with a multidisciplinary approach.

The prevailing belief is that information is doubling in our society about every 18 months. In the field of neuroscience, the pace seems even faster. In short, we are learning about the brain at an unprecedented rate. It's generally acknowledged that research more than two years old is already "old information." In the coming years, we can expect new and more accurate technologies to further illuminate the brain's mysteries.

Even with all the exciting new research, it's easy to understand why many educators were turned off by the early attempts at applying it in the classroom. Typically, select and qualified "translators" of brain research shared their knowledge with staff developers and administrators who, in turn, set up professional development sessions to share the translated knowledge with classroom teachers. If these professional development sessions used role modeling and other effective techniques, the teachers often had reactions like "Wow! This is great stuff!" But if "application of brain research to the classroom" was presented as dry science, the responses were more along the lines of "Ho-hum. Tell me something new." Some educators got such a shallow, trivialized version of (mis)understanding—advice like "put water bottles in the classroom"—that it was difficult to have a serious conversation about the value of the research.

Let's remember, too, that errors of omission, commission, or enthusiasm come with every major paradigm shift. Educators have also seen laughable "translations" of learning styles, cooperative learning, multiple intelligences, and differentiated instruction. Early in any movement, it's tougher to separate the wheat from the chaff. But it's important to stay the course and consider recent brain research as part of the major rationale for today's educational practices. Why? Because *all learning involves the brain*. The more we can understand how the brain naturally works, the better we can structure educational practices to align with that functionality.

Here's a simple example. A good bit of evidence from studies of both animals and humans suggests that 30 minutes of vigorous exercise at least three times a week can contribute to enhanced mood, increased brain mass, better circulation, more brain cells, and improved cognition (Adlard, Perreau, Engesser-Cesar, & Cotman, 2003; Churchill et al., 2002; Markakis & Gage, 1999; Sutoo & Akiyama, 2003; Tomporowski, 2003; Van Praag, Kempermann, & Gage, 1999). This research suggests that schools that eliminate physical education programs may be more than shortsighted; they may be reckless and hurting their own causes.

Here's another example. Each year, tens of thousands of students are helped by a computer software program called FastForWord, which helps them develop phonological awareness (Temple et al., 2003). Several neuroscientists developed this educational program as a direct result of brain research.

Yet, despite all that we're learning from brain researchers, school boards and shortsighted policymakers continue to scream "budget cuts" and eliminate the things that can make the biggest difference. If your physical education program is ineffective, don't throw it out, fix it. When done right, PE can improve health, increase brain mass, reduce the likelihood of childhood-onset diabetes and teen depression, boost neurogenesis, and provide a host of other benefits. I know of no other subject or discipline that can make those claims. Choosing to keep a physical education program is choosing well—*with the brain in mind.* Although every school decision does not need to be made by consulting recent studies from neuroscience, we should be paying more attention to what the research says. Brain-based learning is a force to be reckoned with, and it's here to stay.

1

Meet Your Amazing Brain

Key Concepts

- Basic brain anatomy
- How the brain changes over time
- Cooperation and competition in the brain
- How the brain learns

You've heard for much of your life that the human brain is amazing. It's true. That soft, squishy blob between your ears—the blob that runs your life—*is* pretty amazing. Every day in classrooms around the world, teachers are amazed by what the human brain can do. Because exploring *all* the facets of the brain is beyond the scope of this chapter, we'll focus on three relevant and essential features:

- *Adaptability.* The brain changes constantly.
- *Integration*. Brain structures compete and cooperate.
- *Sophistication*. The brain is highly complex.

These themes help to establish the nature of the brain: it is constantly working; it operates with a high level of structural cooperation; and seemingly simple processes, like learning to read, are actually highly complex. This dynamic and versatile structure is unlike anything else on earth. That may be why we are so attracted to the study of the brain—it evokes both wonder and curiosity. At the simplest level, the brain is an organ that we are all born with, and we'll explore that concept first. But the brain is much more than an anatomical structure; it is also an active processing center, always at work.

The Raw Material

To begin learning about the brain, consider a grocery store's produce and dairy departments. In shape, the brain closely resembles a head of cauliflower. In size, it's similar to a large grapefruit or cantaloupe (see Figure 1.1). The brain is mostly water (78 percent), fat (10 percent), and protein (8 percent). From the outside, the brain's most distinguishing features are its convolutions, or folds. The wrinkles are part of the cerebral *cortex* (Latin for "bark" or "rind"), the brain's outer covering. The cerebral cortex is about as thick as an orange peel. The folds allow the covering to maximize its surface area (have more cells per square inch). In fact, if the cortex were laid out flat, it would be about the size of an unfolded, single page from a daily newspaper. Remember, the brain is only a grapefruit-sized organ. It's general texture is about the same as soft butter, but some parts are as gooey as raw eggs or yogurt.

Brains have both neurons and glial cells (see Figure 1.2). The most well-studied brain cells are *neurons*, which consist of a cell body with fingerlike input extensions, called *dendrites,* and a single output, called an *axon*. Neurons have different shapes depending on the part of the brain they're in and their function. There are many types of glial cells, each with different functions. Recently, scientists have discovered that glia—also known as interneurons—are not, as once thought, just a "support" or "housekeeping" cell, but are quite important in brain development, function, and growth.

Figure 1.1

THE HUMAN BRAIN

Estimates vary on the actual number of neurons and glia in the human brain. One researcher who has done detailed studies in this area, William Shankle of the University of California–Irvine, asserts the human brain has about 30 to 50 billion neurons. His studies (Landing, Shankle, Hara, Brannock, & Fallon, 2002) also show a 20 to 40 percent variance among humans, meaning the real numbers vary by *billions* from one person to another. No wonder differentiation in teaching makes sense!

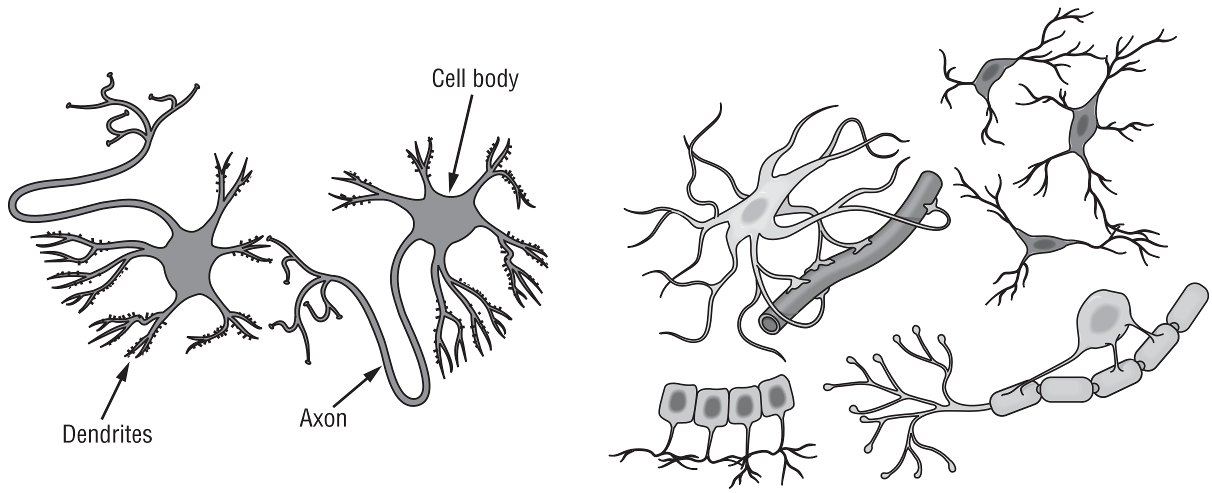
A more mainstream view is that we're born with about 150 to 200 billion neuron cells and keep about 100 billion of them. (The rest disappear for various reasons, as explained later.) By the time we're adults, we also have about 500 billion to 1,000 billion glial cells. For the sake of comparison, a fruit fly has 100,000 neurons, a mouse has 5 million, and a monkey has 10 billion. A single cubic millimeter (1/16,000th of an inch) of human brain tissue has more than 1 million neurons.

Humans have large brains relative to body weight. The adult human brain weighs about three pounds (1,300–1,400 grams). But would a

Figure 1.2

Neurons and Glial Cells

Both neurons and glial cells integrate neural outputs, release transmitters, have long-range signaling, can enwrap synaptic terminals, and are connected by gap junction.



Typical neurons

Neurons receive stimulation from their branches, known as dendrites. They communicate with other neurons, creating a network with millions of other by firing a nerve impulse along an axon.

Various types of glial cells

Glia carry nutrients, speed repair, provide myelin for axons, support the blood–brain barrier, and may form their own communication network. They are also involved in neurogenesis.

bigger brain make you smarter? That's unlikely. A sperm whale's brain weighs about 17 pounds, or 7,800 grams.

The brain's various parts and its nerve cells are connected by nearly 1 million miles of nerve fibers. The human brain has the largest area of uncommitted cortex (with no specific function identified so far) of any species on earth. This gives humans extraordinary flexibility for learning.

Scientists divide brain areas into lobes (see Figure 1.3). The *occipital lobe* is in the middle-back area of the brain, and it's primarily responsible for vision. The *temporal lobes* are located above and around the ears on the left and right sides of the brain. These areas are primarily responsible for hearing, memory, and language. Connect visual areas to language areas, and you can "see" what you hear and say. That's part of the essence of reading: high visual-auditory connectivity. The *frontal lobe* is the area around your forehead. It's involved with purposeful activities like judgment, creativity, problem solving, and planning. It also holds short-term