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

Separating Neuromyth From Neuroscience

It is readily acknowledged that the field of neuroeducation is just beginning to bring to educators usable knowledge. Nonetheless, 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 (e.g., Dubinsky, 2010; Fischer, Goswami, & Geake, 2010; Fischer et al., 2007; Hardiman & Denckla, 2010; Meltzoff, Kuhl, Movellan, & Sejowski, 2009; Tallal, 2004; Varma, McCandliss, & Schwartz, 2008). 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 of the general themes from the neuro- and cognitive 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.

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Neuromyth in Education

In considering neuromyths, we must be aware of not only why they are incorrect, but also how they came to be widely believed among educators. In particular, 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, Pickering, and Diack (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 neuro- and cognitive science research.

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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). Gazzaniga, Ivry, and Mangun (2009) point out that, while each hemisphere ***does have specializations***—for example, Broca's area in the left hemisphere controls much of speech production—(see also the description of Bowden and Jung-Beeman's study in Chapter 8), 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.

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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, Shaw, and Ky (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., 15-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 very 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 10-minute intervals each hour. Thompson, Schellenberg, and Husain (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.

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 60, but we might want to think twice about booking Carnegie Hall.

Language acquisition is a particularly important 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 fully develop language skills. 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, Adelstein, Bryden, & MacKinnon, 1998; Mayberry & Eichen, 1991).

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Second language learning is another, much more controversial area in the study of critical periods. According to Singleton and Lengyel (1995), 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. Recent 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 sensive 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!

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We Only Use 10% of Our Brain

With all of the attention in popular media about the workings of the human brain, it is amazing that this myth still perpetuates. Indeed, many believe that 90% of the brain is inactive (Higbee & Clay, 1998). 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 don't 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.

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

A very 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, McDaniel, Rohrer, & Bjork (2008) found no evidence that children taught in their preferred learning style performed any better than if they were taught through a nonpreferred style.

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Pashler and colleagues (2008) point out, however, that incorporating diverse teaching methods still appears to be a valid way of reaching *any* student. In particular, they suggest that varying presentation methods based on curriculum or content appears to be an efficient teaching strategy. 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 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.

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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 neuro- and cognitive sciences that can and should inform the philosophical beliefs as well as practices of educators at all levels. 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.

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Neurogenesis

Until recently, most neuroscientists believed that, although connections between cells continue to increase in number throughout life, the brain produces no new cells. The discovery of neurogenesis, the production of new cells in certain brain regions, represented an enormous breakthrough in understanding the human brain. In animal studies, 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 (Gould et al., 1999). In addition, it appears that neurogenesis can be enhanced through exercise, nutrition, and stress reduction (Kempermann, Wiskott, & Gage, 2004).

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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. Schools and classrooms, we believed, 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

Regulation of attention to relevant tasks (or even elements of tasks) clearly affects every aspect of learning. 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 (p. 59). 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 (p. 115). The chapter on Brain-Target Two will address how the classroom environment can be shaped to maximize attending behaviors in children.

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Executive Function

The term *executive function* is used to describe basic cognitive processes that underlie on-going, 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, and together allow us to carry out more complex actions such as planning future events, organizing processes, self-monitoring, and regulating emotional response. Many children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) display deficits in one or more of the skills associated with executive function. Although executive function is necessary for most, if not all aspects of learning, this topic will be addressed in conjunction with Brain-Target Five, which focuses on the higher-order thinking processes and application of knowledge. This is one area in which executive function is especially critical for effective learning as it requires being able to draw novel associations and flexibly use information in different contexts.

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The Importance of Movement and Learning

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 latest 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 (p. 53). 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 of various sorts. For instance, heading the Dana Foundation Arts and Cognition Consortium, Michael Gazzaniga (2008) reports a tight correlation between study of the arts and improvement in attention and various cognitive abilities. In addition, James Catterall (2009) reports significant differences in academic achievement and social behaviors between youth highly involved in arts programs compared with those with no arts engagement. 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 15 months of music training showed significant changes in specific brain regions that were also correlated with improvements in musically relevant motor and auditory skills. Building from these connections between the arts and learning, Brain-Target Four 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.

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Adolescents, Sleep, and Learning

Research in the neuro- and cognitive sciences is beginning to shed light on the way 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. A recent study demonstrated significant brain plasticity during the teen years evidenced by both biological and behavioral measures. Ramsden and colleagues (2011) found changes in verbal and non-verbal 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 non-verbal 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.

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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 the academic literature and popular media. In a special *Newsweek* issue dedicated to the topic, Po Bronson and Ashley Merryman (2010) point out that although IQ scores for children over the last 30 years have improved, creativity indices have declined. They cite analyses that examined the declining scores of more than 300,000 children and adults on the Torrance test, a popular measure of creative thinking. Sir Ken Robinson (2001) believes 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.

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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 (Berkowitz & Ansari, 2010; Chávez-Eakle, Graff-Guerrero, García-Reyna, Vaugier, & Cruz-Fuentes, 2007; Fink, Benedek, Grabner, Staudt, & Neubauer, 2007; Limb & Braun, 2008). 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 in order to move children beyond the mere 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.