Educating the Young Child 7
Advances in Theory and Research, Implications for Practice

Leslie Haley Wasserman
Debby Zambo *Editors*

Early Childhood and Neuroscience – Links to Development and Learning

Springer

Early Childhood and Neuroscience - Links to Development and Learning

EDUCATING THE YOUNG CHILD

VOLUME 7

This academic and scholarly book series will focus on the education and development of young children from infancy through eight years of age. The series will provide a synthesis of current theory and research on trends, issues, controversies, and challenges in the early childhood field and examine implications for practice. One hallmark of the series will be comprehensive reviews of research on a variety of topics with particular relevance for early childhood educators worldwide. The mission of the series is to enrich and enlarge early childhood educators' knowledge, enhance their professional development, and reassert the importance of early childhood education to the international community. The audience for the series includes college students, teachers of young children, college and university faculty, and professionals from fields other than education who are unified by their commitment to the care and education of young children. In many ways, the proposed series is an outgrowth of the success of Early Childhood Education Journal which has grown from a quarterly magazine to a respected and international professional journal that is published six times a year.

Leslie Haley Wasserman • Debby Zambo
Editors

Early Childhood and Neuroscience - Links to Development and Learning

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Preface

Educational Neuroscience and the Double Entendre

As you read the following words, jot down or at least notice the meanings that automatically come to your mind. Ready? Here is the list: *attention, plastic, enrichment*, and *concept*. If you are a teacher, you may think of attention as a socially mediated process or of moments in a classroom when children lack it due to either pathology or boredom. Like a tax, it must be minded and paid. If you are a neuroscientist, you are likely to wonder what kind of attention (spatial, selective, orienting, or perceiving) and related to which cognitive process (response inhibition, cognitive control) are we talking about? The word “plastic” may bring images of picnic silverware or possibly your ID. Plastic is a noun, an adjective, and an artificial and sometimes toxic substance but also a fundamental functional characteristic of the body’s most precious and necessary organ, the brain.

“Enrichment” is a word used to describe some programs for gifted students or something extra that teachers add to curriculum when the basics are mastered. It also describes the means by which Marian Diamond discovered that the brains of rats grew more robust dendritic connections when allowed to live in more physically complex environments, and that these connections change dramatically and quickly under different circumstances. Teachers hear the word “concept” and seek to link fact-based information in one domain (the quadratic equation, the parts of speech, cycles of war, photosynthesis, iambic pentameter, harmony) to another using “system” or “pattern” to link them and create higher-level meaning and deeper, more persistent learning. Neuroscientists hear the same word (“concept”) and think of “chair,” “face,” “tool,” and “house,” which are some of the most basic functional elements detected in areas of the brain’s visual system by the early application of functional magnetic resonance imaging (fMRI). Herein lies the story. The fields of education and neuroscience are crossing paths on the street, starting to dance, stopping to stare in each other’s windows, and even looking for the occasional blue light special. We’re interested, intrigued, nervous, and cautiously aware that we are in the age where we can observe learning and performance from the outside and from the inside.

These four seemingly simple words (attention, plastic, enrichment, concept) cascade in one's mind toward vastly different meanings depending on whether you are an educator or a neuroscientist. Fortunately, due to the early crossings of these fields and exchanges between and among renowned and hearty scholars such as Michael Posner, Stanislas Dehaene, Usha Goswami, Brian Butterworth, and others, we find ourselves, today, in this place of unintended *double entendre*. Here, the real work begins. The coin flips. Are there useful concepts within domains such as reading and mathematics that readily lend themselves to examination by neuroscience? How do you represent the true nature of learning in an artificial setting like a laboratory? The complexity of a classroom is daunting to the cognitive neuroscientist wanting to pare down a process to its ramparts. The restraints of this exercise to an educator are wholly unrecognizable as learning. What are we to do?

This volume is an attempt to enter the space of this *double entendre* between neuroscience and education on behalf of learners in the earliest parts of life, the time where informal processes of learning (imitation, emotional attachment and security, and social interaction) shape an individual and turn them toward the formal processes of school. In essence, early childhood is time of free-range learning and discovery. School, at its best, retains these qualities while introducing the structures, skills, and knowledge of disciplines. As fast as neuroscience is making discoveries in the lab, we, as humans, are eager to understand new knowledge and attempt ways to apply it to better the human condition. Education is a natural consumer. The fact that this knowledge advances at such a breathtaking pace, and that in our enthusiasm it ends up extended far beyond itself, challenges us to simultaneously negotiate ourselves out of the *double entendre*. We need to access each other's vocabulary and begin to establish a shared vocabulary. We need a set of ethics, knowledge, and first principles (OECD-CERI, 2007; Tomlinson & Kalbfleisch, 1998) that will keep us from the early adoption of myth and understand that nearly every new finding will be vulnerable to this possibility due to the subjective nature of our own minds and natural tendencies to predict and pattern-find.

Indeed, early cognitive neuroscience research aimed at education and the attempt to remediate basic processes such as how the brain reads (Temple et al., 2003) or multitasks (McNab et al., 2009) show that intervention changes the brain and changes behavior. The brain is plastic; it is designed to respond to experience. One would hope to observe changes in these instances, and science has shown that we do. The gold standard of this plastic change, however, has yet to be measured. Do these changes lead to higher achievement, social success, and quality of life? What are the gains beyond increased metabolism in specific areas of the cortex and a better response time from the learner? Will these technologies become the heart of enrichment, remediation, or cognitive enhancement (Kalbfleisch, 2012)?

Yet, neuroimaging has already given us confirmation of a few ways in which contributions from these methods will spur paradigm shifts across education, society, and medicine. First, exercise is one of the single best things we can do for ourselves; it influences the efficiency of autonomic and neurochemical processes in the body and preserves the life and function of gray matter in certain parts of the brain that support memory across life (Erickson et al., 2011). Second, neuroimaging has shown us that the brains of bullies experience basic emotional processes differently (Viding, McCrory, Blakemore, & Frederickson, 2011) but also that a picture of a pathological process in a single individual predicts nothing (a neuroscientist who studies psychopaths measured that identical functional profile in himself despite the fact that he experienced a good upbringing and lives a productive, well-respected life). Finally, neuroimaging has also shown us that comatose individuals can and do respond in their minds to requests to imagine themselves performing different types of tasks (Coleman et al., 2007). Like Alice through the looking glass, we can measure the differential nature of the biological systems that give rise to behavior. In a 2008 article designed as a neuroprimer for education researchers, I call the nervous system an "endogenous heuristic," our template for understanding the nature of learning that is present in each one of us (Kalbfleisch, 2008).

The issues of learning in early childhood, how nature and nurture contribute to early skill development and individual differences, and the impact of extreme environmental factors on learning (poverty, emotional neglect) are just some of the questions being tackled by public policy, programming, education, and neuroscience research alike. Approaching from separate paradigms, we are interested in the same issues and the same gains in young lives. As much as the vocabularies of neuroanatomy and the methods of neuroscience are important to understand, so, too, are the research methodologies and the nature of the statistics used to examine the noisy signal in the brain. Most people do not realize that most of the computational power leveraged for data analysis is designed to quiet the irrelevant and prominent noise in the signal data we acquire during a brain scan more than to enhance meaningful signal. We seek simply to detect it. Most neuroscientists do not realize that teachers also seek to optimize the signal-to-noise ratio in a classroom to optimize learning. Teachers are engineers and experimentalists every day, but how they are currently trained does not propel them to see the profession in that regard. The methods of education researchers (action research, ethnography, and other qualitative methods) properly paired with neuroscience in the research enterprise will give deeper explanatory power and avenues for translation and application. Educators and neuroscientists have the same goal, to better understand both individual and social levels of learning and to master the transformative power to assess and characterize meaningful learning. The advent of educational neuroscience provides a new way to storyboard our efforts into the same space and onto the same page. This volume provides several avenues into that space and onto that page on behalf of learning in early childhood.

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We would like to thank Mary Renck Jalongo for the opportunity to be a part of this amazing series. Her vision has made it possible for us to reach educators, researchers, and parents alike and set the record straight about neuromyths.

This volume would also not have been possible without its contributors. When this volume was conceived, there was a clear call to be scientific and realistic and to temper the glorious views of neuroscience too often seen. Revealing the truth and reality of applying neuroscience to education were the challenges, and to meet these, the contributors researched the best ideas and used their common sense and practical knowledge to ground neuroscience in the realities and needs of teachers, parents, and young children. Each contributor answered challenging questions, made multiple revisions, and met time demands. As editors, we remain in awe of the bounty and depth of their knowledge, appreciate their collegial spirit, and appreciate the hard work they did to turn a vision into reality.

I would like to thank my parents (James and Joan Haley), husband (David Wasserman), and children (Timothy-TJ, Haley, and Sarah) for their continued support as I follow my educational journey.

I would also like to thank Debby Zambo for her expertise and encouragement throughout this endeavor.

Leslie Haley Wasserman

I would like to thank my husband (Ron Zambo) and my family (Nikki and Perry Parmely). You are always there to listen, challenge, and support me.

I would also like to thank Leslie Haley Wasserman who out of the blue contacted me and asked if I would like to coedit a text on young children and neuroscience. How could anyone say no?

Leslie has been the driving force of this volume because of her vision to make things better for young children. Leslie's caring nature, commitment, and knowledge have been inspiring. It has been an honor to work with her.

Debby Zambo

Contents

Chapter 1
Introduction

Leslie Haley Wasserman and Debby Zambo

How Does a Volume Such as This Come Together?

The authors and editors of this book also have this same goal and believe that findings from neuroscience can become an additional layer of understanding. Each one of us wants to foster the learning of children and help them fit and be successful in the world, and each one of us is passionate and hopeful that findings from neuroscience can help us accomplish these goals. By using this passion, we will broaden our knowledge and discover things that were once unknown. Our passion will help us make a difference.

Importance of This Book for Educating Today's Children

As neuroscientists learn more about brain development, chemistry, and structures, their findings are seeping into the education and care of young children. Teachers and caregivers are reading about brain development in magazines and watching television shows that explain how the brain learns. What was once a specialized field with technical jargon is being disseminated, yet some of this information is more reliable than others. Neuroscience can be used to create false hopes. The field of education needs conciliations of ideas, and this volume *Early Childhood and Neuroscience: Links to Development and Learning* will do just this.

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This volume fits with Springer's *Educating the Young Child* series and contributes to it by bringing together a group of 15 distinguished authors writing on an array of interrelated educational topics and practices. Authors were sought based on their cutting-edge research and/or expertise in the field of neuroscience and early childhood education. Authors were invited because they knew neuroscience and understood how it could and could not be applied to early childhood education. Each author is well respected in the field. They have published their works in many different venues such as books, peer-. Given this expertise, the authors have blended research, theory, and practice, in an attempt to provide proven and effective strategies educators and caregivers can use to shape the learning, emotional, social, and behavioral needs of all young children, including those with exceptionalities. Chapters in this volume focus on the ethics of neuroscience, brain development, best practices including good curricula, healthy environments, reliable information, and assessment strategies to use to ensure young brains are educated appropriately.

This volume is necessary and timely. We hope it will become a valuable resource for you and offer strategies that help you affect children today and influence the adults they will become tomorrow.

Overview of Book

This volume dispels neuromyths and gives insight into how to use neuroscience to understand and utilize the information gleaned to educate young children. Each chapter discusses a different topic that is intertwined with neuroscience and how it impacts young children.

In Chap. 2, you will find information about the practical and ethical concerns of using neuroscience to teach young children. In Chap. 2, Dr. Debby Zambo raises questions that can be used when neuroscience is involved in educational decisions. These questions are posed because even though information from neuroscience is growing, and becoming part of our daily conversations, we must not lose sight of the fact that it is a new and quickly evolving field. As educators, parents and caregivers we need to be fascinated of neuroscience and skeptical of it at the same time and we need to understand the types of moral decisions we make, how we make them, and what this means to the children in our care. In many ways Chap. 2 brings more questions than answers, but it has been written to provoke thought and reflection and, when necessary, encourage preemptive actions to preserve the identities, destinies, and development of young children in our care.

Chapter 3 discusses how everyone is unique and how sharpening each of our perspectives on child development and learning is important. This chapter written by Dr. Diane Connell and Ms. Jena Van Stelton, M.Ed., applies selected strategies to the field of early childhood education and strategies that are designed for diverse and inclusion-based early childhood education classrooms. An in-depth focus on hereditary and environmental influences on learning is discussed. From a genetic perspective, it appears individual neurological strengths and weaknesses develop in utero; from an environmental perspective, it is clear that a child's early home and school experiences affect his/her brain growth and development over his/her lifetime. To help readers find ways to reach every learner, this chapter intersperses mind, brain, and education research along with recent observations of older preschool students.

Well-known authors of books on reading, Drs. Nancy Frey and Douglas Fisher, have been widely read by educators everywhere. In Chap. 4, these authors share their wealth of knowledge about reading and the young brain. They discuss how neuroscience confirms and extends our understanding of reading development in young children and raise further questions that are not yet answerable. They help educators realize their work functions as a bridge builder. As teachers we seek to utilize the findings that allow us to create instructional environments that work. And while the field of educational research has long been conversant with psychological research, the more recent body of knowledge coming from the neurosciences has posed a challenge. How can educators incorporate findings from neuroscience into their work? Are there findings that confirm what is already known? Are there any findings that shed new light on compelling issues that matter to early childhood education? As reading researchers, these authors pose these questions to wrestle with as the participatory theories of neuroscience are transferred into the action theories of education.

Chapter 5 written by Drs. Valeri Farmer-Dougan and Larry Alferink compares recent educational curricula that purport to utilize research findings from neuroscience to promote improved learning and retention with the actual neuroscience findings. The authors note that much of the reasoning behind these new curricula is based on misinterpretation or oversimplification of neuroscience findings and/or is just not supported by the actual data. Even though the chapter is critical, it is also optimistic and informative. It concludes neuroscience does have much to say about the developing brain and how it learns.

Chapter 6, written by Dr. William Mosier provides an overview of the existing literature on how the affective domain impacts learning during early childhood. Developmental concepts are presented that have emerged from many decades of research. A consensus of what is understood about the emotional and social development of young children is presented for critique and exploration. A framework is offered within which the emotional needs of young children can be optimally addressed. The goal is to promote a clearer understanding of the science of early childhood development and its underlying neurobiology.

Learning about how early literacy trends for children identified as at risk for school failure and how they are consistent with contemporary neuroscience and learning theory is discussed in Chap. 7 by doctoral candidate, Rae Ann Hirsch, M. Ed. Current trends in early childhood curriculum for children identified as at risk for academic school failure need to embrace current neuroscience and learning theory to fully provide a strong cognitive foundation for learning and literacy. Healthy emotional development is a powerful building block in the brain and needs to be addressed in policy and practice as a necessary conduit to cognition is discussed.

Chapter 8 discusses autism spectrum disorder (ASD) and was written by Dr. Diane Branson. This chapter contributes much because advances in neurocognitive testing have established that ASD is a neurodevelopmental disorder affecting many different brain areas. There is evidence that ASD is a disorder of underconnectivity among brain regions that would typically work together in cortical networks to accomplish higher-order cognitive tasks, including language processing and production and social interactions, and goal-directed planning and monitoring are discussed.

Throughout Chap. 9, Dr. Leslie Haley Wasserman reveals the complexities of students identified as twice exceptional and the implications of this complexity in classrooms today. A brief overview of gifted education and special needs is provided as background for the reader so that the information provided is clear and leads to identification and understanding of just who twice-exceptional students really are. The relationship between twice-exceptional young learners and the role neuroscience plays in making their lives and the lives of those who live and work with them more successful will also be discussed.

Chapter 10 written by Dr. Niamh Stack, examines government and local intervention programmes designed to augment the development of children from at risk populations through a developmental neuroscience lens. From this work Dr. Stack discusses how advances neurobiological issues might be used to inform policy and practice.

Chapter 11, written by Drs. Billie Enz and Jill Stamm, concentrates on effective strategies to help teachers learn about brain development. Sharing new understandings about the brain and brain function has become essential to the preparation of teachers. There is little doubt that the organ of learning should be a staple in teacher education. A close examination of what learning principles motivate these teacher actions shows that there are solid, well-researched principles that underlie the behaviors. The real reason however why effective teachers do what they do is actually because of the ways in which the brain works. They discuss how knowing some brain basics helps us, as teachers, to look deeper than our behaviors to then be able to understand *why* learning occurs more successfully when we behave in one way versus another.

Chapter 12, written by Dr. George Hruby, discusses metaphors of developmental processes for brain-savvy teachers. He argues that to make good use of educational neuroscience and to contribute effectively to the conversation about its application in schools, teachers require more than a smattering of brain facts, hackneyed rhetoric, and overconfident commandments supposedly authorized by "hard" science. Teachers need to know a lot more about science itself, and about the dynamics of biological development, to make sense of brain transformation through instruction. But, to begin, teachers and teacher educators need a cohering metaphor to make sense together of the brain, brain processes, student learning, and effective teaching. From such a metaphor, easily grasped narratives of how such things work and work together can emerge to inform high-quality teacher professional development. From this, a compelling picture of what student achievement and effective instruction look like from the purview of educational neuroscience should emerge to direct teacher professionalization.

Conclusion

As you, the reader, can see, this volume covers many of the important topics in early childhood today. It is our hope that each chapter will help you understand that each child brings his/her own unique strengths and needs to us. We, as educators and caregivers, need to have an understanding of children's diverse backgrounds such as their differing ethnic cultures, religious views, family structure, and prior knowledge. This is an obvious statement that teachers already are aware of and are putting into practice. Teachers also follow best practices and allow for children to use their particular intelligences within the classroom. Teachers understand and apply various theories such as Vygotsky's social learning theory or Piaget's cognitive development theory that we learned in our methods' courses in higher education. But when, where, and how do teachers and caregivers learn about brain development and the importance of the windows of opportunity within the brain to teach our students to the best of their abilities? This volume is a wonderful addition for this knowledge and how to reach your potential as an educator by inspiring and teaching your students how to reach their own potential to achieve success.

Chapter 2
The Practical and Ethical Concerns of Using Neuroscience to Teach Young Children and Help Them Self-Regulate

Debby Zambo

Introduction

In the 1990s, neuroscience was burgeoning because of technological advances. As technology developed, neuroscientists began to glimpse brain development and see brains functioning as they learned and performed tasks. However, with technological innovations come challenges, and nowhere is this more evident than early childhood education. Neuroscientists and others are attempting to translate what was once a specialized field filled with technical jargon and findings into understandable information teachers of young children can use. And teachers are interested in this information. Educational neuroscience (or the intersection between mind, brain, and education) is seeping into the textbooks teachers are reading, the curriculum they are receiving, and the products they are purchasing. This information has the power to help teachers understand how young children learn, self-regulate, and think, but it also has the power to radically alter how children are nurtured and taught (Stein, Chiesa, Hinton, & Fischer, 2010).

As a teacher of young children (grades K-3) with learning and self-regulation challenges, I came to value neuroscience when I took an educational psychology course for my Master's degree. My teacher was Dr. Jill Stamm (a contributor to this volume), and in her class I learned about brain structures and functions, and this helped me understand how different and unique the brains of my young students were and how this difference translated into their actions. In Dr. Stamm's class I learned about the amygdala, and how it worked with other structures to activate the fight or flight response. When I learned this, I came to understand why David, a young boy in my classroom who had been neglected and abused as an infant, hid under his desk every time he heard a loud noise. When Dr. Stamm showed our class a picture of a brain with fetal alcohol syndrome and one without it, I was able to see

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the size and structural differences in these brains. Seeing these images helped me understand why Matthew, a boy in my class with fetal alcohol syndrome, struggled so hard to learn. Neuroscience helped me understand the biology of my students' learning and behaviors, and I'm sure it has done the same for countless teachers, parents, and caregivers like you.

Thanks to a teacher like Dr. Stamm, the good information she supplied, and my own experience, I came to understand the usefulness of educational neuroscience. However, when I moved from teaching young children to teaching educational psychology and child development to preservice and in-service teachers, I began to see another side of neuroscience. Even though our textbooks had chapters on brain development and talked about the limitations of neuroscience for educators and even though I provided information on brain structures and functioning in class lectures and discussions, I always heard students misusing or overextending ideas from neuroscience. Students were telling me about the hemispheric strategies they were using to remedy complex learning problems like dyslexia and autism, and they were standing by Ritalin and Adderall as the only means to help young students with attention problems learn to self-regulate. Worried about these practices, I began to wonder why so many of my students were buying into neuromyths or ideas with only a nugget of scientific truth. My students were misreading, misquoting, and overextending ideas from neuroscience and using these to confirm the biases they had. Instead of opening their minds to the valid information in their textbooks and from my lectures, my students were only paying attention to what aligned with their beliefs, forming their own folk theories, and building narratives based on the telling and retelling of their beliefs. This behavior concerned me because I knew it could have both educational and ethical implications (Farah, 2005; Organization for Economic Cooperation and Development [OECD], 2007). Fallacious beliefs about neuroscience and education could cause the students in my classes to waste valuable instructional time, treat young children unfairly, set low expectations, and spend their hard-earned money on worthless products and programs that did little good. Howard-Jones (2010) notes that neuromyths have a major influence on shaping the perceptions and views of educators, and this seemed to be the case with my students.

Realizing this, I became concerned but knew I needed data. So in 2006 a colleague and I began to investigate what preservice and in-service teachers at varying stages of their careers and other college students knew, thought, and believed about neuroscience and education. Since 2007, we have gathered data from approximately 850 individuals, and this data leads to some interesting insights. Our data from educators shows that they are interested in neuroscience and are using the Internet, television, workshops, and courses to gain information from it. Educators believe neuroscience should be a part of their training, and they believe that it will make them better teachers especially when dealing with students with special needs. Many of the teachers we surveyed believe that the products and strategies they are using help learning because there is a link to neuroscience (e.g., *Baby Einstein*, *Your Baby Can Read*, and *Brain Gym*®). For too many teachers, fads take precedence over research and facts (Zambo, 2008; Zambo & Zambo, 2009a, 2009b, 2012).

However, when it comes to believing in the value of neuroscience for teachers, our research told us not all teachers are the same. Many believe wholeheartedly, some hold reservations, and others, although few in number, see no use for neuroscience at all.

Believers see neuroscientists as experts and accept neuroscience because of its reliance on new technologies. Believers think neuroscientists can tell them what and how to teach, and because of this they want this information. Believers attend workshops, take courses, and buy DVDs to help them learn about the brain, and they share this information with each other. Believers see neuroscience as the most current and up-to-date information teachers can receive. They believe neuroscience is especially valuable to help them know how to teach students with special needs. To this group, neuroscience can be used to diagnose learning problems and understand how to differentiate instruction for different learning styles.

Believers with reservations were fewer in number than believers. These teachers always started saying something positive about neuroscience and education but stopped midstream and changed their mind. Believers with reservations thought information from neuroscience was useful, but as they began to articulate their reasoning, they always became less sure. Believers with reservations accepted neuroscience but felt it was only part of the information they needed. When it came to teaching and learning, they wanted information from educational psychology, psychiatry, and child development as well.

Whereas the believers saw neuroscientists leading them in the right direction, believers with reservations did not believe they were capable of understanding the vocabulary and technical ideas neuroscience posed. They said things like: "Teachers are not neuroscientists or doctors. They need someone to help them sort ideas out." Believers with reservations would not mind learning about neuroscience, but they wanted this information to be focused on their students' needs.

In contrast to these groups, nonbelievers were cautionary and hesitant. These teachers were not going to accept information from neuroscience without evidence and facts. Nonbelievers wanted results from carefully controlled studies, and they wanted to know how conclusions were drawn. Nonbelievers saw neuroscience as a cult-like fad and advocated for the human side of teaching. To them children were more than what was captured in brain scans. This group believed the interactions between teachers and students mattered more than an image on a screen (Zambo & Zambo, 2011).

Our data told us teachers were interested in neuroscience, but not all teachers were the same and this had implications. It told us that many preservice and in-service teachers were interested in neuroscience, consuming this information, and had hopes that it would make them better at their work. Wanting to understand the differences between believers and nonbelievers and what was so alluring about neuroscience to so many preservice teachers, we replicated one of McCabe and Castel's (2008) experiments. Like these researchers we gave students a fallacious passage about the positive effects of television on mathematical learning and supplied evidence for this claim with an fMRI (functioning resonance magnetic imaging) image, a graph, or nothing at all. With these three conditions we found that the students both in and out of education, in our college like McCabe and Castel's, could be misled with information from neuroscience, especially when an image was involved. From this work we found our participants, like McCabe and Castle's, thought the article with the fMRI image was more credible than the articles with a graph or no image. Participants also linked fallacies about learning to neuroscience. They believed neuroscience confirmed the reality of learning styles, the importance of multisensory learning, and the fact boys were active hands-on learners. This study helped us understand the neuromyths that can be perpetrated when the direct implications of neuroscience for educators are "oversold" (Zambo, Zambo, & Sidlik, In press).

Being intrigued by the fact our respondents felt that neuroscience was especially useful to understand and teach students with special needs, we investigated what a group of preservice teachers knew about attention deficit hyperactivity disorder (ADHD) and what they thought about medical science and neuroscience in terms of helping them educate students with this disorder. In this study we had a general questionnaire and manipulated the type of information participants received. Half of our participants saw an fMRI image and read about ADHD from a neuroscience perspective (e.g., faulty neuroreceptors responding to the neurotransmitter dopamine). And the other half saw an image of a premature infant and read about ADHD from a medical perspective (e.g., infants being born prematurely and weighing less than 3.3 lb often develop ADHD).

Data from this study showed that preservice teachers really know a lot about the students with ADHD. They know children with ADHD are hyperactive, excitable, impulsive, irritable, and seldom tired, and that medication suppresses some of these symptoms for some children. They also know these characteristics inhibit a student's learning. They know children with attention challenges are distractible, have trouble focusing/concentrating, are off task much of the time, struggle to process information, and have social and family problems. When asked where they learned this information, they said they, their friends, or their family members have ADHD, celebrities on television talk about it, and it is discussed in their courses (especially special education courses).

Data from the two conditions (neuroscience and medical science) showed slight differences. Participants who saw the fMRI image and read information from neuroscience believed it was useful to help them. These participants felt neuroscience could help them identify students with ADHD earlier, advocate for their needs, understand how their brain works, and understand why they behave in certain ways. Participants in the neuroscience condition also thought neuroscience would help them teach these students. They thought neuroscience could help them learn how to create learning environments conducive to these students' needs, create and teach better lessons, and know how to redirect students so they would remain on task.

In comparison, participants who saw the image of the premature infant and read information from medical science also saw it as useful but in slightly different ways. Participants in this group thought medical science would help them understand the cause, signs, and symptoms of ADHD, if medications were working, and know how to manage students.

This work over the years maps a trend in educators' thinking and beliefs about neuroscience. It is safe to say that students in teacher preparation programs and teachers working in schools are being exposed to information from neuroscience. When it comes to believing in the benefits of neuroscience, however, educators fall along a continuum such that some accept unquestioningly that neuroscience can offer ways to improve their instruction (particularly for students with special needs) and manage students in the classroom, while others view brain research with considerable skepticism. While there is little doubt that neuroscience—particularly when it is combined with other disciplines like human development, cognitive science, and behavioral science—can illuminate the biological basis of learning, confirm developmental differences, and help educators, parents, and caregivers understand how a brain learns; it is also clear that for many educators, how to use this information, where it fits, and what is valid are not totally clear (della Chiesa, Christoph, & Hinton, 2009). Neuroscience can be used to create false hopes and market products that have little or no salutary effects (Dubinsky, 2010; Howard-Jones, 2010; Stamm, 2007; Wolfe, 2001; Willis, 2006). Calling it "a bridge too far," long-time critic John T. Bruer (1999, 2006) has warned educators to take a cautionary stance in applying neuroscience to their field. Likewise, Bear, Connors, and Paradis (2007) note that when it comes to neuroscience, educators are often overzealous. Others echoed similar sentiments and conducted research as to why neuroscience is so alluring. In their work, McCabe and Castel (2008) and Weisberg, Keil, Goodstein, Rawson, and Gray (2008) found fMRI images to be persuasive and lead to misunderstandings. To these researchers, images appeal to intuitive, reductionist notions of learning, and educators need to be careful when they think about the complex process of learning. More recently, Sylvan and Christodoulou (2010) found neuroscience being used to create learning theories and principles, develop strategies to change behaviors, and create products that claim to have explicit brain links. These researchers concluded that each of these uses of neuroscience makes sense if they match the educational needs of children, are cost-effective, align with other scientifically based research, and produce observable behavioral effects. Hruby and Goswami (2011) offer solutions to the problems facing the neuroscience education interface by calling for varied disciplines (brain, social, cognitive, cultural) to converge. Neuroscientists can help educators understand how the brain decodes and comprehends language if methodological and conceptual challenges are aligned. Given these potentials and concerns, it is important that teachers and other caregivers realize that:

- Some information from neuroscience is being overextended, misinterpreted, and oversimplified, and this has implications.
- There are curricula, books, and products that purport to use findings from neuroscience to promote improved learning without any scientific backing.
- Emotional catch phrases are being used to pose quick and easy answers to complex learning and behavioral challenges.
- Testimonials are not the same as empirical facts gathered by researchers with reliable and valid tools.

- Neuromyths exist and are difficult to change because they fit reductionist and intuitive notions of how the brain works.
- Images from new technologies can be persuasive and misleading.
- If interpreted literally, and in isolation, neuroscience can reduce learning, behavior, and emotions to biological processes alone.

Teachers want to be effective, are looking for new ideas and strategies, and are turning to neuroscience for insight and support. However, if teachers are sold faulty information and bad ideas, they may unfairly determine the trajectory of children, offer unnecessary or unethical treatments, and reduce learning and behavior to processes devoid of the need for human contact. The gap between neuroscience and education is being forged—but educators need to be cautious. Teaching is a moral enterprise, and teachers must not only consider what science can provide but they must also consider the ethics involved. Scientific answers come from tools and techniques that are detached, systematic, and precise. Moral questions come from the application of these tools and findings on young children's lives (Gopnik, 2009).

The remainder of this chapter is devoted to explaining some ethical issues neuroscience brings to educators, parents, and caregivers of young children. It begins with overarching ethical concerns related to neuroscience then transitions into the ethics and morals of teaching and caring for young children. This chapter ends with insights into how moral judgments are made and links this decision-making process to practical implications of neuroscience and young children. Due to the fact that moral issues are complex, this chapter cannot supply all the answers. However, it should provoke thought and reflection, and when necessary encourage preemptive actions so the identity, destiny, and development of young children will flourish and grow.

Ethical and Moral Issues Arising from Neuroscience

Neuroscience is affecting all of us in many ways (Goswami, 2004; Hruby & Goswami, 2011). Baby boomers are benefitting from treatments designed to maintain mental acuity, and young children are benefiting from early interventions. The mind and brain have always been of interest to philosophers, but because of technological breakthroughs, the brain has become the focal point of more and more research and writings. In the past 50 years, more information about the brain has been distributed to laypersons than in the past, and this trend is likely to continue to grow (Stamm, 2007; Stein et al., 2010). More findings will likely lead to more interest, more treatments, and fewer calls for restraint. Neuroscience is seeping into our lives and the lives of our young children, and because of this ethical and moral concerns are beginning to surface more and more. Neuroscience can be used for good or bad purposes, and because of this the field of neuroethics was born. Neuroethics sits at the intersection between neuroscience and the ethical, legal, and social implications it brings. To Racine and Illes (2006) neuroethics focuses on the right and wrong, good and bad treatment of, perfection of, or unwelcome invasion of, and worrisome manipulation of the human brain. Gazzaniga (2005, 2011) extended the idea with specific implications related to social issues like mental illness, mental degeneration, and mortality. To Gazzaniga, neuroscience should help everyone develop a brain-based philosophy of life. However, this is not easy because we tend to focus on ideas that align with our beliefs and allow our beliefs and emotions to cloud our judgment. To develop a brain-based philosophy, we need valid information and time for deep and reflective thought. Beliefs are not easy to change and neuroscience and ethics do not easily mix. Some findings from neuroscience are difficult to consider because they make us question the very fabric of who we are, who we can become, and how we will live our lives.

New technological developments and the spread of information are bringing two concerns to everyone. The first concern asks what neuroscience can be used to do or its technical capabilities (e.g., use brain images to determine personalities, prescribe drugs to alter brain chemistry, and utilize treatments to enhance functioning). The second concern focuses on what can be learned from neuroscience or its practical implications (e.g., use the biological basis of cognition, behavior, and personality). Buller (2005) has coined terminology for such concerns, referring to them as the "ethics of neuroscience" and the "neuroscience of ethics." To him, caution should accompany any scientific advancement. Without it, things can go awry.

If educators, parents, and caregivers fail to act fairly and responsibly, keep information confidential, or consider the safety and unintended consequences of treatments neuroscience can bring to the lives of children, neuroscience will be used in unethical ways. An example of this comes from medication and young children diagnosed with attention deficits. Neuroscience has revealed that the neurotransmitter dopamine is lower in individuals with attention challenges, and because of this they have trouble with self-regulation and are impulsive and quick to grab at rewards. Regulatory problems are being translated into biological functions, and psychopharmacology is being used to remedy difficulties (Stein et al., 2010). Medications like methylphenidate (Ritalin) and amphetamine (Adderall) slow the reuptake of dopamine and decrease symptoms in 70–90 % of cases. In the past 10 years, more and more children, at younger ages, and adolescents are being medicated because their parents and teachers want them to succeed academically, socially, and emotionally. Unfortunately, medication is often the only treatment some young children receive despite the fact that absolute proof of its benefits is not available at this time, and little is known about its effects on children and adolescents (Farah, 2005). While there is no doubt that medication helps many young children, there are also unintended side effects like weight loss, sleeplessness, and cloudy minds (Chau, 2007). Neuroscientists, physicians, psychiatrists, psychologists, and social workers warn that medication alone is typically not enough to treat attention challenges. Medical interventions need to be coupled with behavioral, social, and emotional support. So while medicine is a piece of the puzzle, it is not the entire solution. Locating an attention problem solely in a child's brain and treating it with a brain-altering medication get quick results but do not offer a cure or help a child understand his/her challenges. Medication focuses on changing behaviors. It does not increase self-awareness or heal a body or mind (Farah, 2005; McCabe et al., 2005; Morse, 2006; Stein et al., 2010). Neuroscience tells us that interaction is key. If we place young children on medication and fail to interact or talk with them, their esteem and self-worth will become damaged.

The intent of this chapter is not to criticize or condone the use of medication. It is, however, intended to make educators, parents, and caregivers aware of the moral questions that can arise like: Can using medication cause psychological harm to a young child (e.g., lower esteem and motivation)? Will a young child on medication be robbed of his/her identity? When it comes to medication, what are our responsibilities? Answering these questions determines how systems and families intervene in children's lives. Given the fact that the minds and personalities of young childern are just forming, medical interventions could rob children of their identities and make them incapable of assuming authorship of their own lives. Habermas (2003) noted that the careless use of biomedical advances could undermine the organismic conditions that allow for ethical self-understanding and responsible agency. In the wake of biotechnologies that allow adults to directly intervene in children's neurobiology, teachers, parents, and caregivers need to reflect on their actions and ensure that all children are allowed to be themselves and have a voice in their lives (Dubinsky, 2010; Stein et al., 2010; Mahoney, 2009).

Moral and ethical issues are surfacing and affecting children, teachers, parents, and society, and as caregivers we must begin to take note. Our beliefs and decisions have consequences because young children depend on us.

Education as an Ethical/Moral Enterprise

In 2005, Bullough set out to investigate the ethical and moral matters being investigated and reported in education. To do this he reviewed research articles published, including the well-respected peer-reviewed journal *Teaching and Teacher Education*. To organize this review he asked the following questions:

1. In what sense is teaching an ethical and moral enterprise?
2. What is the nature of the ethical issues confronting teachers and how do they think about them?
3. What must teacher educators do to help teachers learn how to make moral decisions?

Results from Bullough's investigation indicated that the authors of manuscripts in this journal believed teaching was a moral enterprise. To them, what teachers did and how teachers thought and acted were morally laden. The manuscripts written for this journal revealed the status and power teachers' held over children's lives and explained how, ethically, this could be either good or bad. Teachers could use their power to track children, set low expectations, or teach in ways that imparted only their point of view. Power could stifle ideas and exclude certain points of view. To be moral, teachers needed to listen to the voices of their students, respect their opinions, and care about the cognitive, physical, social, and moral development of every child. Unfortunately, this is not always easy because teaching is embedded in a political world full of uncertainties, difficult choices, and fast change. Neuroscience is changing the way children are viewed, and today's teachers are facing issues that 10 years ago would never have come into play. Caring for each child's free will, identity, and self-worth are a few of the many and complex issues today's teachers are facing, and not all teachers respond the same way. Life experience, values, and convictions help a teacher and others in children's lives respond with sensitivity and care.

So if teaching brings power and demands ethical thinking, what can teacher educators do? Will incorporating ethics in teacher training matter and if so how should ethics be taught? Looking at the articles in his review, Bullough found a consensus that teacher training, at all stages of development, should include ways to develop the moral and ethical reasoning of teachers. To achieve this goal, Bullough supplied a set of promising practices such as using case studies focused on moral issues (e.g., due process, authority, the hidden curriculum), teaching a moral vocabulary, and offering time in teacher preparation to discuss and reflect on moral issues that matter in children's lives and their lives as teachers. Yet, even with this type of instruction, Bullough acknowledged that old ways of thinking are difficult to change. Ethical and moral development takes time and experience. It is "hard won" (p. 13).

This statement is powerful, and Bullough concluded saying that even though the works he reviewed were published in a top-tier educational journal, they focused on a limited number of ethical issues, failed to capture the complexity of moral issues teachers face, and failed to translate theory into practice. To him, there a gap remains in our understanding of ethical issues. In Bullough's eyes too many educational researchers and teachers are speaking metaphorically about ethical issues instead of talking about real problems and reflecting on their practice through an ethical lens. Teachers confront injustices and teaching is a moral occupation.

Another individual who has written about the ethics of teaching is Nell Noddings (1999, 2005a, 2005b). Noddings advocates teaching the "whole child," and to her, this means focusing on each child's physical, moral, social, emotional, spiritual, and aesthetic development. To Noddings, the purpose of school is to produce graduates who are thoughtful citizens with consciousness and the ability to think and act with care. To Noddings the development of these qualities should be embedded in each subject. They should not be fragmented or added-on. Noddings' ideas have practical application. For example, as children learn about science, they can also read poems about the effects of their behaviors on the environment and read biographies of scientists who have advocated moral ideals. Activities like these can make science more interesting and help children understand the social and ethical consequences of their actions. Once children become aware that they have influence, they will act to make things right.

In a similar vein to Noddings, Brunkhorst (2005) wrote that the values teachers have were a key part of the moral actions they take. Brunkhorst investigated teachers' values and discovered that teachers with strong values are enthusiastic about their subject matter and know how to teach it in a way that encourages creativity, interest, and talent. Teachers with strong values instill curiosity and an undying passion for deep learning, and they do not gloss over difficult issues or moral challenges.

A practical way to teach values is to model an ethical stance through one's actions and words by showing genuine respect for each child, his/her family, and the community in which they live. Ethical teachers model ways to be empathetic and understanding. They go the extra mile if they see a family or child in need. These teachers approach life with honesty, dignity, and self-respect and inspire students to do the same.

Bruce Law (2005) has similar beliefs to Noddings and Brunkhorst, but instead of focusing on developing moral individuals, he promotes developing moral schools. To Law, schools should be humane places, and to make them this way, he believes a collective intentionality, or shared vision to make the world a better place, must be forged between administrators, teachers, and children. A practical way to achieve this vision is to reflect on one's biases, privileges, convictions, and perspectives. To Law, the good of others should become a school's primary concern, and administrators, teachers, and students need to collaborate to make this a reality.

This brief review of education as a moral enterprise is by no means exhaustive. There are countless others who have written on the ethics, morality, and values of teachers, education, and schools (e.g., Beckner, 2004; Campbell, 2004; Colnerud, 2006; Noddings, 2005a, 2005b). This brief review was written to show the importance of thinking about teaching as a moral enterprise, what ethical practice means, and how schools, teachers, and children can work together to become moral individuals. As noted earlier, these ideas apply outside of school as well.

Neuroscience, Educators, and Ethical Decisions

Teaching young children at a preschool, at home, or at a community center is a moral endeavor, and as science moves forward the ethical challenges educators and caregivers face will continue to grow and change. Neuroscience is seeping into all of our lives and changing what we know and think about children. Child rearing and neuroscience are entwined and, given modern advances, will become more entwined in the future (OECD, 2007). Today's teachers and parents are using facts from neuroscience to understand children, make instructional decisions, and confirm and disconfirm the beliefs and ideas they have (Zambo, 2008, 2009a, 2009b, 2011). Neuroscience is reforming practice and policy, and because of this, more and more ethical concerns are coming into view and ethical decisions can be perplexing. When it comes to young children and neuroscience, how does an adult know what to believe? How does one judge what is right or wrong, what is just or unfair? Where can one find reliable information? Whose ideas matter most? Neuroethics brings questions like these into focus, and this is important because of the power adults have on the lives of young children. Moral questions have been asked for centuries, and philosophers have uncovered five approaches used to deal with them.

A Utilitarian Approach to Moral Decisions

Individuals with a utilitarian approach question the future effects and benefits of new ideas in terms of the greater good. Individuals with this approach believe in preventing harmful acts, punishing offenders, and rehabilitating those who can be saved. To individuals with this approach, those who cause harm should be punished. No treatment should be used for manipulative or selfish reasons.

A Rights Approach to Moral Decisions

Individuals using a rights approach question how ideas respect rights. Individuals with this approach believe in the freedom to choose. They believe everyone has the right to decide what they want to do with their lives and the right to have their choices honored. To them everyone deserves:

- Truth and information
- What has been agreed upon or promised
- Privacy, or the right to do, believe, and say what they choose in their personal lives as long as they do not violate the rights of others
- Safety and the right not to be harmed or injured unless they freely and knowingly do something to deserve punishment or freely and knowingly choose to risk injuries to themselves

Individuals with a rights approach condone individual choices and the privacy and safety of everyone. When it comes to neuroscience, they would place an individual's right to know and make decisions over any scientific advances.

A Fairness or Justice Approach to Moral Decisions

Individuals with a fairness approach focus on justice and equity. Individuals with a fairness approach ask who benefits from findings and who is left out? To them favoritism and discrimination are wrong. Individuals with a fairness approach would ask whose voices are being heard and whose are being left out? The work of Noddings (1999, 2005a, 2005b) in the previous section captures a fairness approach and leads to understanding how individuals with this perspective would view neuroscience. Who would benefit and who would lose would be their main concern.

A Common-Good Approach to Moral Decisions

Individuals with a common-good approach focus on connections. Individuals with this approach assume individuals are inextricably linked to each other, the community, and the wider world. Individuals with a common-good approach see communities as vital. To them communities should be built upon common goals and values. When it comes to any advances, individuals with this approach consider how social policies, systems, institutions, and environments ensure the development of everyone. Law's (2005) idea of moral schools fits a common-good approach and leads to understanding how individuals with a common-good approach would approach neuroscience. To them neuroscience should be use for the good of every child, adolescent, and adult.

A Virtue Approach to Moral Decisions

Individuals with a virtue approach focus on becoming or being virtuous. Individuals with this approach ask questions like: "What kind of person should I be? How can I develop virtue within myself and my community?" Individuals with a virtue approach ask these questions because they believe everyone should develop and live up to certain ideals. Virtue to them is nurtured with reflection, honesty, compassion, and integrity. Bullough's (2005) view of the moral development of teachers and Brunkhorst's (2005) view of teacher's values fit a virtue approach. When it comes to neuroscience, individuals with this approach would reflect on their beliefs and values.

These five approaches provide insight into the ways individuals approach moral decisions and can be used to raise questions about how the findings from neuroscience can be used fairly, for the common good, and for the betterment of every child. Findings from neuroscience should be stirring ethical questions about the very nature of education and childcare like:

- How are we using findings from neuroscience to influence how we think about, and interact with, the young children in our care?
- How might we use neuroscience with children who depend on adults?
- How might we use neuroscience to better the lives and learning of young children? Is the autonomy and identity of children being respected?
- Can information/main messages from neuroscience be used to teach young children and help them develop self-regulation?
- Are we implementing strategies suggested by neuroscience to help young children reach their full potential?
- How might we use neuroscience fairly, equitably, and justly?
- Are we using neuroscience to understand the abilities and disabilities of young children? Can neuroscience be used to avoid deterministic views, labels, and stereotypes?
- What responsibility do manufacturers have when they say their products or strategies are based on neuroscience? Should there be sanctions when advertising purports scientific findings from neuroscience but are completely false?
- How can we avoid perpetrating neuromyths?

Questioning, of course, does not provide automatic answers to moral problems, but it does bring into focus the need to seek valid information and keep a critical eye on the facts we receive. Findings and treatments from neuroscience can have positive or negative effects. Interventions can help children focus, become better readers, and understand how to regulate themselves. But if we are not careful, they can also rob young children of their identities, absolve individuals of responsibility, confirm biases and hatred, and be so costly that only the rich will be able to afford them (Racine & Illes, 2006). The limits of neuroscience methodology and the complexity of relations between research and practice take center stage in the challenges we face when we try to blend neuroscience into our homes, schools, and communities (Stein et al., 2010).

In some ways we take two steps forward and one step back. But there is no doubt that things are changing and progress is being made. Findings from neuroscience are being blended with other disciplines, and helping educators, parents, and caregivers create environments conducive to learning, but this takes time and dedication to finding the true facts. To use neuroscience appropriately a causal chain of evidence needs to be clear, and teachers and caregivers must work with neuroscientists to help them turn their ideas into practical and cost-effective strategies. We must keep in mind that:

- The best information from neuroscience is gathered with reliable and valid tools, replicated, and combined with personal insights.
- We need to become better consumers of information from neuroscience.
- We need to understand that the tools neuroscientists use are new, popular, rapidly changing, and persuasive. We need to understand these tools, the level of analysis they are able to perform, the reliability/validity of results, and what this all means to us in understandable and useable terms.
- We need understanding and common vocabulary.
- We need to be fascinated and skeptical at the same time.

Neuroscience cannot tell us what or how to care for children. However, it can be used to confirm, enrich, and refine theories and models of learning and behavior. Different vantage points, or a consilience of disciplines (e.g., human development, cognitive science, neuroscience, behavioral science), are best (Wilson, 1998). A multivoiced perspective leads to interventions that work. Even though information from neuroscience has grown, given insight, and become part of daily conversations, we must not lose sight of the fact that it is an evolving and quickly changing field.

The authors in this volume are both hopeful and skeptical at the same time. They have reflected on their practice, asked ethical questions, and taken a cautionary stance. The dangers of oversimplifying and overextending findings from neuroscience are noted along with the need for disciplines to come together in the service of children's welfare. As teachers, parents, and caregivers themselves, the authors recognize the power they have on children's lives and the power they and others have to end to neuromyths and transform valid ideas from neuroscience into the lives of young children. Our schools, homes, and communities can become fair, equitable, and just places if we use findings from neuroscience, psychology, sociology, and education to understand each child's strengths, abilities, and needs. This volume is full of ways to use neuroscience in ethical and reasoned ways.

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Chapter 3
Neuroscience: The Genesis of Our Individual Brain Strengths

Diane Connell and Jena VanStelten

Old MacDonald had a farm
E-I-E-I-O
And on this farm he had a cow
E-I-E-I-O

The familiar tune played gently in the background of the Early Childhood Center at Rivier University, as the children gathered around their teacher. "Today we're going to start learning about farms," she told the youngsters and went on to explain all the different activities they could choose from to discover what farms are like. The children grew more and more excited until, at last, teacher released them from the large group circle.

With no hesitation, Brooklyn (a pseudonym as all names in this chapter) headed directly to the dramatic play area, where she and a friend sang and talked as they learn how to "milk a cow." Meanwhile, Miguel organized a posse to construct an elaborate farm scene at the block area. He ordered his crew like a construction manager. Mark, on the other hand, carefully considered his options before deciding to work alone with geometric tiles and plastic animals at the math table talking to himself all the while. Within a short time, all three children experimented with many different materials and activities as they explored the day's theme, "On the Farm."

The three selected students Brooklyn, Mark, and Miguel were between 4 years 6 months and 4 years 11 months old, students in the same "older preschool" classroom.

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Each child chose a different activity and one may wonder… What happened in their brain that caused each child to choose those particular activities? What influences are at play? If researchers can tease out the forces at work, then can educators use that knowledge to provide better learning experiences for our early childhood students? Recent advances in our understanding of neuroscience and brain-based learning are helping to answer these questions.

A natural merger is currently taking place between education and the fields of biology, cognitive science, and development. This international merger has become known as Mind, Brain, and Education (Fischer, 2009). Information gleaned from Mind, Brain, and Education (MBE) research is being use to enhance teacher instruction and early childhood student learning. Researchers and educators are currently designing and implementing teaching strategies extrapolated from recent findings based in cognitive neuroscience. The intention is to integrate research and practice from a classroom-based perspective. Strategies focus upon learning and memory and are based on the way that the brain learns most efficiently. "Understanding the biology of abilities and disabilities helps educators and parents to facilitate individual students' learning and development" (p. 3, Fisher).

Introduction

There are approximately seven billion people alive today. Amazingly, every individual is different. Every person has a unique personality with varying interests and proclivities for work, play, and selection of hobbies. The premises of this chapter are threefold: first, to examine the newest research on the genetic influence on learning; second, to examine ways in which specific neurological strengths exert influence over choices made over a lifetime; and third, to suggest ways that parents and teachers can honor and support each student's neurological strengths and weaknesses.

This chapter applies selected strategies to the field of Early Childhood Education; the strategies are designed for diverse and inclusion-based Early Childhood Education classrooms. We have included an in-depth focus on the hereditary and environmental influences on learning. From a genetic perspective, it appears that individual neurological strengths and weaknesses develop in utero; from an environmental perspective, it is clear that a child's early home and school experiences effect his or her brain growth and development over his or her lifetime. To help us find ways to reach every learner, this chapter will intersperse MBE research along with recent observations of older preschool students. To place our ideas in context, we provide a scenario:

The Early Childhood Center (ECC) is a laboratory school located in the Education Building at Rivier University in Nashua, New Hampshire. The school is unique in that it incorporates findings from brain-based research. Academic lessons and the large outdoor playground pivot around the theoretical framework of Howard Gardner's multiple intelligences (MI). Undergraduate and graduate ECE students can complete their student teaching at the Center as well as fulfill observations for class assignments. Teachers at the ECC develop daily lesson plans that incorporate the use of multiple intelligences by utilizing an MI color code system that ensures daily use of all intelligence areas. Indoors, each classroom is large and spacious, containing learning centers that change based upon the emergent interests of the children. During the year, the centers are changed to reflect upon different themes, along with developmentally advancing academics. The outdoor environment also contains MI centers that correspond to the varied intelligences observed within each class.

The following section provides an inspection of the characteristics and theory behind each of the multiple intelligences. Also provided are the practical aspects of how the multiple intelligences manifest in the selection of preferred activities of early childhood students and the preferred work and hobby choices of adults.

Brain-Based Aspects of Multiple Intelligences

Howard Gardner's theory of multiple intelligences (MI) has made a lasting global impact in the fields of psychology and education. Gardner explains that each of the eight MIs uses specific parts of the brain (Gardner, 2006). Drawing evidence from brain research, patients with brain injuries, human development, and cross-cultural comparisons, Gardner describes how different brain functions are related to particular brain-injury locations. He states, "The consequences of such brain injury may well constitute the single most instructive line of evidence regarding those distinctive abilities or computations that lie at the core of human intelligence" (Gardner, 1983, p. 63). In the book *Multiple Intelligences* (2006), Gardner explains why the existential intelligence is only considered as half of an intelligence as opposed to the ninth MI. Existential intelligence is seen as "the intelligence of big questions" (p. 20, 2006). While Gardner has found evidence of existential intelligence in all cultures, he cannot find evidence "that parts of the brain are concerned particularly of these deep issues of existence" (p. 21). He believes that the inferotemporal lobe is part of the area of the brain that deals with the broad issues. He has found evidence of existential issues all around the globe taking the form of ancient artwork, myths, philosophy, and religion, and yet he will "continue for the time being to speak of 8 ½ Intelligences" (p. 21, 2006).

Educators around the world have come to understand that the neural connections in the brains of their students relate to their teaching and their own learning (Connell, 2009). Globally, millions of teachers currently are designing and implementing MI lessons to reach increasingly large numbers of diverse students with special needs, English language learners, and their ECC regular education students with strong preferred learning styles. Gardner contends that while everyone's brain contains each of the MIs, due to heredity and genetic influences, each person's compilation of them is different. The theory of MI provides a framework that early childhood teachers can use to create lessons that will reach all learners. The majority of us have a range with some highly developed, some moderately developed, and a few underdeveloped multiple intelligences. Most of us have a cluster of MI brain strengths that work together when we teach, play sports, create art, garden, and engage in other activities. For example, a person acting in a Broadway musical would utilize the cluster of highly developed musical, bodily-kinesthetic, and verbal-linguistic multiple intelligences.

Surveys and observations have found that the majority of teachers use only some of the eight and half MIs in their classrooms (Connell, 2005). Connell found that the MIs they use the most often when teaching constitute their strongest MIs and brain clusters. Below is a chart that describes the characteristics, preferences, and likely careers for adults. In the first column on the table below, the titles in parenthesis constitute Thomas Armstrong's (1999) descriptors that he adapted from Howard Gardner's MI theory to use with students under the age of nine. Armstrong's descriptors are ideal to use when talking to early childhood students and their parents (Table 3.1).

Readers may want to see which MIs constitute the strengths and underdeveloped areas of their students. Two questionnaires are available at the end of the chapter: one for elementary students (ages 6/7 through 12–/13) and one for younger children (ages 2–6/7). To account for developmental differences, the age range on the two children's questionnaires overlaps.

The Environment Part I: The MI Early Childhood Classroom (ECC)

Due to the combination of prominent hereditary and environmental influences, every person's brain and personality are distinctive. For centuries, there has been an ongoing debate regarding whether heredity or the environment exerts the most influence over one's life. On one hand, the hereditary factors shape our life beginning in utero; on the other, environmental factors shape our lives starting with birth and continuing through the course of our lifetime.

To address this issue, we begin by looking at the environment factors in the ECC. These factors are based on the brain-based theory of Howard Gardner's multiple intelligences, giving each student the opportunity to both use his or her neurological strengths and to develop his or her moderate or underdeveloped multiple intelligences.

The emergent theme being studied in this particular room at the time of the observations was "On the Farm." Due to interest shown by many of the children, the creative teachers had transformed their entire classroom into a "working farm." The educators prepared the following teacher-directed activities, in which children are able to freely choose what activities they would like to participate in and how they manipulate the materials provided. In each curriculum area, there is a different activity that relates to the theme, "On the Farm," and contains a focus on one to three of the multiple intelligences. Connell and VanStelten were interested in studying individual student selections: When given an opportunity to choose, which centers would students select? Would there be a range of selection between the three students? Why did each student select this particular center? A description of the centers follows.

Table 3.1 Synopsis of Howard Gardner's 9 MIs

Definition of each MI	Likely careers of those strongly developed in this MI	Preferences of ECE students with this MI
Verbal-linguistic (*word smart*) This intelligence covers a continuum, with strong speaking abilities on one end and strong writing abilities on the other end. People can be either excellent writers or excellent speakers, or both	Love of words; uses words for primary occupation (e.g., newspaper editor or reporter; weekly columns in magazines such as Time and Newsweek); teachers; professors; psychologists; poets; authors	Good with crossword puzzles; enjoy journal writing, I-spy games involving alphabet letters, "reading" song charts, word games, dramatic play, assigning roles, playing teacher, "reading" books and poetry to/with friends, avid talkers, enjoys listening and telling stories, organizing playground games and classroom activities; thrives on being classroom helper and can be seen as a social leader
Logical-mathematical (*math smart*) This intelligence also covers a continuum, with mathematics on one end and science and research on the other end	Love of numbers. Think in terms of cause and effect. Strong ability to interpret data and analyze abstract patterns. Good at chess and computer programming. Occupations tend to be mathematicians, statisticians, scientists, doctors, medical researchers, math teachers, special education teachers, tax accountants	Like to count; enjoys analysis, reasoning, and predicting; asks how and why questions; identify fiction from nonfiction; strong inductive and deductive reasoning abilities; participate in inquiry-based discussions; enjoy math/board games; thrives on rules, routines, and transitions. Strong one-to-one correlation abilities and problem-solving skills; tendency to be a classroom coordinator/organizer; ability to work independently for a lengthy time
Spatial (*picture smart*) This intelligence encompasses eye-hand skills. These are people who can see images in their mind's eye and replicate the images with paint, architectural blueprints, clay, and sculpture	Spatial people think in images and pictures. Their careers include beauticians, book illustrators, architects, artists, interior decorators, seamstresses, mechanics, vocational teachers, art teachers, cartoonists	Like puzzles and are good at putting them together; enjoy artistic expression and freelance art; see the end result; very imaginative and skilled at creating complex mental images; appreciate classroom and outdoor aesthetics; enjoys designing and organizing environment; can be exact and precise. Skilled at visualizing patterns and sequence; visionary; see things in relation to others and use imagery; observant within the environment

(continued)

Table 3.1 (continued)

Definition of each MI	Likely careers of those strongly developed in this MI	Preferences of ECE students with this MI
Musical (*music smart*) This intelligence includes those who compose and perform music. Gardner believes that we need to bring this intelligence into the classroom more often	People with a strongly developed musical MI think, feel, and process information primarily through sound. Careers include composers, conductors, sound engineers, music teachers, early childhood teachers, song writers, and musicians	Like to sing, dance, listen to music, participate in dramatic play experiences, put on puppet shows and plays; enjoy utilizing classroom tape player and musical instruments, memorize classroom song charts easily, and enjoys musical transitions; skilled at distinguishing tone, pitch, and rhythmic patterns; composers of music; can be heard singing, humming, or tapping to internal rhythm throughout their day
Bodily-kinesthetic (*body smart*) This intelligence includes a wide spectrum of physical abilities including athletics, dance, cheerleading, swimming, acting, gymnastics, and martial arts	People with this MI are highly aware of the world through touch and movement. They control their body with grace and expertise. Careers include ballet dancers, actors, professional athletes, dance teachers, coaches, mime artists, PE teachers, early childhood teachers, occupational therapists, and physical therapists	Excels at utilizing the body and handling objects; like to play ball, swim, run, dance, spin, swing, dig; thrive on gym and outdoor time with gross motor challenges; constantly move around the classroom; utilize gross motor body movements within classroom play; float around and visit multiple centers; will assist with classroom jobs such as stacking chairs. Active within classroom; expresses self through body movements; typically on the move; usually very coordinated
Naturalistic (*nature smart*) This intelligences refers to one's natural interest in the environment. Outside, they easily recognize and categorize plants, animals, and rocks during the day and can classify constellations at night	Naturalistic people have a deep interest in the environment. They like to spend time in nature and protect it from getting polluted. They see patterns in nature. Likely careers include science teachers, early childhood teachers, environmentalists, water quality monitors, biologists, meteorologists, Girl or Boy Scout leaders	Like all living creatures; enjoy process work such as planting a seed and watching it grow; enjoy inquiry-based approach to learning; may choose to spend time alone in the classroom and outdoor environment; tend to study materials, asking relevant questions. Reflective, quiet, observant. Preference for nonfiction books and tendency to gravitate toward like-minded friends

Interpersonal (*people smart*) This intelligence refers to an ability to get along with others. They are effective leaders, communicators, and mediators	Those with this MI have a strong ability to understand and get along with others. They are good leaders, using their insights about others to negotiate, persuade, and obtain information. They tend to have a lot of friends. Likely careers include political leaders, principals, nurses, TV talk show hosts, bartenders, teachers, sales people, and psychologists	Sensitive to others feelings and moods; easily gets along with others and has lots of friends; ability to read both verbal and nonverbal cues; good at negotiating; works well in divers groups; strong communication skills and enjoys talking; like to be the boss and leader, telling friends what to do; initiate activities; lead other children into indoor or outside play and activity; may express acknowledgment of peer emotion and act on it; enjoy social activities and large group exchanges. Classroom leader, organizer of games and groups of peers; typically one of the more popular children
Intrapersonal (*self-smart*) Those with this MI have a deep awareness of their own feelings, ideas, and goals. Many researchers believe that this is the most important MI to have	People who know themselves. They accept their developed, moderate, and underdeveloped multiple intelligences. They take responsibility for their actions. They are introspective and need to spend time alone each day. Likely careers include writers, clergy, theologians, teachers, psychologists, researchers	Understand own emotions and has a well-developed sense of self; awareness of various feelings and emotions and can express them; enjoy individual and small group activities; quiet, reflective, and have tendency to latch on to like-minded peers; enjoys solitude, self-discovery, and often is a daydreamer
Existential (*philosophy smart*) This is the intelligence that Gardner refers to as a "half-intelligence" because he could not find a physiological location for it in the brain. He does believe that people possess this intelligence across countries and cultures. I also call this intelligence a spiritual intelligence, as those who score high in it are concerned with the big questions	Existentialists are concerned (often at an early age) with big questions (e.g., Who Am I? Where am I going? What is the meaning of life?). There is a spiritual concern for humankind, animals, and the Earth. Likely careers include philosophy professors, priests, rabbis, or ministers, inspirational speakers, and writers	Understand own emotions; verbalize feelings and emotions well; enjoy individual and small group activities. Quiet, reflective. Have tendency to latch on to like-minded peers; may consider questions such as "why we are here and what happens when we die?"

Brief and concise descriptions taken in part from Connell's book *Brain-Based Strategies to Reach All Learners* (pp. 67–68)

The sensory table caters to the student's naturalistic, visual-spatial, bodily-kinesthetic, and interpersonal multiple intelligences. On the day of the observations, it contains hay, plastic animals, and squirt bottles filled with water for the children to manipulate and explore. The song "Old MacDonald Had a Farm" plays quietly in the music center. The children have the opportunity to sing and play rhythm instruments with the song and the option of recording their singing and instrument playing to be reviewed later. The use of the musical, interpersonal, and linguistic intelligences is strongly evident within this center along with the intrapersonal intelligence for some children, as a few preferred solo acts.

The large block area contains a plethora of wooden unit blocks of all shapes and sizes, along with farm equipment, including a green tractor and trailer. On this day, the children were given the challenge of creating animal stalls for about twenty farm animals. The educators had provided the children with farm books, picture dictionary, paper, and writing utensils from which to plan if they so desired. This center accommodates the visual-spatial, bodily-kinesthetic, and interpersonal multiple intelligences.

Abutting this area, the raised loft has been transformed into a red barn, complete with a cozy reading nook where children can take advantage of the array of thematic fiction and nonfiction books along with the puppet theater. The loft and book nook area is always an available choice for the children. This quiet area clearly supports Howard Gardner's verbal-linguistic and intrapersonal multiple intelligences.

Various carpenter tools, glue, and nails are displayed at the woodworking bench along with pieces of wood in various shapes and sizes. To add to the dimension of this area, the teachers added animal stampers and Popsicle sticks for their play today. The children are encouraged to create 2-D or 3-D farms utilizing the materials provided, relying on visual-spatial, logical-mathematical, interpersonal, and bodily-kinesthetic multiple intelligences.

The writing center is outfitted with books on tape, children's CDs, headsets, chalkboards, thematic word wall, tracers, paper galore, and many styles of writing utensils. The children were asked to listen to the book titled *The Cow That Went Oink* by Bernard Most and draw a coordinating picture with markers. A teacher would then document their words if so desired. This area supports Howard Gardner's verbal-linguistic, spatial, and intrapersonal multiple intelligences. The math and manipulative area is designed to accommodate the visual-spatial, interpersonal, and logical-mathematical multiple intelligences. It contains many items ranging from pattern tiles to puzzles which children can freely choose to utilize. The children are given the task of completing an animal patterning sequence using precut paper farm animals which they were to paste onto a tagboard strip. They are then asked to explain their pattern to the teacher.

The children can take advantage of an open-ended activity at the science table, which contains exploratory items such as dirt, mini rakes, seeds, magnifying glasses, eye droppers, and a cup of water. Along with these materials, nonfiction books pertaining to gardening are on hand. It is the goal of the teachers that the children till the soil, plant bean seeds, and water appropriately. The results will be monitored over the next few weeks and documented in a science journal. The science area activity supports work on the naturalistic, interpersonal, verbal-linguistic, existential, and bodily-kinesthetic multiple intelligences.

An exploratory table capitalizing on naturalistic, interpersonal, verbal-linguistic, and existential intelligences, located near the science table, is an extension of this area. It includes materials related to the life cycle of a chick, a hard-boiled egg, a fish tank complete with living fish, and a journal writing/documentation based on observations. Today the children are asked how an egg turns into a chick. The children are asked to express their thoughts via picture representation while a classroom teacher documents their verbalizations and discussions in their journals. Within the art area, the children are presented with paper bags, construction paper, markers, paint, various sizes of cardboard boxes and tubes, markers, glue, newspaper, scissors, yarn, and hay. The children are given the task of creating their own 3-D cow by manipulating the materials as they see fit, involving visual-spatial, bodily-kinesthetic, and interpersonal multiple intelligences.

A math table area with many colorful clear magnetic geometric tiles is available for the children, fostering logical-mathematical, visual-spatial, and interpersonal multiple intelligences. With the inclusion of plastic farm animals and people, the children are given the task of creating a 3-D barn, silo, farmhouse, and stall area. A classroom nook, the dramatic play area, has been transformed to represent a farmhouse. There are various costumes including overalls, boots, straw hats, plaid shirts, jeans, and sundresses. The center also includes a kitchen table, stove, refrigerator, and various cooking utensils and faux food items. Nearby, there is a cow, complete with milking udders, a bucket, and a stool with which the children experiment with "milking" the cow. The song "Old MacDonald had a Farm" can be heard in the background. The open-ended activity affords children the ability to utilize their imagination, incorporating the interpersonal, verbal-linguistic, musical, and bodily-kinesthetic multiple intelligences.

Lastly, a life-size teepee draped with a cowhide-patterned fabric and containing stuffed farm animals, cozy pillows, and a few books is always available for use by the children. The teepee is a space where children can go if they choose to have alone time. This area touches upon the use of the existential multiple intelligence and intrapersonal self-reflection.

The Observations

Three ECC students were observed on November 20, 2011. They were given a 45–50-min long "free-choice period" to play and work in their favorite activity center(s). We wanted to observe which centers the students would select and to study their choices in relation to their multiple intelligence "brain strengths." Throughout the chapter, the authors will juxtapose the students' choices and decisions based on their MI selections and relevant brain-based neuroscience research.

Brooklyn chose to go to the dramatic play area; she can often be seen in there where her imagination and social abilities shine. Of good nature, her friendly personality seems to spark a sense of enjoyment in others as she typically fosters many classroom friendships in which peers are eager to play with her. Her musical nature is evident on a daily basis, as she can be heard singing and frolicking around the classroom, exercising her extroverted talents. With her love for creative arts, if she isn't in the dramatic play area, you can find Brooklyn in the language arts areas of the room, such as the art or writing centers where she exercises her passion for creativity as she enjoys art supplies, cutting, coloring, experiences with the written word, and telling fanciful stories. Her personality traits extend to the outdoor environment as well, as her whimsical play carries over into the dramatic portrayal of girls narrowly escaping the dangers of jungle creatures as she and friends dash off into a tree hut. She also participates in artistic expression in nature as supplies are always available.

Mark, who chose to work alone at the light table, is thoughtful and systematic in his approach to tasks. A logical thinker with a spatial forte, he tinkers, builds, or explores concepts throughout each day. Marching to the beat of his own drum, he spends the majority of his time independently completing tasks but will participate in peer play when approached. He seems to enjoy time spent alone and may get overwhelmed or lost in large group experiences. Mark's power of observation plays an important role in his ability to infer and enjoy an inquiry-based approach to learning. Scientific in nature, Mark often chooses to wander around outside with no specific goal, as he observes the nature that surrounds him. Contemplating the bigger picture, he often asks reflective question and thinks about his own thinking. He can be seen sitting near an ant hill or fallen tree, closely scrutinizing the workings of the active structures. Mark's building skills also extend to sandbox play as he creates intricate works of sand construction that includes natural materials.

Miguel, a lively student leader, not only chose to go the block area first and then the sensory table but he also chose who would go with him. A natural-born manager, Miguel expresses grand amounts of confidence with his skills and abilities, as he spearheads many activities, especially ones that incorporate gross motor movement. Peers flock to his side to carry out the missions Miguel deems worthy on any given day. With his flair for expressive arts, he gravitates toward activities that utilize his natural attraction for rhythm and movement such as singing and playing musical instruments. Experiences with extended time on task are challenging for Miguel, as he prefers to mingle among his peers, bouncing among activities of strength for him. You will rarely find him partaking in language arts activities, as he struggles with letter identification and phonemic awareness, showing little interest in the written word.

VanStelten reports that the choices the students made on this particular day are consistent with their choices on other "free-choice" days; so then how do we explain these differences from a neuroscience perspective? In the next section, information gleaned from recent neuroscience research studies will provide a background for how Brooklyn, Mark, and Miguel's brains each began to develop differently in utero.

Heredity Influences: Neurologically Speaking, Each Brain Is Unique

Studying the Outside of the Brain

Looking at the outside of the human cerebral cortex (see Fig. 3.1), we observe a complicated landscape of hills (gyri) and valleys (sulci). One wonders what happens during the 9-month human gestation period that makes the outside of the human brain so "wrinkled" or so "convoluted looking."

During the first two trimesters, the outside of the human brain is relatively smooth in appearance. Using functional MRIs (fMRIs) and ultrasound techniques, scientists can see that the gyri and sulci that are so clear on Fig. 3.1 are only starting to develop around the embryo's seventh month. During month eight, significantly more gyri and sulci develop giving the outside of the human cortex a truly wrinkled appearance. By the ninth month, the outside of the embryo's brain looks similar to the outside of the brain of an adult (Hilgetag & Barbas, 2009).

The cortex has developed its gyri (hills) and sulci (valleys) on the outside of the brain; in the next section, we will look at what is happening inside the brain that causes these large brain convolutions.

Looking from the Inside-Out: Brain Development in Utero

Studying the human brain the way it develops, from the "inside-out," we notice a substantial amount of brain tissue. During the course of evolution, the cortex of humans and other large-brained mammals expanded significantly more than the

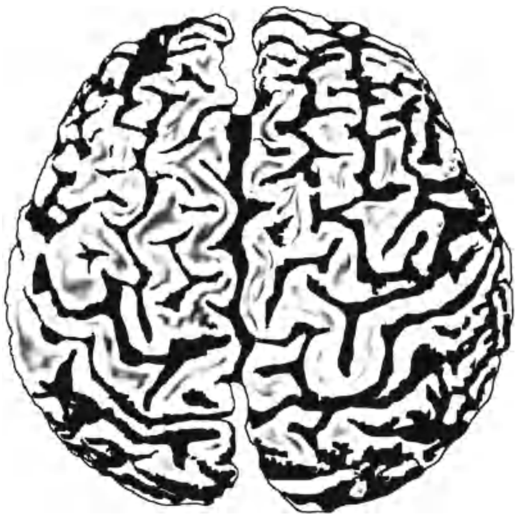

Fig. 3.1 The gyri (hills) and sulci (valleys) of the human brain (Dr. Jerome L. Rekart)

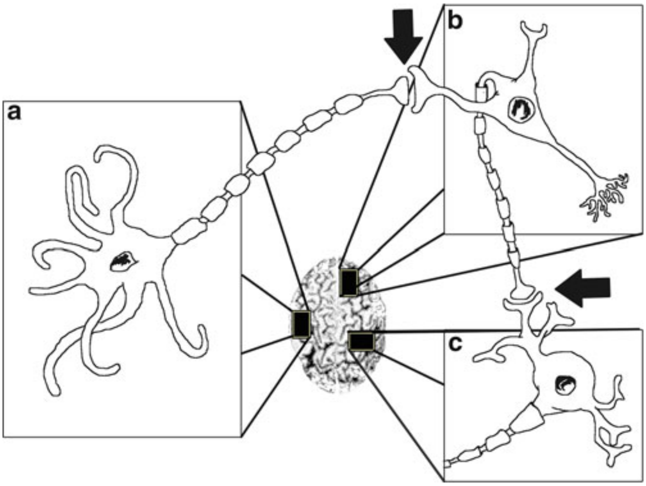

Fig. 3.2 One-way communication between neurons (Dr. Jerome L. Rekart)

skull (Hilgetag & Barbas, 2009). When the human cortex is flattened, it is three times larger than what should be able to fit into the skull. What happens to the embryo's developing brain that allows this vast amount of brain tissue to fit inside the skull?

Brain tissue is composed of brain cells called neurons. The developed human brain contains approximately 100 billion neurons, all of which have three major parts. First, the *cell body* (*soma*), which contains the nucleus and the DNA, is responsible for the cell's overall health. Second are the *dendrites* which look like branches on a tree. Their main responsibility is to receive messages from other neurons and pass them to the cell body. Third, the long structure seen in the figure is called an *axon*. The axon transmits messages from the cell body to the dendrites of other neurons. The brain creates electricity when the neurons communicate with one another. Specifically, when the dendrites are stimulated by other neurons, they become electrically charged, sending a message to the cell body, which then sends an electrical impulse along the axon (Ormrod, 2012). Scientists estimate that there is enough electricity in the average adult human brain to power a 25-W light bulb.

Scientists studying how the human brain develops during its 9 months in utero have found that brain tissue tends to fold in a systematic manner (Hilgetag & Barbas, 2009). The hills and valleys that we can observe on the outside of the brain are the result of brain tissue folding multiple times during the 9 months in utero. Inside the brain, neurons are busy sending out axons that will eventually connect with the dendrites of other neurons in different regions of the brain (see Fig. 3.2).

Before the billions of neurons settle, there is a unique "pulling" and twisting of our brain tissue. Clause and Barbas (2009) explain that "a network of nerve fibers physically pulls the pliable cortex into shape during development and holds it in place throughout life" (p. 66). Essentially, the folding and pulling of the cortex inside the brain creates the gyri (hills) and the sulci (valleys) that we can see when looking at the skull. The hills are the centers for the most neural activity in the brain; the neural activity in our valleys shows less activity on fMRI brain scans.

How Do Our Individual Brain-Based Preferences Develop?

Although brain folding is indicative of normal brain development, due to our genetics and brain plasticity, each brain develops in utero differently from that of any other human being's brain (Sporns, 2011). Therefore, from a genetic perspective, it appears that some individual neurological strengths and weaknesses are formed in utero. Heredity represents the characteristics that are passed down from our parents, grandparents, great grandparents, etc. Genetics is the scientific study of heredity. While genes may determine most physical traits, it is unlikely that they determine behavior. Zull (2002) states, "There is no doubt that the growth of axons, dendrites, and synapses depends on expression of certain genes and that individual differences in those genes produce individual differences in neuronal structures—that is, *differences in genes can produce differences in the brain*" (p. 112).

In utero, long axon nerve fibers link different regions of the cortex, enabling them to communicate with one another (Van Essen, 1997). Neurons form neural passageways that help different brain regions connect with one other. These connections are likely to stay joined together throughout the course of a lifetime. Van Essen hypothesizes that when two regions of the brain are connected by many axons, these brain regions are drawn together during the development of the fetus' brain, thus creating the hills (sulci). As more neurons are born, their fibers draw parts of the brain together creating the large hills that are apparent from the outside of the brain. Also, during the 9-month gestation period, most parts of the cortex end up having six layers of neurons. To summarize, most of our individual brain differences are due to the way that each individual brain folds in utero and to the changes in the thickness of the six layers of brain cells: our gyri and sulci are created during this process.

We have an understanding now about our genetically based brain strengths, but what causes our underdeveloped brain areas? To answer, Clause and Barbas (2009) have found that during the 9 months in utero, the weakly connected brain regions drift apart; in essence they become the valleys (sulci) that we observed when looking at the outside of the skull. To summarize, the sulci (valleys) are most likely indicative of our more weakly connected brain regions.

When we think and learn, our brain "lights up," displaying neural activity similar to that in Fig. 3.3. This lighting up provides the evidence that the patterns generated by neural networks underlie all of cognition and perception, and that further analyses of our neural network may be the key to understanding the brain. There is mounting evidence that dynamical patterns generated by brain networks underlie all of cognition and perception (Sporns, 2011). Each individual neuron in our brain is capable of making approximately 10,000 connections, thus creating the possibility of one thousand trillion connections in most adult brains.

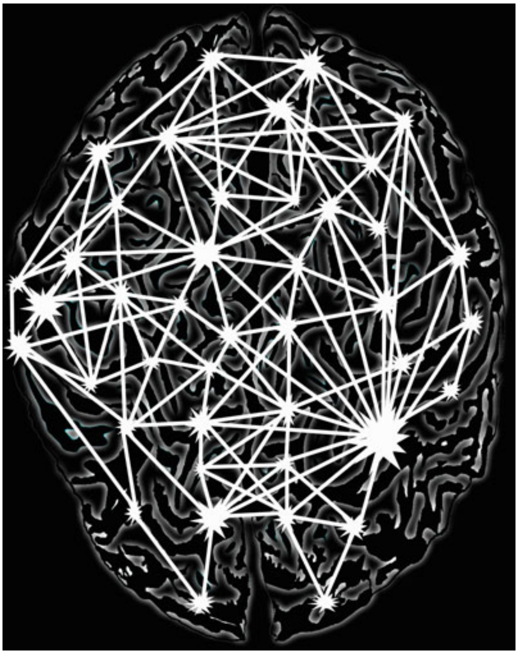

Fig. 3.3 Simulated Hubs in the human brain (Dr. Jerome L. Rekart)

Neuroscientist Olaf Sporns and others (LeDoux, 1996; Raichle, 2010) studying the nature of human consciousness hypothesize that our neural passageways comprise our human consciousness. Consciousness may be rooted in the integration of information that requires a structural network capable of sustaining this process. Analyzing the networks of the brain may be the key to understanding and harnessing the remarkable computational and informational power of the brain. Many of the brain's connections are conveyed through central "hubs" (Sporns, 2011). Comparisons have been made between the organization of the brain's hubs and neural connections to the global airline system, which has "central hubs" in metropolitan areas. In the brain, "such 'small-world' networks of hubs help our brains process information more rapidly and allow the organ to maintain its structural integrity efficiently" (Zimmer, 2011, p. 62).

Connell and VanStelten hypothesize that these hubs help connect the brain matter that is needed for our multiple intelligence brain strengths. Neural hubs can also aid in the connection of several MI brain strengths that work together, helping us perform tasks efficiently. Passageways that are used most often "wire and fire" together, forming the equivalent of "neural super highways" (Jensen, 1996). For example, a Girl Scout leader, when organizing a hike, is likely to draw on a combination of highly developed bodily-kinesthetic, naturalistic, and interpersonal multiple intelligences.

Connell and VanStelten infer from this research that the valleys most likely become our most weakly developed multiple intelligences. To further support this inference, use of structural magnetic resonance imaging (MRI) has shown that the neurons in the hills look different from the neurons in the valleys. Hilgetag and Barbas (2009) discovered that the neurons in the hills are elongated, while neurons in the valleys are flattened. The shape of a neuron is often associated with its function. Additionally, Hilgetag and Barbas have established that the brain matter in the gyri (hills) is thicker than the brain matter in the sulci (valleys). Thicker brain tissue means more neurons; more neurons indicate the probability of making more neural connections. More neural connections suggest brain strengths.

Neural Networks Are Knowledge

In the brain, knowledge is a "concrete thing." There is a neural network for everything that we have learned (Zull, 2002). This includes letters of the alphabet, types of cars, and differences in D major and D minor chords on the piano. "It seems that every fact we know, every idea we understand, and every action we take has the form of a network of neurons in our brain" (Zull, p. 99). The longer we spend doing something, the stronger the neural passageways used in this activity becomes.

The simpler tasks such as naming letters or animals require much less of our brain than an abstract task such as writing a chapter in a book. The neurons that are needed to understand a specific concept are connected to one another: they form a network of neural passageways. The more complex the task, the more parts of the brain are used. Neurons that are repeatedly used grow stronger synapses and more effective neuronal networks. And the more they fire, the more they send out new branches looking for more new and useful connections (Zull, 2004).

What About Our Three ECE Students' Brain-Based Strengths?

If we peer inside the brain, where do we find our brain talents? "Modern neuroimaging methods have enabled scientists to test the notion that cortical convolutions or the amount of gray matter in different brain regions can reveal a person's talents" (Hilgetag & Barbas, 2009, p. 71). Connell and VanStelten hypothesize that the hills in the brain may be indicative of our multiple intelligence strengths and the valleys may be indicative of our underdeveloped multiple intelligences. Extrapolating from the recent neuroscience research mentioned above (Clause & Barbas, 2009; Gage & Muotri, 2012; Hilgetag & Barbas, 2009; Sporns, 2003; Van Essen, 1997; Zull, 2002), Connell and VanStelten made a decision to link each of the three student's free-time choices, with their hypothetical brain strengths. Please note that the same student choices observed on November 9, 2011, have been seen repeatedly over the academic year by VanStelten and other ECE teachers.

Brooklyn chose to run to the dramatic play area on the date of the observation, November 9, 2011. VanStelten reports that when given a choice, Brooklyn will choose this center time and time again. Brooklyn displays her strong interpersonal multiple intelligence each time that she takes the initiative to reach out to her peers. To summarize, using research coupled with multiple observations, we believe that Brooklyn most likely possess gyri (hills) in her interpersonal, linguistic, existential, visual-spatial, and musical MI strengths.

The authors believe Mark has hills in the intrapersonal, visual-spatial, logical-mathematical, naturalistic, and existential strengths. Preferring activities that support Mark's need for reflection and individualized expression, he immediately gravitates toward activities that complement his MI makeup. Mark was in his element when he was able to construct at the light table in solitude, and later when he was able to reflect and contemplate his own thoughts during a science activity. VanStelten states that these learning preferences are consistent with classroom activity choice observed throughout the year.

Miguel also displays consistent learning preferences. He incorporates socialization, gross motor movement, and expressive arts, throughout daily activities. Miguel's choices express strong interpersonal and linguistic skills, along with musical, bodily-kinesthetic, visual-spatial, logical-mathematical, and naturalistic intelligence. His natural peer management and high energy levels seem to foster his classroom leadership skills. Taking the reins, he immediately recruits willing participants, leading them to an area of play where his MI strengths blend together: he is in his glory. This practice repeats day in and day out during the course of center time according to VanStelten.

The Wisdom of Activating Prior Knowledge

Knowing that knowledge is stored in our neural networks, teachers might wonder how "new knowledge" enters into the existing neural passageways. What if the new knowledge seems to conflict with what a student has already learned? For example, let's say that one of your early childhood students, Sam, has confused the colors green and brown. Sam is 5 years old and "knows" he is right and teacher is wrong. How do you change the prior learning in Sam's brain without getting into a power struggle?

Researchers Ausubel (1968) and Zull (2002) explain that since prior knowledge is real and persistent, teachers cannot magically erase the networks that are already in the student's brain. Instead, we need to build on the student's existing neural networks. Any change in knowledge must come from some change in the neural networks (Zull, 2002). Thus, we have to intentionally activate Sam's idea of the truth and go from there.

"The more ways something is learned, the more memory pathways are built" (Willis, 2006, p. 34). Teachers are encouraged to use their knowledge of the nine multiple intelligences to activate prior learning. For example, the authors suggest taking a walk in nature with Sam and asking him to look for green and brown colors. Ask Sam if he can find "something green." Sam goes to a large dirt pile and gleefully starts digging in the "green dirt." Teacher can say something like "You know, Sam, someone must have told you that this dirt is 'green' but they were not right. The dirt you are playing in right now is really 'brown.' Can you find anything else that is brown on the playground?" This brain-based strategy will work because neurologically speaking, we have to first get the student's attention by activating the prior learning in his brain; then we can add new information. In essence, new teaching changes your student's brain! Students will learn and remember when new information is connected to an existing neural passageway.

The authors draw from Ausubel and Zull to sum up this section: "The single most important factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, 1968). Zull (2002) modified Ausubel's assertion with the following: "The single most important factor in learning is the existing networks of neurons in the learner's brain. Ascertain what they are and teach accordingly" (p. 95).

Individual Brain Talents

Neurologists are currently using fMRIs to determine whether the cortical hills represent brain-based strengths, or brain talents. Although this research is in its beginning phases, Hilgetag and Barbas (2009) have found evidence to support the hypothesis that the hills constitute the brain strengths. Using fMRIs on the brains of professional musicians, they found that "the connection is clearest in people who routinely engage in well-defined coordinated mental and physical exercise" (p. 71). Hilgetag and Barbas also found that the motor regions in the brains of professional musicians "systemically differ from (the brains of) non-musicians in the motor regions of the cortex that are involved in the control of their particular instruments" (p. 71). It is likely that the brain patterns of the musicians developed from both hereditary and environmental influences. Genetically, it is likely that their brains had a hereditary predisposition to master music proficiently.

That said, however, we know that children need support from the environment for their genetic strengths to mature and grow strong. The experiences we have during our life matter; they can influence the strength of the neural connections that already exist between sets of neurons and our brain hubs (Gage & Muotri, 2012). In the case of the musicians in the study mentioned above, "support" could include encouragement from parents and teachers in terms of supplying musical instruments, allowing the student to take music classes in school, providing individual music lessons after school, and setting up a home environment conducive to studying, playing, and creating music.

Practical Applications: Using the Environment to Develop Students' Neurological Gifts and Remediate Their Underdeveloped MI Areas

How do we honor each student's unique brain proclivities? By providing the best early childhood environment imaginable. Knowing that the theories of MI and activating prior learning are brain based, Connell and VanStelten conclude that we must identify each student's strong MIs and encourage him or her to excel in these areas while simultaneously working to build up the underdeveloped MI area. Provided are five suggestions to help accomplish these goals: (1) intentionally set out to find the MI brain gifts of each of our students using observations and BBL questionnaires, (2) intentionally work on remediating students' brain-based underdeveloped MI areas, (3) share all MI findings with the students' parents, (4) include them in the student's records for future teachers, and (5) on a daily basis, plan to access the students' prior knowledge through an inquiry-based teaching approach.

First, as we have discussed, the MI strengths can be observed in children's play and in the ways that they approach tasks. As educators begin to understand each child's MI learning preferences, they can apply this knowledge to everyday teaching practices and the environmental design of the classroom. To reach all learners, it is essential for educators to discover a teaching approach that lets them know when students have experienced the "ah ha" moments. Teaching with techniques gleaned from neuroscience allows us to help students develop a healthy self-esteem. Strong neural passageways can develop when we emphatically recognize brain strengths and showcase them to the student, their classmates, and their parents.

Second, remediating the MI weaknesses requires us to work at helping students develop their underdeveloped MIs. For students with special needs as well as the English language learners in our classrooms, it is critical that we identify both the brain strengths and underdeveloped MI areas. For example, extracurricular activities that Miguel would most likely enjoy may include soccer, tee ball, and karate as he would be able to use his bodily-kinesthetic strength. Within the classroom, this strength can also be utilized to foster academic areas of potential weakness such as language arts. We recommend incorporating a highly developed MI strength within an activity that may make the student anxious. For example, letter recognition is an area that is difficult for Miguel. His MI lesson plan is "walk tracing" alphabet letters of his name on the playground and then writing these same letters later in the classroom. Using both the strong and underdeveloped MIs together will strengthen Miguel's underdeveloped skill areas. Remember to utilize strengths to enhance learning in an underdeveloped area; in doing this you can eliminate frustration and promote self-confidence and a sense of accomplishment.

Third, using information based on Mind, Brain, and Education can help bridge the home/school gap. It is beneficial for educators to communicate information to parents about their child's brain-based strengths and weaknesses. Parents can provide information about their child's learning preferences and after-school hobbies. Such exchanges of information are likely to result in a partnership, producing strategies and ideas that relate to home and school settings

Fourth, it is essential for teachers to pass along this invaluable brain-based information to future teachers so as not to lose valuable time, energy, and data. Understanding the baseline of a child's Mind, Brain, and Education strengths and weaknesses is like winning the lottery for an educator. The guessing game has already been played, with an answer key at your fingertip. Why start from the beginning, resulting in losing valuable time by reinventing the wheel? Keeping the wheel turning provides more opportunities to make more neural connections. By understanding a child's strengths or brain gyri (hills), educators can take advantage of this knowledge to modify or develop strategies to strengthen the sulci (valleys). Year after year, if the knowledge of a child's MI strengths and underdeveloped areas have been passed along, an appropriate approach to learning can successfully be deployed at the start of each year.

Finally, accessing prior knowledge through an inquiry-based teaching approach affords educators the opportunity to identify children's current levels of understanding. Accessing prior knowledge allows us to "peer inside the student's brain" to determine what the student already "knows." Without first understanding the student's current level of knowledge, we are essentially trying to construct a building without blueprints, possibly starting the construction on the top floor of the building instead of building from the foundation. Remember, knowledge is a "concrete thing"; there is a neural network for everything that we have learned. Each person's unique blend of multiple intelligence skills depends upon the complex mix of our heredity coupled with our experiences in the world. Our students have neurological gifts that can be highlighted to help them feel proud: let's nurture these gifts.

Conclusion

During the past two decades, teachers have been interested in learning about the brain and how it affects learning and teaching. The work that began in the field known as brain-based learning has developed into a global movement currently recognized as Mind, Brain, and Education. Especially exciting is that this research is being designed to bring cognitive neuroscience and biology into the classroom. Prior studies were often conducted mostly in cognitive neuroscience laboratories (Coch, Michlovitz, Ansari, & Baird, 2009; Fischer, 2009). The new Mind, Brain, and Education research has tremendous implications that can continue to shape the fields of Early Childhood and Early Childhood Special Education. Results of new MBE research are likely to enable teachers to simultaneously (1) focus on recognizing and reinforcing their students' genetic brain strengths as well as (2) shape their students' learning environment. It is projected that results of new MBE research will help teachers design lessons that will enhance the brain strengths as well as guide us in ways to appropriately shape the underdeveloped areas.

When the "Clean-Up Song" begins at Rivier University's Early Childhood Center, all of the children respond according to the strengths that move them. As unique as each of the Seven Dwarves on their way to the diamond mine, Brooklyn, Mark, and Miguel add to the amazing diversity of human life. It will be up to their parents and teachers—and eventually, the children themselves—to develop their talents and improve their weaknesses so that they can live to the fullest of their abilities. The guidance of wise, enlightened adults and the work of neuroscientists can do much to help them reach their goals. After all, we don't construct a building from the top down; we build it from the ground up. The more knowledge and research within the area of Early Childhood Education equals a stronger foundation for the children of our future. As a society, we must never lose sight of the fact that every child deserves the best foundation that we can provide, capitalizing on strengths and improving areas of struggle. If we devote energies toward enlightening teachers with Mind, Brain, and Education research, we are well on our way toward achieving the strongest building design yet.

Hi ho, hi ho
It's clean-up time
So off we go
Let's put away
Our work and play
Everyone join in
As we begin
Hi ho, hi ho, hi ho, hi ho!

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Chapter 4
Reading and the Young Brain

Nancy Frey and Douglas Fisher

Walk the aisles of the exhibit hall at any major educational conference and be prepared for the blitz of brain-appended products and services. Computer learning games are now "brain friendly" and curriculum programs are "brain based." Some will throw in a neuroimage of a brain for good measure, which no one in the booth can interpret anyway. It is reminiscent of the McCabe and Castel (2008) study that found that people were more willing to accept inaccurate scientific information in an article if it was accompanied by a brain scan image. The explosion of information about the brain has found its way into a marketplace aimed squarely at parents and teachers of young children.

Perception is powerful, and we have the field of psychology to thank for our understanding of that. The fact is that *brain-whatever* is appealing, but it is our brain as well as our *mind* that determines what we will pay attention to, for better or for worse. Grotzer (2011) notes that the way our brain and mind function—an interplay of attention, perception, cognition, and memory—causes us to selectively screen information, including the applications for neuroscientific research to educational settings. Grotzer raises the issue of confirmation bias, that is, the tendency to attend to information that is consistent with what we already believe while ignoring that which contradicts:

> This recursive pattern underscores the difficulty of communicating findings that do not fit with people's experiences and the likelihood that they will resort to confirming explanations that they already find meaningful and/or believe. A challenge for those communicating any type of research outcome is to find ways that extend beyond these tendencies. (p. 110)

Confirmation bias is an issue all of us must combat, as it can narrow our view and leave us vulnerable to false claims, such as the belief that infants watching television will increase their language abilities, when it fact it actually lowers it (Zimmerman,

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Christakis, & Meltzoff, 2007). False claims are perpetuated within education as well, for example, the notion that the left hemisphere is "academic" and the right is "creative," a gross misapplication of basic neuroanatomy. Although this falsehood has been thoroughly disproven (see Lindell & Kidd, 2011 for a review), it continues to be repeated and reinforced.

The Convergence of Neurosciences, Psychology, and Education

Much of the information about the brain comes from a loose confederation of related fields collectively termed neuroscience, including neuropharmacology, neuroimaging, and even neuro-economics. In each case, the structure and function of the brain is the common thread. But it is essential to look beyond the brain as an organ to what it is we know about the mind as well. The fields of psychology and education play a vital role in understanding how we think and interact with our world and under what circumstances. Psychology and education have long been historically linked, as each is informed the other about matters of human development, learning and cognition, behavior, attention, perception, motivation, and memory. But the newer fields of the neurosciences often leave readers both dazzled and bewildered. We are intrigued by findings that are explained through complicated statistical formulas of data obtained from complicated machinery. And the images! They are breathtaking, if only they give us a portal to a world we know is there, but can't see. It is much like the photographs of previously unknown species discovered during deep ocean explorations. We aren't always quite sure what we're looking at, but it's amazing all the same.

What all of us—neuroscientists, psychologists, and educators—have in common is a deep interest in the brain and mind. But each field approaches the subject from a different vantage point, and, therefore, the research each produces serves different purposes. The neurosciences examine the functions and structures of physical brain, and the field's body of research informs us about that. Psychology looks closely at the constructs of the mind, and how a variety of external factors can inhibit or enhance development. Likewise, psychology research echoes this interest in the social brain. As brainworkers, educational researchers look at which teaching methodologies are best applied under specific circumstances to positively affect learning. The convergence of these fields has resulted in the emergence of neuroscientists, psychologists, and educators who engage in translational research to bridge knowledge, application, and expertise. A chief goal in translational research is to identify useable knowledge for the field (Perkins, 2009). A vital role in translational research is in determining what constitutes usable knowledge.

But just as these fields share a common interest, the misapplication of their research findings can lead to overgeneralizations (Pasquinelli, 2012). It is helpful to consider where the research diverges. Perkins (2009) notes that explanatory theories and action theories are related but differ in their use. To borrow his analogy, an explanatory theory is broad because it seeks to uncover fundamental principles. The details are stripped away in favor of the big picture. The theory of gravity is an example of an explanatory theory, and it is applied to everything from apples to space travel. On the other hand, action theories exist for the details. An engineer who builds bridges must understand the theory of gravity but must also apply knowledge of metallurgy, weather, and air resistance if the bridge is going to stand. The action theories of building safe and durable bridges are just as important as the participatory ones related to our understanding of physics. However, they differ in their research methodologies and the ways they report their findings.

As educators, our work is closer to the bridge builders than Sir Isaac Newton. We seek to utilize the findings from the neurosciences and psychology to create instructional environments that work. And while the field of educational research has long been conversant with psychological research, the more recent body of knowledge coming from the neurosciences has posed a challenge to us. How do we incorporate findings from neuroscience into our work? Are there findings that confirm what we already know as educators? Are there any that shed new light on a compelling issue in early childhood education? As reading researchers, these are the questions we wrestle with as we attempt to translate the participatory theories of neuroscience into the action theories of education. In this chapter, we will discuss how neuroscience confirms and extends our understanding of reading development in young children and raise further questions that are not yet answerable.

Reading Development in Young Children

At one time, reading acquisition was thought to begin with formal schooling, and families were discouraged from introducing written systems before their children entered school. In fact, one of the authors recalls her own mother telling her not to let the first-grade teacher know that she was already reading, for fear that she would be scolded. We now understand that reading is a later expression of the language development that begins at birth. What we now call emergent literacy includes speaking, listening, and viewing, as well as initial reading and writing. Considered together, these are the dimensions of receptive and expressive language.

Language development begins at birth and continues at a breathtaking pace in the first five years of life. Some observed literacy behaviors are clearly in imitation of how a parent or caregiver uses it: the boy who “reads” a picture book to his stuffed animals, the girl who “writes” a shopping list to take to the grocery store with her father. Others are not so easily discernible. Adults are startled when a young child uses a phrase they never heard before or they sing snatches of a song you weren’t aware they knew.

These children arrive at our classroom doors armed with years of experience with the language. In some cases, these experiences dovetail neatly with the school literacies we will be teaching them. At other times, their emergent literacy experiences are more removed from those associated with school, and we need to work a bit harder to link what they know with what they will need to know. For some children, their emergent literacy experiences are meager, and we need to find ways to accelerate their learning in order to close a gap that began the first day of school. For a few others, a physical, sensory, or cognitive disability means that their emergent literacy experiences will need to be accommodated in order to ensure full access.

For each child, the journey to learn to read and write began on the day of their birth. Some will be better equipped than others to unlock the code to written language, but in all cases, it is our job to teach them. The neurosciences, along with educational and psychology research, can provide us with guidance about our literacy practices. And neuroscientific research can provide teachers and parents with key explanatory theories that they can apply to the development of action theories. In the next section, we will discuss five such explanatory theories that inform early childhood reading instruction:

1. Experiences shape brain development.
2. Reading is not innate and must be taught.
3. Learning two languages does not harm the learner.
4. Repetition leads to automaticity.
5. We are hardwired to imitate.

Experiences Shape Brain Development

There was a time at the turn of the last century when it was believed that the brain was a relatively immutable organ and that intelligence was fixed. This belief coincided with the rise of intelligence testing, especially for the purposes of sorting out individuals. Originally applied by the US Army during World War I as a means for identifying officer candidates (Binet & Simon, 1916), the practice soon found its way into schools. By the 1920s, "Binet classrooms" for children who scored between 75 and 95 were established for the "educationally retarded" (Gates & Pritchard, 1942). Ironically, though Binet himself did not believe that intelligence was fixed, this misapplication of his work persisted for many years. However, by the 1960s a growing number of psychologists and educators came to believe that early education and intervention could positively influence intelligence, giving way to programs such as Head Start and the Abecedarian Project.

Today we know that experiences shape intelligence and learning, and that thoughtfully constructed early events can change the trajectory of a student's achievement (Li-Grining, Votruba-Drzal, Maldonado-Carreño, & Haas, 2010). Neuroscientific evidence supports and extends our understanding of the vital role early literacy experiences play in brain development. A growing number of studies have demonstrated that the brain has plasticity; that is, it undergoes physical changes due to experiences (Bryck & Fisher, 2012; Buonomano & Merzenich, 1998). This plasticity extends into adulthood, as evidenced by Eden et al.'s (2004) study of neuronal changes in adults with dyslexia who participated in reading remediation. Even more remarkably, the brain has the capacity to rewire itself in order to compensate for the loss of function due to injury or stroke. Early childhood educators can point to the results of intervention studies on poor readers on the physical changes in the brain. Meyler, Keller, Cherkassky, Gabrieli, and Just (2008) used functional magnetic resonance imaging (*f*MRI) to show that 100 h of sentence comprehension instruction changed the neuronal activation patterns in elementary students and that these changes remained 1 year later. Similarly, Keller and Just (2009) used a different technique, called diffusion tensor imaging, to track the increase in myelination (white matter) in 8–10-year-old poor readers who received 100 h of intensive remedial reading over a 6-month period. These findings are significant because increased connectivity and white matter are correlated with reading ability (Deutsch et al., 2005). Studies like these demonstrate that both the physical structure (anatomy) and its functional organization (physiology) are affected by learning experiences.

The implications for early childhood reading education are clear and further reinforce what is already considered best practice in our field. From birth, children thrive when exposed to a rich sea of talk (Hart & Risley, 1999). The resultant gains in language development translate into earlier and firmer acquisition of reading and writing skills (Snow, Burns, & Griffin, 1998). For students who persist in the struggle to read for longer than most, early intervention can reverse the predicted achievement slide before the intermediate grades (Vellutino & Scanlon, 2001). The effectiveness of rich home oral language environments and participation in early reading intervention when warranted have become hallmarks of parent education programs across the world.

While Language Is Innate, Reading Is Not

A second participatory theory we can derive from neuroscience is in knowing that reading, unlike language, is not innate. In other words, typically developing infants will develop spoken language. It is truly wondrous to watch how infants and toddlers experiment with the sounds, syntax, and meanings of the language, all the while systematically constraining its application until they perfect it. Cognitive scientist Deb Roy wired his home to capture the birth of a word as his infant son went from "gaa gaa" to "water" (you can view this video at http://www.ted.com/talks/deb_roy_the_birth_of_a_word.html). Importantly, Roy also notes that there is a tight feedback loop between child and caregiver, with a dip in the length of utterances by the caregiver at the time a word enters a child's spoken language and then a systematic rise as the child learns to apply it. Stated differently, the caregiver simplifies his or her language usage to make it comprehensible to the child and then scaffolds language experiences for more complex applications. We do the same thing when we introduce simple books to students and systematically scaffold reading instruction along a text gradient.

But while the development of spoken language is innate, written language is not. Writing developed about 6,000 years ago, a mere blink of the eye in terms of human development. This is not enough time for human brains to evolve so that the structures of the brain are hardwired for reading. Therefore, every brain must be taught to read anew (Wolf, 2007). And reading doesn't reside in one part of the brain. Rather, it is the result of the activation of a complex network of systems that include the visual cortex, a phonological loop that links sound and shape of letters to decode, and areas of the brain responsible for word meaning, all while holding this in working memory (see Joseph, Noble, & Eden, 2001 for an excellent overview of these processes).

The precise coordination of these systems is within the reach of most, but not all, children. In the words of Pinker (1999), "children are wired for sound, but print is an optional accessory that must be bolted on" (p. ix). That act of bolting print onto spoken language requires purposeful instruction, and a disruption anywhere in this system means that a reader will struggle. Part of this coordinated system is called the dorsal stream, which links the visual cortex with the spatial attention area, responsible for locating objects in space. A series of studies using *f*MRI on students entering kindergarten by Kevan and Pammer (2008, 2009) found that difficulty along these pathways was predictive of reading difficulties 18 months later.

Early childhood and elementary educators know that a systematic approach to reading is essential for children to learn. A haphazard reading curriculum that overlooks the necessary elements of emergent and early literacy development will fail the children. Phonemic awareness (discerning the sounds of language) is essential for students to read, as they utilize auditory processing in reading (Hulme et al., 2002). Phonics instruction ties the sounds of the language to their written symbols and is critical for decoding (Adams, 1990). In addition, children need learning environments that offer rich narrative and informational text experiences to build their knowledge of themselves, their peers, and the world (Duke, 2000; Morrow & Gambrell, 2001). Young children also need texts that are carefully scaffolded so that they can gain control of the decoding and comprehension skills they are using (Hiebert, 1999). A carefully constructed comprehensive reading program helps to ensure that students are gaining the necessary experiences to repurpose brain structures for reading.

Learning Two Languages Doesn't Suppress Either

For many decades, there has been a widespread belief that young children whose home language is something other than English require a language instruction designed to "hold back" one language in order to foster literacy in English (Petitto, 2009, p. 186). The intent of these programs, often called English immersion, is to develop competency in English, but are not intended to foster similar literacy in the home language. These programmatic decisions are complicated by political and legislative belief and are outside the scope and purpose of this chapter. However, these decisions are also driven by a well-placed concern that dual language instruction could result in suppressed literacy in both. Much of the concern has been focused on whether the introduction of a second language while the child was still learning the first might interrupt language development or cause the child a confusion of languages. Examination of neuroscientific evidence can inform our decisions about practices and programs.

One concern for new parents who speak two languages is whether speaking to children in both will result in language confusion. Infants typically lose the ability to discern phonemes from languages that are not their own by 14 months of age. But current research is showing that bilingual babies are able to discern the differences in the phonemes of both languages and are sensitive to a wider range of phonemes than monolingual babies (Norton, Baker, & Petitto, 2003). In another study, bilingual infants displayed a longer open period for phoneme sensitivity, when compared to monolingual infants, further affirming the belief that young bilingual brains adapt to dual exposure to two languages (Garcia-Sierra et al., 2011).

Imaging studies on the brains of bilingual children and adults show that a distinctive bilingual signature of functionality exists in the ways they recruit different parts of the brain as they read. As bilingual infants grow to school age, their parents face a myriad of programmatic decisions. Two models of bilingualism dominate. The first is a truly dual immersion program where the language of instruction is evenly divided (50/50). A second, more common model is also referred to as dual immersion but begins in kindergarten with 90 % instruction in the home language and 10 % in the new language and gradually increases until fifth grade, when 90 % of instruction is in the new language. A study of both found that the age of the introduction of the new language was critical for reading development, and the younger the age, the better they did (Kovelman, Baker, & Petitto, 2008). These findings suggest that bilingual preschool programs may be a viable option for families to consider.

Of course, bilingual education outcomes are fraught with other real-world concerns, such as interrupted bilingual education when a child is enrolled 1 year in a dual immersion program, and then changes districts and finds himself or herself in an English immersion classroom. In addition, there is criticism that some students are redesignated too early as English speakers, leaving them without the language supports they still need (Olsen, 2010). These students may begin in a bilingual primary program but exit before they have fully developed literacy in either language and instead become long-term English learners whose progress stalls by middle school. Although issues of second-language development are far from settled, explanatory research from the neurosciences may yield information that can be translated into action theories of schooling.

Repetition Leads to Automaticity

Whether learning a first language or a second, repetition is a key instructional approach when learning a new skill. We shouldn't expect children (or adults for that matter) to be one-trial learners of complex content. For example, repetition through multiple exposures is elemental to vocabulary instruction, along with authentic experiences and dialogic use with others (Frey & Fisher, 2009; Graves, 2006). Repetition and rehearsal are essential learning behaviors for moving new information into working memory and then into long-term memory (Craik & Watkins, 1973; Landauer & Bjork, 1978).

A participatory theory from the neurosciences is actually one of its earliest contributions to education: that repetition and rehearsal rewire neurons to create pathways. As Hebb (1949) famously remarked, “neurons that fire together, wire together,” meaning that neuronal pathways become more efficient and faster with practice. Decades later, Squire and Kandel (2000) identified three parts of the brain that are activated during new learning—the prefrontal cortex, the parietal cortex, and the cerebellum. These neuronal pathways link these brain structures. In reading terms, we think of this as fluency, the ability to read at a rate and with an appropriate level of accuracy so that it does not interfere with comprehension.

While emergent and early readers are rarely fluent in the ways that older readers are, they are striving for a level of automaticity in decoding that will allow for attention to meaning (LaBerge & Samuels, 1974). With repetition and rehearsal, most children learn the sound/letter connections and are able to process text more efficiently. An exception are the students who continue to struggle with decoding long after their classmates have mastered it. Paulesu et al. (2001) evaluated positron emission tomography (PET) scans of French, English, and Italian college students who had been identified as having dyslexia and found reduced activity at a key point in the phonological loop—the superior temporal gyrus, which links Broca’s area (speech production) with Wernicke’s area, a specialized area essential for language comprehension.

To be sure, not all struggling readers have dyslexia. In fact, the estimate is that 5–10 % of school-age children have dyslexia, far lower than the number of students who read significantly below grade level. But for many of them, automaticity continues to elude them. Repeated reading exercises have been shown to be an effective means for increasing fluency with struggling readers (Biemiller, 1977/1978). The trick is in getting students to find an authentic reason to engage in the repeated reading, as they are often wont to moving on (“I read it once already? Why do I have to read it again?”). Repeated reading games include keeping track of timed readings to gauge one’s improvement, buddy reading with a partner, and performance activities such as Reader’s Theater. This last approach is helpful when there are several children who need fluency practice. In this method, students use a scripted play and perform the parts with one another. The students are discouraged from memorizing the parts and instead are asked to use their scripts even as they perform. Without realizing it, they are engaged in the act of repeatedly reading passages and building their fluency.

We Are Hardwired to Imitate

Imitation is an important teaching approach in early childhood education but is not as well understood from a neuroscientific stance. However, a breakthrough in understanding imitation occurred when researchers discovered the existence of a specialized neuron that was activated when macaque monkeys watched another peel fruit (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). These were soon dubbed “mirror neurons” because of their ability to reflect similar brain activation patterns whether it was the monkey holding the fruit or the one observing it. In due time, these were discovered in the human brain and were understood to operate as a coordinated network of connected brain structures. Heyes (2011) in discussing mirror neuron systems noted that there is "strong evidence that even healthy adult humans are prone, in an unwilled and unreasoned way, to copy the actions of others" (p. 463).

One area of the brain that contains many mirror neurons is Broca's area, the specialized cortical space dedicated to speech production. Rizzolatti and Arbib (1998) speculate that these mirror neurons are vital in helping infants and toddlers imitate language. Others have forwarded theories about the role of mirror neuron systems in the frontal lobe in understanding the intentions of others, with deficit functioning linked to autism (Oberman & Ramachandran, 2007). It is important to note that there is no widespread agreement on the function of mirror neuron systems and their role in understanding the actions of others. One point of contention is in generalizing findings in primates to those in humans (Hickok, 2009).

However, we are clear on the importance of imitation in reading instruction. A chief way this is accomplished is through teacher modeling during read alouds and shared readings. A student of effective elementary teachers who modeled during reading found that they commonly thought aloud about their cognitive processes as they read (Fisher, Flood, Lapp, & Frey, 2004). These included think-aloud statements about comprehension strategies, resolving unknown words, and using text structures and text features to support their understanding of the book or passage. Even for very young children, modeling and demonstrating is essential for long-term retention. A study of 18- and 24-month-old children examined whether they would retain a skill after it was no longer modeled for them. The toddlers either watched a video or were read a book of still shots from the video that required them to perform three actions: pushing a ball into a jar, attaching a stick to the jar, and then shaking the stick and jar three times to make a rattling noise. The 18-month-olds were able to perform the skills 2 weeks later, and the 24-month-olds could still do it 4 weeks after the modeling ended, with no differences in using either medium (Brito, Barr, McIntyre, & Simcock, 2012).

Young readers in early childhood classrooms should be immersed in the language of thinking as their teachers model fluent reading and the internal processes they apply to make sense of the text. These think alouds during modeling are especially important because they are not aware of the internal dialogue a reader conducts with himself. Instead, most believe that reading is simply about accuracy but not meaning. Since children may have difficulty in what is on the printed page, and what is the teacher's think aloud, you may want to use a prop, such as a "thinking cap" or a pair of glasses to don during these times.

Practical Applications

The neurosciences do not provide all the answers for education, but they play a growing role in how we understand reading development in young children. As educators, it is critical that we understand the research that comes from the neurosciences. None of us could imagine teacher development that excluded information from the fields of psychology, sociology, child development, or communication. In similar fashion, we must adequately prepare ourselves to be consumers of neuroscientific information. This is critical when it comes to determining what is relevant in the classroom and what is not. The public is enamored with brain research, and the inclusion of the word and an image or two can falsely raise the perceived level of significance.

Educators have much to contribute to neuroscience research as well. Many researchers are eager to collaborate with educators to identify issues and verify findings. Reading and educational research is primarily behavioral; that is, we are close observers of the outward behaviors of our students as they engage in literacy activities. Neuroscientists let us peer within, but without behavioral data, they are limited to fixed points in time and lack the kind of longitudinal data the educational field is good at collecting and analyzing. Neuroscience can also be our best advocates. The need for preschool funding, early childhood education, and early intervention is well known. Neuroscientists can champion these causes using research that confirms what we have long known, but only if we are at the table. And in order to do so, we must become conversant in the field of neurosciences so we can pose the right questions.

As we have noted in this chapter, there are some convergences between behavioral outcome research and neuroscience research, in terms of language and literacy learning in young children. First, there is considerable evidence that experiences shape brain development. As such, educators and teachers need to carefully consider the type of experiences that young children should have. Second, reading is not innate and must be taught. Young children need systematic and direct instruction if they are going to break the code and develop their comprehension of texts. Third, learning two languages does not harm the learner. In fact, there is evidence that developing proficiency in two languages simultaneously leads to better outcomes (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). Fourth, repetition leads to automaticity. Students need a lot of practice with print, both at home and at school, if they are going to learn to read at high levels. And finally, we are hardwired to imitate. There is behavioral evidence for the power of modeling thinking for children, and now the professional might have an explanation, in the form of mirror neuron systems, for why this works. Although there will be many more studies that clarify these points, educators can be fairly confident that the recommendations that stem from these convergences will hold the test of time and will be useful in designing effective learning environments.

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Chapter 5
Brain Development, Early Childhood, and Brain-Based Education: A Critical Analysis

Valeri Farmer-Dougan and Larry A. Alferink

Introduction

The last several decades have witnessed significant developments in neuroscience and in technology that allows researchers to monitor brain function while students are reading, solving mathematical problems, or performing other educational tasks. Accompanying this has been an effort to link these advances in neuroscience to education and the process of teaching. Jensen (2008) has called this "a new paradigm," commonly referred to as brain-based education. Some educators quickly joined the bandwagon and attempted to provide a cloak of respectability in this new paradigm by linking a number of techniques to these new developments, even though these new curricula did not originate in neuroscience research. As Bruer (1999a) has noted, brain science is said to "support Bloom's Taxonomy, Madeline Hunter's effective teaching, whole-language instruction, Vygotsky's theory of social learning, thematic instruction, portfolio assessment, and cooperative learning." Note that none of these theories or approaches originates from neuroscience.

We assume, and most readers would probably agree, that teaching methods which have been demonstrated to be effective via evidence-based approaches will also be supported by research on neural mechanisms and the neurobiological basis of learning. However, the demonstration of teaching and learning effectiveness is not dependent on neuroscience; rather, it must be demonstrated independently. Evidence of effectiveness does not come from efforts to link an educational

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technique to neuroscience research without an independent demonstration of educational effectiveness through careful research studies. Thus, while this new paradigm has given rise to a number of claims that techniques are "brain-based" and therefore presumed to be effective without such independent documentation of their effectiveness, the claim of a link to neuroscience is superficial at best. Rather than being driven by neuroscience research, such claims appear to be made in the hopes that such claims will provide a cloak of respectability to the uncritical eye.

Neural Development

Prenatal Development

Before one can understand the implications of early childhood experiences on later cognitive development, it is critical that a basic understanding of neural development be obtained. The human brain does not simply turn on and begin to experience sensations and have perceptions and even cognitions at birth. It is critical to understand that important changes in utero occur in conjunction with and in response to environmental experiences which then set the tone for later cognitive development.

The central nervous system (the brain and spinal cord) as well as the peripheral nervous system are composed primarily of specialized communication cells called neurons. These neurons are supported by glial cells, which both help hold the position of neurons and assist in neural transmission. Neurons are specialized cells composed of dendrites, a soma or body, and one or more axons. The dendrites are composed of hairlike projections that end at the synapse, the space between neurons. These dendrites have specialized receptors on their cell walls that allow them to capture the chemical (a neurotransmitter) released from other neurons. Axons are long projections off of the cell body. A neuron may have one axon or many axons. These axons are critically involved in sending messages between neurons via neurotransmitters. Further, axons lengthen to form pathways and connections to other nearby neurons as an organism experiences the world. In fact, this lengthening and creation of neural pathways, or neural circuits, form the neural underpinnings of learning (Garrett, 2011).

During the embryonic stage (14 days to 8 weeks postconception), the full formation of the embryonic disc begins (Kalat, 2007). This includes the mesoderm, which will develop into the nervous system (Rosenzweig, Breedlove, & Leiman, 2002). The nervous system begins as a hollow tube that later becomes the brain and spinal cord. This neural tube begins when the surface of the embryo forms a groove and the edges of this groove curl upward until they meet, forming a tube. The neuroectoderm forms when the foundation for the three main brain structures has been developed: the hindbrain, the midbrain, and the forebrain (Rosenzweig et al.). The closed neural tube will then become the spinal cord, central canal, and ventricles of the brain. The central canal and ventricles will form the irrigation system for the brain, while the spinal cord is the major pathway for sensory input and motor output for the body (Kalat). From this point, development of the nervous system proceeds through six distinct stages: (1) cell proliferation through mitosis, (2) cell migration, (3) differentiation, (4) synaptogenesis or initial circuit formation, (5) cell death or circuit pruning, and finally (6) synapse rearrangement.

Cell proliferation is the first of these developmental stages. Once the neural tube is formed, many new cells are produced through mitosis or neurogenesis in the ventricular (i.e., ventricle) zone, the area surrounding the hollow tube (Rosenzweig et al., 2002). One cell division leads to the formation of a daughter cell, with additional divisions forming an immature neuron. The cells that will become neurons divide and multiply at the rate of 250,000 new cells every minute. During this stage, most of this proliferation occurs in the ventricular zone. This ventricular zone then develops into the actual ventricles and central canal. Cells in the hindbrain, or lowest portion of the brain, and the midbrain or middle brain then begin rapid proliferation and division.

Migration is the next stage. The newly formed neurons migrate from the ventricular zone to their final location in the brain (Kalat, 2007). This is how the cortex and higher brain areas are formed. To do this, the cells are aided by specialized radial glial cells. These glial cells provide the structure upon which the neurons can migrate to their final location. *Filopodia*, or tiny cytoplasm projections, assist the neurons in finding their location after leaving the radial glial cells (Mattli & Lappalainen, 2008). Finally, these glial cells will also provide the necessary structure to "hold" the neurons in place.

Once the newly formed neurons have migrated to their final location, *cell differentiation* begins. This process gives rise to specific types of neurons and glial cells (Kalat, 2007). During synaptogenesis, or neural maturation, there is an elongation of the axons, with growth cones forming on the ends of the axons (Marin & Rubenstein, 2001). Terminals, the area from which neurotransmitter is released, are then established at the ends of the axons. Dendrites also elongate, and the neuron begins to express its neurotransmitter. A neuron can express one or more types of neurotransmitter. Special proteins called neurotrophic factors help stimulate this cell growth and maturation of the neurons (Kalat). Any disruption in the combination of proteins and chemicals during this process can result in brain deficits, including mental retardation and developmental delays, and have even been linked to schizophrenia (Crossin & Krushel, 2000; Poltorak et al., 1997).

Synaptic rearrangement and circuit formation occur once the cells have formed. Here the axons of developing neurons grow toward their target cells to form functional connections (Rosenzweig et al., 2002). These functional connections will provide the pathways for not only basic brain functions but also cognitive functions. To do this, special growth cones form at the tip of the axons. The growth cones allow the neuron to sample the environment for directional cues and help the axons to find their way along the glial cells. That is, chemical and molecular signposts attract or repel the advancing axon, coaxing it along the way until the neuronal axons reach their final destinations. There is quite a bit of pushing and pulling and hemming in of the neurons from the sides via these chemical and molecular changes.

The chemical and molecular forces guide the neuron to intermediate stations and guide them past inappropriate targets (Rosenzweig et al.). This stage is very critical for appropriate development of basic life and cognitive functions.

Pruning is the final stage of neural development. This actually involves the *elimination* of excess neurons and synapses. Neurons that are unsuccessful in finding a place on a target cell or that arrive late die off (Oppeneheim, 1991). Thus, normal cell death occurs during synaptogenesis, typically through apoptosis. Apoptosis is the process of active cell death, while necrosis is passive cell death due to injury. The circuit formation, then, is critically dependent on this pruning. Which neurons die and which neurons survive is dependent on the interaction between apoptosis and environmental stimulation. Cells that are part of an active circuit are kept; cells that are not used may die (Rosenzweig et al., 2002).

While scientists have extensively studied early brain development, one disorder, *Fetal Alcohol Syndrome* (*FAS*), demonstrates the importance of early experiences on the developing brain. FAS, often characterized by mental retardation and behavioural dysfunction, is typically the result of a mother's use of alcohol during a critical period of brain development. Symptoms include low birth weight, a small head circumference, failure to thrive, developmental delays or disabilities, and poor organ development. Facial anomalies are the hallmark of FAS, including smaller eye openings, flattened cheekbones, and an underdeveloped philtrum, or groove between the nose and upper lip. This philtrum is the location of the final fusing of the facial features, and underdevelopment is suggestive of delayed and muted cranial development.

Interestingly, FAS brains are often small and malformed, with the neurons dislocated compared to typically developing brains (Garrett, 2011). These dramatic brain changes appear to occur during migration, where cortical neurons fail to line up in columns as they normally would. While neurons in the normal brain tend to line up along vertical axes, in the alcohol-exposed brain, neurons line up randomly (Gressens, Lammens, Picard, & Everand, 1992). The radial glial cells appear to revert to their more typical glial form prematurely, failing to contain neurons in their appropriate location. Thus, many neurons may continue migrating beyond the usual boundary of the cortex. Because of the disruption in neuron location and lack of appropriate circuit formation, many of these children develop significant cognitive delays or disabilities and seizure disorders.

Postnatal Development

While these six stages of neural development occur in utero, circuit formation and pruning are also critical throughout a child's life. As the child experiences the world, they will continue to experience circuit formation and pruning throughout their lifetime. Circuits are strengthened or weakened depending on a child's life experiences, including academic and social experiences. Certainly neural development occurs most rapidly during prenatal and then postnatal periods, but it is important to recognize that neural development is a lifelong process.

Between birth and age 6, the brain continues to undergo its last major wave of neurogenesis and massively increases synaptic connectivity and circuit formation. The proliferation of glial cells is critical in this postnatal development. At birth, the brain weighs approximately 25 % of the full adult brain weight. By age 6, this increases to 95 % of adult weight. This increased weight is due primarily to myelination.

Importance of Myelin

Myelin is of critical importance in postnatal brain development. Myelin, consisting of specialized glial cells, is formed from cholesterol. Myelin provides a guide tube for the sprouting end of a newly formed neuron to grow through, thus allowing the extending axon to be guided to its destination. At birth, the brain is myelinated through the thalamus. However, the postnatal process of myelination of the cortex, or thinking area of the brain, is largely based on experience. For example, a premature baby will have significantly more myelin than a full-term baby of the same gestational age, because that premature baby will have had life experiences outside the womb at an earlier age than a full-term baby.

Interestingly the peripheral nervous system has myelin formed from much more rigid glial cells, such as Schwann cells. In contrast, the myelin of the central nervous system does not have a rigid structure. This allows more flexibility in the formation of neural circuits but also makes neural repair a much more difficult endeavor: When the axon is injured, the myelin does not remain rigid but may collapse and actually block the path as the axon regenerates. Thus, central nervous system regeneration is much more difficult than peripheral nervous system regeneration.

As noted above, the nervous system refines its organization and continues to correct errors by eliminating large numbers of excessive synapses. Forty percent of active neuronal death occurs during the first two years of life. This neuronal death is critical because it eliminates unconnected or useless neurons. Failure to eliminate unused circuits or damage to critical circuits may result in development delays or disabilities. For example, there is evidence of apoptosis dysfunction in postmortem brains of children with autism, particularly in the cerebellum, midbrain, and hippocampus. This suggests an insufficient degree of circuit formation or synaptic connectivity of neurons in the brains of these children.

Remember, however, that reorganization will continue throughout a child's life. Indeed, brain development occurs in waves until approximately age 21 (Gogtay et al., 2007). The cortex and in particular the temporal, parietal, and frontal lobes as well as the limbic system are refined through these waves of development. Large episodes of increased circuit formation occur from birth to three, with other bursts from ages 7 to 9, and again in mid-adolescent years (ages 13–17). The temporal or language areas of the brain show the largest increase in synaptic connectivity from birth to three, and again in mid-adolescence. Changes in the parietal-temporal areas for higher cognitive functioning show a large increase in synaptic connectivity from birth to three, with continued smaller bursts throughout the childhood years. The limbic system, integral for emotional growth and attachment, shows large episodes of synaptic connectivity from birth to three, again at approximately ages 7–9, and then in mid to late adolescence, or ages 15–17. Finally, frontal lobe development bursts are found from birth to three, with a slight increase in middle childhood. However, the largest burst of frontal lobe development occurs during the late adolescent years, ages 17–21. This may explain why adolescents are more impulsive and are more likely to engage in risk-taking behaviour: Their frontal lobe development is incomplete, and the neural circuits necessary to control these behaviours are not fully formed.

Life Span Changes in the Brain

While early childhood is critical for a large portion of cognitive, language, and emotional development, the brain undergoes additional critical development during the middle childhood and adolescent years. Importantly, frontal lobe functions such as impulse control and critical thinking do not appear to reach full development until late adolescence (Gogtay et al., 2007). Further, synaptic connectivity and circuit formation occurs throughout the life span.

How does this reorganization occur? Synapses between neurons are strengthened or weakened depending on whether the presynaptic neuron and the postsynaptic neuron fire together. Those that fire together are strengthened in a process called Long-Term Potentiation (LTP). LTP involves an increase in synaptic strength following repeated high-frequency stimulation (Garrett, 2011). There is an increase in dendritic growth as well as changes in the number of receptor sites in the synapse. Conversely, neurons that fail to fire together are weakened, a process called Long-Term Depression (LTD). LTD involves a decrease in synaptic strength when an axon of a neuron is active, but the postsynaptic neuron is not stimulated (Garrett). This, then, may result in decreased dendritic growth as well as a reduction in the number of receptor sites at the synapse. Specialized chemicals that enhance the development and survival of the neurons, called neurotrophins, are critical in this process. Recent research suggests that the postsynaptic neuron sends feedback to the presynaptic terminals via these neurotrophins. Neurotrophins decrease the plasticity, or ability to be modified, of these synapses. Thus, the synapses become more permanent via the action of neurotrophins.

Experience does indeed affect neural development (Bennet, Diamond, Krech, & Rosenzweig, 1964; Gottleib, 1976; Rosenzweig & Bennet, 1977, 1978). Neural activity due to environmental experience appears to regulate gene expression that directs the synthesis of cell adhesion molecules (Kalat, 2007). Further, neural stimulation regulates the release of neurotrophins (NGF) that are released from dendrites after synaptic connectivity. NGF stimulates the foundation neurotransmitter and promotes subsequent reorganization and synaptic connectivity (Garrett, 2011).

A child's experiences in the world continue to shape synaptic construction and reorganization throughout the individual's life. As noted above, this reorganization or a shift in connections that change the function of an area of the brain may occur at any point in the life span. Of course, the older the individual is, the more difficult reorganizing the brain becomes. This is not because the brain becomes "inflexible" but is due to the increased complexity of the neural circuits resulting from environmental interactions as the child grows. An analogy may be made with remodelling a house. A house undergoing its first remodel will have a relatively straightforward and timely remodel. Not much has been changed from the original plans, modifications have been minor, and changes may be easily made. However, a house that has been remodelled numerous times over the years is much more difficult to change, as the many restructuring and reforming of walls, wiring, plumbing, etc., make it a much more complex and less straightforward endeavor. So is true of the brain. A 20-year-old brain has many more circuits, and those circuits have many more extensive connections and reorganizations than a 2-year-old brain. Reorganizing or repairing the older brain is, by definition, a much more complicated process.

Repairing an Injured Brain

Neurogenesis, or the formation of new neurons, was once considered impossible in the older brain. Typically, neurons do not reproduce or replace themselves. Once a neuron is killed, it is often irreplaceable. However, newer research has shown that the nervous system does have some ability to repair itself by growing new neurons. The adult mammalian brain produces some new neurons, but research has only found these new neurons in two crucial areas: the hippocampus and near the lateral ventricles which supply the olfactory bulb, which is responsible for our sense of smell. Interestingly, both of these areas are critical for memory function. Thus, perhaps memory does indeed continue to "grow" (Kalat, 2007).

Recent research suggests that there may be several strategies for inducing self-repair following damage to the brain (Garrett, 2011; Kalat, 2007; Rosenzweig et al., 2002). First, neuron growth enhancers have been found which counteract the chemical forces that inhibit regrowth. These neural enhancers provide guide tubes or scaffolding for axons to follow in a manner highly similar to that found during the migration stage of neural development. Stem cells may also be critical for neural repair. Stem cells are undifferentiated cells that can develop into specialized cells such as neurons, muscle, or blood. Recent research has demonstrated that placing embryonic stem cells into an adult nervous system encourages new neurons to differentiate into neurons appropriate to that area. While this research is still in its infancy, it again demonstrates that the brain is a continuously changing and growing organ.

What is the take-home message here? Brain circuits are formed and pruned throughout the life span. While the biggest burst of neural development occurs prenatally and then in the first three years of life, middle childhood and adolescence are also critical time points for brain development. Finally, human brains continue to change throughout an individual's life, and these changes are highly dependent on experiences in the world. Thus, brain development must be considered a lifetime endeavor. The old adage of "use it or lose it" takes on significant meaning for the brain. An individual who is active physically and mentally will be an individual whose brain continues to organize and reorganize, and perhaps even grow, throughout their entire life.

Practical Applications

Advances in neuroscience over the past several decades have resulted in a variety of proposals that claim to improve education. Ostensibly, these practical applications are based on advances in our understanding how the brain is linked to learning or to other processes that impact classroom performance. There are a variety of ways in which the term "brain based" has been applied (Sylvan & Christodoulou, 2010), ranging from simply labelling a practice as brain based to actually attempting to apply research in neuroscience to educational practices. There are reasons to view all such claims with skepticism unless there is direct evidence of educational gains that can be specifically tied to that practice through well-designed research (Alferink, 2007; Alferink & Farmer-Dougan, 2010).

The Brain, Educational Policy, and Critical Periods

As described above, research has demonstrated age-related changes in the brain and some have linked these changes to educational policy. From birth to around age 3, there is a period of very rapid synapse development such that the brains of very young children are densely packed with synapses. These high-density levels continue until about age 10. After age 10, synaptic pruning occurs and density declines to adult growth levels by around age 15 (Bruer, 1999a, 1999b). Brain volume increases until around age 14 and then shrinks over the remainder of the life span (Courchesne et al., 2000). In addition, there is some evidence indicating that the brains of young children use more glucose than adults, with glucose uptake levels following a similar time course as synaptic density. For example, Chugani, Phelps, and Mazziotta (1987) found that glucose metabolism in the brain increases from about age 4 to age 10 and then declines to adult levels at around age 16.

Based on these age-related changes in synaptic density, glucose uptake, and levels of neurotransmitters, Shore (1997) suggested that the brains of young children might be primed for learning. Indeed, Jensen (1998) and Kotulak (1996) suggest that it is during the early school years, the ages between approximately 4 and 10, when we learn material quickly and easily. Chugani (1998) suggested that there may be a critical period when learning occurs at its highest rate. Sousa (1998) suggested that critical period is between the ages of 4 and 11.

While there is a critical period for the development of vision (Bruer, 1999b; Fox, Levitt, & Nelson, 2010) or when we are more likely to learn specific tasks such as a language (Bruer, 1999b; Fox et al., 2010; Kotulak, 1996; Sousa, 2001), the observations cited above are said to suggest a critical period for learning in general (Bruer). This critical period is a window of opportunity, a window that closes if one fails to take advantage of it. As a matter of public policy, this implies that resources should be shifted significantly from funding high schools and universities to preschool and elementary education.

In contrast to current educational trends, there is no evidence either linking the number of synapses or glucose uptake as direct causal factors for rate of learning or indicating that 5-year-olds are better at learning than are students who are 15 (Bruer, 1999b). Learning is based on the formation of new synapses (Garrett, 2011), not on the number of existing ones. Children who do not learn to read by the third grade can still learn to read in adolescence, and adults can certainly learn numerical skills typically learned in childhood (Bruer, 1999b; Tokuhama-Espinosa, 2011). Further, critical thinking and analytic skills appear to develop later in childhood, and attempts to teach such skills in early childhood have met with failure. Appropriate levels of funding are important for children at all ages and well-designed early childhood education is strongly supported by the evidence in helping provide the foundation for future educational success. Importantly, though, it is not appropriate to single out one age group for especially high levels of funding based on an overinterpretation of the neuroscience research.

"Right" Versus "Left" Brain

The interest in brain-based education may have started with research on brain lateralization (Jensen, 2008). The cortex of the brain is divided into two hemispheres that are joined by a band of fibers, the corpus callosum. This band of fibers permits electrical impulses to travel between the two hemispheres. When the corpus callosum is severed, this communication is no longer possible.

In cases of severe epilepsy, the corpus callosum allows inappropriate electrical impulses to travel between the two hemispheres, and this can result in uncontrolled seizure disorders. In an effort to control these seizures, the corpus callosum has often been severed in these patients and the two hemispheres operate independently. Research with these individuals clearly demonstrates some degree of lateralization of function across the two hemispheres (Gazzaniga & Sperry, 1967). While these split-brain patients seem perfectly normal, careful testing showed that subjects would name objects that they could "see" with their left hemisphere and point to objects they could "see" with their right hemisphere (Gazzaniga, 1972). This research suggested that each hemisphere had specialized functions, with the left hemisphere linked to language and the right to spatial functions.

Continued research in neuroscience strongly supports this lateralization of function but would also note that these lateralized functions are integrated and occur simultaneously in individuals with an intact corpus callosum (Carlson, 2010). That is, in typical individuals, information is processed differently but simultaneously by both hemispheres.

Right- versus left-brain teaching approaches suggest that the different brain hemispheres control different academic functions. According to right- versus left-brain theorists, the "left brain" is said to be the "logical" hemisphere, concerned with language and analysis, while the "right brain" is said to be the "intuitive" hemisphere concerned with spatial patterns and creativity (Sousa, 2001). "Left-brain" individuals are said to be verbal, analytical, and good problem solvers, while "right-brain" individuals are said to be good at art and mathematics. Thus, brain-based learning came to mean that teachers should teach to each specific hemisphere. To teach to the left hemisphere, teachers should have students engage in reading and writing. To teach to the right hemisphere, teachers should have students create visual representations of concepts (Sousa).

In the intact human, there is little evidence to support these teaching methods. True separation of function occurs only in individuals without an intact corpus callosum or those with specific brain damage, a group certainly representing a very small percentage of the student population. Thus, it is neither accurate nor realistic to believe that individuals may selectively use one hemisphere of their brain at a time for separate academic functions. It is highly improbable that any given lesson, regardless of analytic or spatial type, only stimulates activation of one hemisphere. Further, analytic and spatial functions are not as localized as is promoted by many of those developing such curricula (Garrett, 2011). Whether a visual-spatial task involves the right or left hemisphere depends on details of the task (Chabris & Kosslyn, 1998). The development of left-brain/right-brain curricula was debunked 25 years ago but continues to shape school curricula (Lindell & Kidd, 2011).

Brain Lateralization and Gender Differences

Recent research also suggests differences between the brains of boys and girls. Brain scans reveal structural differences between the genders and also suggest that different brain areas may develop at different times for boys and girls (Gurian & Stevens, 2005; Whitehead, 2006). In addition, a variety of research investigations have found significant differences in language and spatial processing between the two genders (Benbowa, 1988; Burman, Bitan, & Booth, 2008; Garai & Scheinfeld, 1968; Witelson, 1976). This research on specialized skills has been interpreted to support differences in academic performance and in brain lateralization. Boys were said to be "right-brain" dominant, while girls were said to be "left-brain" dominant (Gurian & Stevens, 2010). Schools were supposedly left-brain institutions, favoring girls over boys, supposedly explaining the academic achievement gap between the genders and the greater difficulty in managing the behaviour of boys in the classroom (Sousa, 2001). Based on brain differences between boys and girls, one school in Owensboro, Kentucky, even separated boys and girls into different classrooms so that it would be possible to teach to these brain differences. Of course, again the problem with this is that few students have had their corpus callosum severed and as noted above, attempting to teach to one hemisphere is misguided. In addition, brain differences between the genders are generally small and have not been shown to have broad practical importance (Bruer, 1999a; Eliot, 2010). Such differences reflect group differences, not necessarily individual variation. Addressing brain differences simply by segregating the genders into different classrooms without direct measurement of differences such as lateralization is likely to result in two classrooms that have a mixture of “right- and left-brain” individuals but of different genders.

One may argue that increased academic progress and higher test scores result from gender-based classrooms, but the evidence does not support this argument (Eliot, 2010; Halpern et al., 2011). Halpern et al., after a review of the evidence, argue that claims of the advantages of sex-segregated education may be due to other uncontrolled factors and that no evidence exists from carefully controlled studies supporting these claims. They also note that gender segregation has its own problems. For example, increasing the number of boys in a group increases violence and aggression particularly in the early school years. Gender differences, then, must be interpreted cautiously, and isolating children by gender for education purposes does not appear to improve learning.

Brain-Compatible Teaching

Several educators have attempted to link educational techniques to recent progress in neuroscience, suggesting that some instructional techniques are brain based (Jensen, 2008; Laster, 2008), brain compatible (Ronis, 2007; Tate, 2003, 2004, 2005, 2009), brain friendly (Biller, 2003; Perez, 2008), or brain targeted (Hardiman, 2003). One prominent proponent of brain-based education, Tate (2003), not only provides examples of the brain-compatible activities but she suggests that some educational practices “grow dendrites” and others do not.

Proponents of brain-compatible instruction emphasize that only some forms of instruction are brain compatible. Indeed, these authors suggest that teaching practices such as drill, practice, and memorization do not “grow dendrites,” while the techniques they support do (Tate, 2003, 2004, 2005, 2009). They suggest that instructional methods that are brain compatible follow constructivist approaches which involve open-ended, process-based, and learner-centered activities. This is where the applications of neuroscience may have jumped beyond the data. Tate (2003) provides no data indicating that the methods she disparages do not in fact grow dendrites, or that her preferred methods do. Further, she provides no evidence that dendritic growth is most critical for learning and education.

“Growing dendrites” is, at best, an incomplete picture of neural changes over time and inaccurate as a description of the neural mechanism for learning. Indeed, the literature suggests that it is long-term potentiation (LTP) that is critical for learning and memory formation (Freeberg, 2006; Garrett, 2011). As described above, LTP is an increase in synaptic strength that allows for the development of neural circuits which underlie memory and cognitive processing. It is not necessarily having more dendrites that are critical, but it is the increased number and strength of connections between neurons within the newly formed neural circuits.

Any instructional technique that produces learning must necessarily be accompanied by changes in the neural bases that support learning. Claiming that some instructional techniques produce these neural changes while others do not is jumping beyond the data provided by neuroscience research. The data suggest that *repetition-based activities* such as *memorization* and *mastery learning* appear to strengthen and solidify the formation and maintenance of these circuits (Freeberg, 2006; Garrett, 2011). Data strongly support the use of precision teaching, mastery learning approaches, and programmes such as DISTAR or direct instruction approaches (Kim & Axelrod, 2005; Kirschner, Sweller, & Clark, 2006; Mills, Cole, Jenkins, & Dale, 2002; Ryder, Burton, & Silberg, 2006; Swanson & Sachse-Lee, 2001) as effective instructional techniques.

Ignoring the neuroscience literature on memory formation, Perez (2008) provides "more than 100 brain-friendly tools and strategies" for teaching reading and developing literacy. She reviews several findings from brain research, suggesting that neuroscience research and instruction have never been so closely linked. For example, she indicates that research shows that reading originates and relies on the brain systems for spoken language. While this should not be surprising since reading aloud so that others can assess reading skills is an important component of increasing reading skills (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001), it is unclear what this finding tells us about how to teach children to read. Perez indicates that this means reading must be taught actively, not passively. It is unclear how this suggestion is based on neuroscience and whether any evidence-based reading programme would suggest that children will learn to read by simply passively looking at the word on the page. Independent from brain research, we know that advocating that children read silently without feedback, rather than aloud with feedback, does not improve reading (National Reading Panel, 2000), or that training teachers not to correct reading mistakes results in unacceptably large numbers of children who can't read (Rayner et al.). It would seem that the neuroscience research on reading cited by Perez follows from how children learn to read in effective reading programmes rather than the opposite. It could be argued that neuroscience may tell us something about why ineffective programmes result in many nonreaders; the critical issue is how does one design reading programmes that work based specifically on that neuroscience. Here, Perez does not provide us with any guidance.

Brain-compatible education is perhaps an unfortunate outcome of the "Decade of the Brain." Linking educational practices to neuroscience, however superficial that linkage might be, provides a false sense of credibility for those that are in awe of advances in neuroscience. Thus, one must interpret untested "neuro-based" curricula with caution. Purporting to link educational practices to the brain really adds nothing to how one understands effective teaching practices. Instead, obtaining direct evidence of the effectiveness of various educational practices would be far more useful and likely provide greater support for neuronal changes. There is little basis to doubt that effective practices will be brain compatible, but there are reasons to be skeptical of claims that studying the brain will guide us to develop new effective practices.

Brain-Compatible Teaching, Learning Styles, and Multiple Intelligences

Attempts have been made to arrange classrooms so that they are "brain compatible." These authors suggest that this can be accomplished by teaching to different learning styles or a child's multiple intelligences (Ronis, 2007; Sprenger, 1999; Tate, 2003, 2004, 2005, 2009). Following Gardner's (1983) hypothesis, they suggest that children learn best through teaching methods that are compatible with their specific individual intelligence profiles. One way to accomplish this is to teach to the child's preferred modality. This preference is determined on a self-report questionnaire, and the teacher uses this information to determine whether the child learns best visually, auditorily, kinesthetically, or a combination of modalities (Dunn, 1987; Keefe, 1982; Ronis, 2007). In other words, based on this measurement, the teacher matches instruction to that preferred modality.

However, whenever an assessment instrument is developed, users must be concerned with its psychometric properties. Unfortunately, learning style inventories are known to have problems with both reliability and validity (Dembo & Howard, 2007; Kratzig & Arbuthnott, 2006). Although other ways of categorizing learning styles have been developed, the problem of reliable measures persists or has not been tested.

More critically, it is easy to find studies that show that students differ on their preferred learning style on inventories but difficult to find studies that show that teaching to individual learning styles actually makes a difference in student learning outcomes specifically due to this practice. However, there is evidence that shows that teaching to learning styles is not an effective method (Dembo & Howard, 2007; Kratzig & Arbuthnott, 2006). Many student guides to textbooks advise students who know their learning styles to seek instructors that teach to that style. The evidence indicates that this does not make a difference in class performance (Dembo & Howard). For example, auditory learners that select instructors that emphasize that modality do not perform better than students with other preferred modalities. A recent comprehensive review of the evidence regarding learning styles (Pashler, McDaniel, Rohrer, & Bjork, 2009) found that claims about the effectiveness of teaching to learning styles are not based on the critical methodology they conclude is necessary to justify those claims. Further, some newer ways of categorizing learning styles lack any evidence of educational effectiveness at all. Pashler et al. conclude that for the learning styles hypothesis to have any credibility, well-designed studies must show that students with a particular learning style will perform better in a class tailored to their preferred modality than students with a different preferred modality. That is, research must demonstrate that children learn and perform better when instruction is matched to their learning style. Curiously, few such studies exist. As noted above, matching instruction to learning styles failed to produce this outcome in the Dembo and Howard study.

Related to the teaching to learning styles is the concept of teaching to multiple intelligences. Multiple intelligences are said to be another way in which students may differ in how they input and process information. Gardner (1983) originally identified seven different intelligences, including linguistic, musical, spatial, logical-mathematical, bodily-kinesthetic, interpersonal, and intrapersonal. There have been numerous articles published describing the educational implications of Gardner's model and many teachers have adapted multiple intelligence in the same way that they use learning styles as a means of addressing individual differences. Thus, just as one might teach to multiple learning styles, one also can teach to multiple intelligences.

Unfortunately, just as is true for learning styles, questions exist about a reliable and valid way of measuring Gardner's multiple intelligences (Lubinski & Benbow, 1995). In addition, questions have been raised about whether asserting the existence of multiple intelligences adds any explanatory power over more traditional psychometric approaches that emphasize a single factor (Waterhouse, 2006a). In addition, while the number of articles exploring how the model can be implemented is extensive, the model has not been adequately tested through empirical research (Lubinski & Benbow, 1995; Waterhouse, 2006a, 2006b). Unfortunately, brain science is said to validate many other teaching techniques besides learning styles and multiple intelligence. Yet whatever evidence there is for the effectiveness of those techniques does not come from research on neuroscience (Bruer, 1999a; Eliot, 2010). Changing teaching methods or educational policy based on a model that lacks adequate empirical support carries with it a risk of time and resources being diverted from methods with stronger empirical support. The data on learning styles and multiple intelligence should alert the reader that skepticism about these claims is warranted.

Exercising the Brain

The development of executive function is a cornerstone for not only academic learning but development of important social behaviours. Several clinical disorders appear related to poor executive function development, including attention deficit hyperactivity disorder and autism (Lyon, 1996; Naglieri, 2003). Emergence of executive functions influences a child's ability to apply knowledge as well as influencing the child's ability to know when and how to act in social situations. A child who is unable to plan, update his or her working memory, or shift attention from one task to another will have difficulty in not only academic settings but social settings as well. Barkley (1996) suggests that executive attention may even influence the development of imagination, empathy, creative thought, and self-evaluation. So, what environments or activities support and influence the development of executive functioning in childhood?

A large body of research has shown that organisms exposed to enriched environments are better at object exploration and recognition and are more prone to explore novel stimuli (Mitani, 1993; Rose, Dell, & Love, 1987; Walasek, Wesierka, & Werka, 2002). Studies have also found that enriched environments promote heavier brain weights (Susser & Wallace, 1982; Walasek et al., 2002), lasting changes in the brain including a thicker hippocampus (Susser & Wallace), and increased synaptic transmission in the hippocampus (Port, Murphy, Magee, & Seybold, 1996). These changes in the hippocampus may be critical given that the hippocampus is known to be directly connected to information processing and executive function. Further, several research investigations suggest that the *type of contact* with environmental stimuli may be important (Kiyono, Seo, Shibagaki, & Inouye, 1985; Mohanty & Behera, 1997; Ruiben, et al., 2001).

What kinds of environments appear to increase learning and cognition in children? Video game experiences appear to enhance performance on several tasks including multiple-object tracking task (Green & Bavelier, 2006b), identifying target objects embedded in a distracting background (Green & Bavelier, 2006a), and faster temporal characteristics of visual attention. Children who play video games may also have enhanced mental rotation abilities (Feng, Spence, & Pratt, 2007). However, video games do not appear to enhance every perceptual, attentional, and/or visuomotor skill (Green & Bavelier, 2008). The beneficial effects of video game play appear relatively constrained to attentional and motoric tasks.

Music lessons have also been shown to result in larger increases in IQ scores. Schellenberg (2004) found larger increases in IQ for children who received musical training. Rauscher et al. (1997) found increases in spatiotemporal reasoning for children who received keyboard training, even compared to those receiving computer training. However, there is no magical Mozart effect of music that increases IQ or cognitive abilities for all children in all settings (Green & Bavelier, 2008; Waterhouse, 2006a). Reading to a child has been well established as a factor in developing cognitive abilities (Bus, Van Ijzendoorn, & Pellegrini, 1995; Whitehurst & Lonigan, 1998). Reading to young children provides a variety of unique domains of stimulation including interactive language opportunities, picture-based stimulation, forms and cadences of written language, and sequencing.

Finally, athletics and physical exercise result in significant brain changes. In a study conducted by Kioumourtzoglou et al. (1998), basketball players showed superior selective attention and eye-hand coordination, volleyball players were better at estimating speed and direction of moving objects, and water polo players showed faster visual reaction times and better spatial orienting abilities. Aerobic exercise has been shown to improve a wider range of cognitive abilities and particularly dual-task performance (Colcombe & Kramer, 2003). In early learning, free play may be more beneficial for cognitive development than organized physical activity (Burdette & Whitaker, 2005). Physical activity exhibited during free play differs from typical physical activity in several important ways. Free play often involves gross motor play but also involves activities such as role-playing, manipulating and building with objects, and pretend play. In their review of the effects of free play, Burdette and Whitaker found improvements in attention, social skills such as affiliation, emotional affect, as well as the cognitive effects found by other researchers.

Why are these particular activities so beneficial to cognition and learning? These activities all appear to increase brain activity. Vanyman, Ying, and Gomez-Pinilla (2004) found that exercise and exploration increased levels of brain-derived neurotrophic factor (BDNF) and promoted increased performance and learning on spatial learning tasks in rats. They found that rats with higher levels of BDNF, resulting from the opportunity to explore an enriched environment, were better at learning and recall. The authors suggested that exploration in an enriched environment gave rats multiple routes for exercise, promoting multiple opportunities for making spatial connections, and thus promoted increases in BDNF production and cognitive function. Similar studies show that glutamate transmission in the prefrontal cortex, which appears to play a role in spatial working memory, is deficient in rats reared in an impoverished condition (Melendez, Gregory, Bardo, & Kalivas, 2004).

One current concern is whether too much enrichment may be overstimulating and result in detrimental effects. While few investigations have examined the effects of a too rich environment, a recent study conducted by Lakin & Farmer-Dougan (2007) examined learning and motivation differences in rats reared in highly enriched, modestly enriched, and impoverished environments. Significant differences were found between three housing groups of rats. Rats in the highly enriched condition learned faster and grew faster than rats reared in the other two housing condition. However, these same rats showed *lower* sensitivity to changes in reward. That is, they were unable to effectively shift their behaviour as the reward ratio changed. They also showed lower concentrations of dopamine (DA) than solitary reared rats, indicative of less brain reactivity and motivation to the learning task. Dopamine is a neurotransmitter that is highly critical in the identification and response to reinforcement. Other researchers report similar findings. Bowling, Rowlett, and Bardo (1993) found that rats reared in an enriched condition showed lower baseline locomotion but greater locomotion in response to amphetamine than impoverish reared rats. Rats in the enriched condition also showed greater DA synthesis in the striatum in response to amphetamine in vivo but lower DA tissue concentrations than the impoverished rats. Finally, van der Harst, Baars, and Spruijt (2003) found that rats reared in enriched environments showed a weaker anticipatory response for sucrose reward when compared to a standard housed rat.

These results parallel investigations into enriched versus impoverished environments in humans. Early research with children with mental retardation (Balla, Butterfield, & Zigler, 1974; Butterfield & Zigler, 1970; Zigler, Balla, & Butterfield, 1968; Zigler, Butterfield, & Capobianco, 1970) found that children with Down syndrome who were institutionalized and came from a high-SES environment showed decreases in IQ and academic performance after 1 year of institutionalization. In contrast, children with Down syndrome who were institutionalized and came from low-SES environment showed increases in IQ and academic performance.

Why might over-enriched environments have these effects? One hypothesis is that animals reared in complex and enriched environments have lower basal DA concentrations and may metabolize DA faster Lakin & Farmer-Dougan (2007; van der Harst et al., 2003). Individuals raised in highly enriched environments may learn to "expect" high-value rewards and, when engaged in learning tasks that are not as stimulating, may not react with the same motivation as individuals reared in less enriched to impoverished environments. Individuals reared in highly enriched environments apparently show less attention and sensitivity to tasks that take place in environments that are less enriched than their home environment. This suggests that moderation of enrichment may be a key for early childhood. Opportunities such as reading to a child, exercise, musical training, free play, and even video game play appear very beneficial to the learning environment of young children. Learning settings should certainly promote these types of activities. However, overstimulation and over-enrichment may affect a child's motivation for less enriched settings such as a classroom.

While many different experiences contribute to the development and strengthening of neural circuits, one must again be skeptical of claims of products that are aggressively marketed and attempt to benefit from the glow of advances in neuroscience research. One example of a product that merits such skepticism is Brain Gym®. Presumably developed based on neuroscience research and particularly with respect to issues related to brain lateralization, Brain Gym® attempts to rebalance and integrate the hemispheres of the brain, makes claims of extraordinary gains in academic and sport performance, and has an evidence base that relies heavily on testimonials and on articles that have not been peer-reviewed (Spaulding, Mostert, & Beam, 2010). They report that they were unable to find any empirical studies based on sound methodology that support the use of Brain Gym®. There is no evidence that Brain Gym® has any benefit beyond that of normal play (Tokuhama-Espinosa, 2010).

Summary

Spaulding et al. (2010) echoes an important theme. It is not enough that products, instructional practices, or hypothesis about learning purport to be based on neuroscience or claim to be brain based. Such claims may overreach, be an overinterpretation of existing data, or, in some cases, have no link whatsoever to neuroscience research or be debunked by that research. A sound background in neuroscience may be helpful in evaluating extraordinary claims and battling the illusion of credibility that proponents attempt to gain by labelling something as brain based. While advances in neuroscience are clearly both exciting and impressive, evidence of significant improvements in educational practices based on these developments is not yet evident, and claims to the contrary should be examined with skepticism. The best evidence that an educational practice works is empirical evidence based on sound methodology of significant educational gains.

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Chapter 6
Addressing the Affective Domain: What Neuroscience Says About Social/Emotional Development in Early Childhood

William A. Mosier

Introduction

The future mental health of society depends on the ability of adults to foster the emotional health of young children. Considerable research clarifies the extent to which the interaction between genetics and early experience shapes a young child's mental health. Unfortunately, emotional development often receives less recognition as a core emerging capacity during early childhood than the ability to achieve school readiness. However, the social competence that is developed during early childhood is directly linked to a child's later ability to adjust to social settings, like school, and to form emotionally healthy relationships.

This chapter provides an overview of the existing literature on how the affective domain impacts learning during early childhood. Developmental concepts are presented that have emerged from many decades of research. A consensus of what is understood about the emotional and social development of young children is presented for critique and exploration. A framework is offered within which the emotional needs of young children can be optimally addressed. The goal is to promote a clearer understanding of the science of early childhood development and its underlying neurobiology.

The Affective Domain and Its Role in Learning

The affective domain encompasses learned behaviors that primarily stem from feelings, emotions, values, beliefs, and attitudes. The affective domain deals with all aspects of learning due to how information from the environment is received, responded to, valued, organized in the brain, and characterized as positive or negative.

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Neuroscience, by definition, is the scientific study of the nervous system. Neuroscience deals with the structure, function, development, genetics, biochemistry, physiology, pharmacology, and pathology of the entire nervous system including the brain. The first three years of human life are a period of rapid brain growth in humans. A significant portion of human brain development takes place as a result of an individual's interaction with the environment (Geake, 2009). The brain develops and organizes its functions in direct response to the pattern and intensity of sensory and perceptual stimuli occurring in the immediate environment. It is now asserted that the impact of early experience has a greater influence on development than heredity (Fogel, King, & Shanker, 2009). By the age of three, 90 % of a child's brain has developed (Szalavitz & Perry, 2011). During this first three years of life, 50 % of all human learning occurs. These findings suggest that a child's mental health is directly related to the quality of relationships the young child experiences with the significant adults in his or her environment.

The interactive influence of genes and environmental experiences shapes the architecture of a young child's developing brain. Brain architecture and human abilities are built from neurochemical circuitry and acting on elemental factors. This stimulates behavior that provides the scaffolding for more advanced circuitry and more complex behavior (Saarni, Campos, Camras, & Witherington, 2006).

What happens in the brain when an adult learns a new motor skill and the ability of the brain to reorganize its orientation after loss of sensory input from an amputated limb indicate the brain retains the ability to reorganize itself in response to necessity even in adulthood. Though the majority of brain development in humans occurs during gestation and the first three years after birth, the brain is not biologically limited to only that period. Though the human brain retains some ability to learn throughout life, there is no evidence that deprivation during the early years can be totally reversed in later years. Therefore, it is quite clear that the first three years of brain activity are extremely important in human development (Barrett, Mesquita, Ochsner, & Gross, 2007).

Neuroscience does not suggest that an enriched environment can, magically, augment the number of synapses that a young child will form beyond a set point. It does not appear that providing more stimulation than a baby is capable of taking in will increase synaptic connections. However, it is true that infants that do not receive adequate touch, whose playfulness and curiosity are not encouraged, form fewer critical connections than they could have with adequate environmental stimulation. What science can add to society's understanding of child development and early childhood education are insights about the causes, mechanisms, and leverage points that could most effectively optimize human learning cognitively, emotionally, and socially. Neuroscience can identify efficient leverage points for enhancing brain development in at-risk children (Lipina & Colombo, 2009).

Society's emphasis on early literacy must not diminish the importance of other essential capabilities, such as learning initiative, self-confidence, and perseverance. Beyond the importance of academic achievement, addressing the affective domain during early childhood will enhance the capacities for young children to learn cooperation and problem-solving skills necessary for living in a democratic society.

Providing for a young child's emotional-social needs during the first three to five years of life will ensure a healthy foundation for the core characteristic of social competence: the ability to peacefully resolve conflict with others (Thompson & Raikes, 2007).

Brain Architecture

The architecture of the human brain is composed of integrated sets of neural circuits that are influenced by the continuous interaction between genes and the environment. Genes determine when specific brain circuits are formed and experience shapes how that formation evolves. The developmental process is stimulated by inborn characteristics of human nature. Adequate stimuli to the five senses and stable, responsive relationships construct a brain architecture that provides the foundation for learning, behavior, and mental health (Lagattuta & Thompson, 2007).

Brain circuitry initially processes basic information. As circuitry becomes more complex, more complex information is processed. More complex circuitry builds on less complex circuitry. Adaptation of circuitry for processing of more complex data is more difficult if the basic circuits are not adequately established. Increasingly more complex skills build on foundational capabilities. The ability to name a feeling accurately depends upon earlier development of the capacity to differentiate the facial expressions and sounds that represent a specific feeling and do so in one's primary language of communication. The brain circuitry necessary to put words together to speak about emotions forms the foundation for the subsequent ability to communicate empathic understanding. Just as more complex brain circuitry builds from previously formed brain circuitry, basic interpersonal skills beget more sophisticated interpersonal skills (Taumoepeau & Ruffman, 2008; Tsai, Knutson, & Fung, 2006). Two other important brain processes occur during the first three years of life: (1) the insulation of axons by myelin makes each neuro-connection more efficient by facilitating the faster transmission of neural signals, and (2) the growing of glial cells provides nourishment and additional insulation to support neurons (Carter, Aldridge, Page, & Parker, 2009).

Critical Periods of Brain Development

There is relatively little brain research that could be described as "new." Over the last 30 years, findings from the field of developmental neurobiology have provided the basis for rethinking the relationship between brain science and child development. For well over two decades, it has been known, in scientific circles, that the brain grows and changes during the early months and years following birth at a very rapid rate. Neuroscience has documented that starting even before birth, the human brain is growing rapidly. Infant brains produce trillions more synapses than are found in an adult brain. The brain of a 2-year-old has twice as many synaptic connections between brain cells as the average adult. During the first three years of life, brain connections form at a rate that far exceeds the rate at which connections are lost (Dirix, Nijhuis, Jongsma, & Hornstra, 2009).

Neuroscience has identified critical periods for brain development. These are times during which the brain requires certain kinds of stimulation if it is to develop normally. Critical periods serve as time windows for development. During these critical periods, when given adequate stimuli, normal brain circuitry develops. An adequately stimulating environment can precipitate optimal development of synaptic circuitry. The wrong kind of stimuli or a lack of adequate stimulation during these periods will result in abnormal brain development. Once a critical period ends, the opportunity to create critical circuitry in certain kinds of neural pathways is substantially diminished (Lenroot & Giedd, 2007).

The first three years of human life is a critical period for brain development. It is a period of rapid synapse formation that can facilitate functional nerve cell connections. Although the brain continues to develop after the first three years of life, it does so, typically, by eliminating synaptic connections, not by forming new ones. During the first three years of life, an adequately stimulating environment can have its strongest and most lasting effect on brain development. This critical period provides adult caregivers a biologically limiting opportunity to ensure infants and toddlers an emotionally healthy environment conducive to developing affective resiliency (Bull, Espy, & Wiebe, 2008).

In the first three years of life, the human brain can store more information than it can possibly use. However, by the end of the fourth year of human life, the pace of learning slows. A young child's brain will continue to accept new information but at a decreasing rate. By the time most young children become "language competent" (around age three), the architecture of the brain has essentially completed its basic formation. From that time until adolescence, the brain remains eager to learn with occasional growth spurts, but it will never again attain the incredible pace of learning that occurs during the first three years of life. After this critical period, an irreversibility sets in that will tend to change very little, qualitatively (Bierman et al., 2008).

Human development is, to a significant degree, predisposed by genetic factors. Genes direct neurons to specific locations in the brain and influence how genes will interact with other genes. Genetic factors determine the basic connectivity of the brain. However, genes can be influenced by the input they receive from environmental stimuli. A child's visual, auditory, tactile, olfactory, and taste input received from environmental influences stimulates neural activity. For example, speech sounds stimulate activity in regions of the brain related to language development. The more speech an infant hears, the more neurons related to language development will be activated. The more articulated, nonrandom language a young child hears in the first three years of life, the more synaptic connections are created and strengthened. For example, a newborn is able to recognize the human face and prefer it to other objects in the environment. An infant can discriminate between happy and sad facial expressions and identify the voice of its primary caregiver over the voice of a stranger (Dirix et al., 2009).

Synapses that are insufficiently utilized are weakened and many will eventually be eliminated in the pruning process if they do not continue to receive adequate stimulation. Synapse strength contributes to the connectivity of the neuronal network that supports cognitive abilities (Johnston, 2009). Experiences determine what information enters the brain and influence how the brain processes information. In other words, genes are the brain's blueprint, and stimulus from the environment guides the brain's construction.

Research about the effects of enriched environments on brain structure indicates that developmentally appropriate early childhood experiences can enhance children's cognitive development during the first three years of life. There is no question that an optimally stimulating environment plays a major role in brain development during the first three years of life. However, it can continue to do so after that period, as well. Research indicates that more complex environments continue to have a positive impact on the brain, due to its plasticity, throughout life. Neuroscience does not support that learning after age three stops. Rather, experiences in the first three years provide a foundation that, if absent, tends to restrict the quality of later learning. However, evidence does not support that learning slows down after the first three years of a child's life (Carter et al., 2009).

Neuroscience has uncovered a great deal about the correlation between brain development and developmental disabilities. Research demonstrates that a child's environment, during the first three years of life, has effects that last a lifetime. Understanding how the environment is related to early brain development stems from identifying patterns in brain activity associated with specific types of environmental exposure. The long-term effects of early stress, environmental deprivation, neglect, and maltreatment are well documented from more than 30 years of research. This occurred long before we could see the evidence of this with brain scans. Neuroscience is simply restating what has been well known to the scientific community for decades (Lagattuta & Thompson, 2007).

Nature and Nurture, Not Nature or Nurture

The interaction between nature and nurture results in a young child's brain growth and capabilities during the first three years of life. A young child's environment and experiences mediate his genetic predisposition. Thirty years ago, it was asserted that human intelligence was 51 % genetic and 49 % environmental. Current thinking reverses the balance. It is now more widely accepted that *Homo sapiens* are 49 % genetically determined and 51 % environmentally conditioned (Fogel et al., 2009). This does not dispute the fact that there is an absolute interdependence between genetics and experience, as is illustrated in the following.

Neuroscience provides conclusive evidence that early experiences influence the brain architecture, function, and capacities that:

- Impact gene expression and neural pathways
- Shape emotional development

- Regulate temperament
- Influence coping skills
- Influence social development
- Shape perceptual and cognitive ability
- Influence mental health propensity in adult life

Neuroscience also confirms that the built-in architecture of the brain:

- Has a propensity for adaptation and lifelong learning
- Has an internal programming for neural circuitry designed to strongly influence a child's capacity to learn during the first three years of life
- Has biological pathways developed in the first three years of life that will impact mental health in adult life

The influence of experience versus genetic predisposition differs depending upon the function of the brain in question. In the case of emotional regulation, social skills, and problem-solving ability, stimuli from the environment is the primary influence. How genes can be turned on or off by environmental factors provides an explanation for how experiences in the environment determine the expression of a child's genetic potential (Szalavitz & Perry, 2001).

Neuroplasticity of the Brain

Because of the abundance of synapses produced by the brain in the first three years of life, the brain is predisposed to being responsive to environmental stimuli. During the first three years, the human brain is more responsive to experiences than it will be once the pruning of synapses begins (around age three). The brain's ability to shape itself is referred to as "plasticity" (ability to adapt to the demands of environmental stimuli). The plasticity of the brain is what allows humans to be so adaptive. Because of the brain's plasticity, during the first three years of life, the brain is more vulnerable to the effects of environmental stimuli. Adverse environmental effects can be extremely harmful and have long-lasting negative effects (Johnston, 2009).

The brain develops rapidly during the first year of life. The cerebellum triples in size allowing for motor skill development, and the visual area of the cortex grows to allow an infant's limited sight to develop into full binocular vision (Knickmeyer et al., 2008). By 3 months, an infant's ability to recognize differences coincides with a growth spurt of the hippocampus. The hippocampus is the structure in the limbic system related to memory and the ability to distinguish differences in sensory stimuli. During the first year of life, language circuitry becomes consolidated in the frontal and temporal lobes, influenced by the language an infant hears. By the end of the first year of life, an infant loses the ability to distinguish between sounds from different spoken languages, a skill that, during the first few months, is inborn. The language sounds a young child hears most frequently become hardwired, in memory, for a specific language. This is why infant exposure to multiple languages during the first few months of life is so cognitively valuable. During the second year of life, the language areas of the brain develop synaptic interconnections that stimulate a quadrupling of language, if adequate language stimulation is provided by caregivers (Imada et al., 2006).

During the second year of life, the increase in the rate of myelination of the connections between neurons helps the brain to perform more complex cognitive tasks. During this period, cognitive abilities such as self-awareness allow an infant to become aware of his own emotions and intentions. When a toddler sees her reflection in a mirror, she is able to recognize that it is her reflection and not another child. Synaptic density in the prefrontal cortex reaches its peak during the third year of life. This is approximately 200 % more dense than it will be during adulthood. The strengthening of networks from one region of the brain to the other results in the ability to perform more complex cognitive skills. For example, a toddler becomes better able to use past events to interpret present events, and more cognitive flexibility allows for enhanced ability to understand cause and effect (Holmboe, Pasco-Fearon, Csibra, Tucke, & Johnson, 2008).

The Environment and Its Impact on Emotional Development

Development is shaped for better or for worse within a relational context. The role played by parenting (whether performed by a child's biological parents or by a child care provider) is a primary influence on emotional development. The quality of the relationship between a young child and his primary caregivers is fundamental to the development of the child's brain architecture, functions, and capacity (Fogel et al., 2009). A lack of positive relationships is associated with an increased risk for behavioral and emotional problems (Amelie, Dale, & Fogel, 2009).

Infant brains are very similar to each other. There is very little essential biological difference, at birth, between the male brain and the female brain. However, by adulthood, human brains are extremely different, depending on the type and quality of early experiences (Gilmore et al., 2007).The brain maintains relative plasticity throughout life. The drive for learning remains a lifelong endeavor. Even though genes predetermine the types of neural connections that will be initiated, the development of the brain is dependent on sensory-driven neural activity generated by stimulation coming from the environment. Neuroscience provides the evidence that the brain physically changes, over time, increasing neural connections and strengthening existing neural connections through repetitive experience (Dinstein, Gardner, Jazayeri, & Heeger, 2008).

A newborn has approximately the same number of neurons as adults. However, the adult brain has approximately ten times fewer synaptic connections between neurons. Brain development related to experience involves the growth of neurotransmitters, receptors, and neurons having synaptic connections that form neural clusters. The forming of synapses is called synaptogenesis. This occurs in different parts of the brain at different times depending on environmental stimulation (O'Rahilly & Mueller, 2008).

As a result of environmental stimuli experienced from birth through age 3, the number of neural connections multiplies by a factor of 20 (Marsch, Gerber, & Peterson, 2008). Sometime after age 3, the process of pruning selectively starts eliminating connections that are not being utilized (Holmboe et al., 2008). The process of pruning organizes the brain's architecture into networks called neuro-clusters. This results in each individual's brain being unique, depending directly on the experiences to which each individual is exposed (Frey & Gerry, 2006).

The pivotal ingredient of brain development in the first three years of life is a nurturing relationship. Adult responsiveness to an infant is a major predictor of healthy brain development and social-emotional functioning. The character of the relationship with a primary caregiver has an indelible influence on emotional development. This results in establishing a pattern of expectation that ultimately leads to the way a child will typically respond to environmental stressors (Szalavitz & Perry, 2011).

Young children learn to regulate their emotional responses to people and experiences by watching and perceiving their caregiver's responses. Over time, the child begins to self-regulate. Without a secure attachment relationship, a child may experience prolonged periods of unregulated stress resulting in long-term exposure to elevated levels of stress hormone that can lead to irreversible physical changes in the brain. This may measurably alter developmental trajectories, including emotional development and social cognition (Schechter, 2012). If children's attachments are not secure or are disorganized, cognitive-regulating structures do not develop to their full capacity, limiting the development of self-regulation, social cognition, and empathy (Anda et al., 2006).

The neurodevelopment of the human brain is dependent upon the presence, pattern, frequency, quality, and timing of experiences occurring in the first three years of life. The human brain has a basic structure, size, organization, and functioning that adapts, over one's lifespan, according to each individual's genetic makeup as impacted upon by experiences in the environment (Szalavitz & Perry, 2011).

Relationships with Caregivers

Secure and stable relationships with caring adults contribute significantly to healthy brain development. Young children are highly vulnerable emotionally to the adverse influences of parental mental health problems and family violence. One of the most extensively documented of these vulnerabilities is the negative impact of a mother's clinical depression on her young children's emotional development, social sensitivity, and concept of themselves, effects that have been demonstrated in both developmental research and studies of brain functioning. Young children who grow up in seriously troubled families, especially those with vulnerable temperament, are prone to the development of behavioral disorders and conduct problems (Brodsky et al., 2008).

One of the strongest predictors of social and emotional functioning is the level of attachment to a primary caregiver during the first three years of life. The inclination to become attached to a significant adult is an innate drive (Smyke et al., 2012).

Brain imaging research suggests there is a neurological basis to the human need for establishing a secure attachment with others (Marsch et al., 2008).

Parenting practices such as reading to a child, using complex language, being emotionally responsive, and communicating unconditional positive regard are all associated with a positive developmental outcome. Forty-six percent of parents are not aware that the first three years of life are the most critical for healthy emotional development. Even more sadly, 57 % of fathers are unaware of the importance of the first three years of human experience. Having a primary caregiver that is consistently warm and responsive during the first three years of life is a strong predictor for positive cognitive, emotional, and behavioral outcomes (Farroni, Massaccesi, Menon, & Johnson, 2007).

The quality of the mother-infant relationship can influence gene expression in areas of the brain that regulate social and emotional function and can even lead to changes in brain structure. The nature of the relationship will have long-term influence on how the child is able to cope with stress, both physically and emotionally. Although young children can establish healthy relationships with more than one or two adults, prolonged separations from these familiar caregivers with repeated "detaching" and "reattaching" are emotionally distressing and can lead to enduring emotional insecurities (Szalavitz & Perry, 2011).

The Inseparability of Thoughts and Feelings

Adults who are responsive to infants model behavior that facilitates the healthy regulation of emotions. Infants that receive predictable responsiveness develop a healthy sense of trust in social relationships. Research documents that early attachment is extremely important to the healthy emotional development of an infant. In the first year of life, nurturing, stable, and consistent caregiving is key to the healthy growth and development of an infant. The emotional responsiveness of caregivers increases the likelihood of positive emotional and social development. Early care and education professionals can support the social-emotional development of infants and toddlers through implementing developmentally appropriate adult-child interactions. Healthy interactions with significant adults provide young children the opportunity to learn social competence from predictable and responsive communication of unconditional positive regard (Strathearn, Li, Fonagy, & Montague, 2008).

Neuroscience indicates that the neural mechanisms underlying emotional regulation are the same as those underlying cognitive processes. Emotion and cognition work together, jointly forming a young child's interpretation of the behavior of others and influencing the young child's behavior in return. The learning of social competence occurs within the context of emotional support received from adult significant others. Emotions and cognition form an unbreakable interaction for young children. The cognitive process of problem solving is strongly influenced by emotion. Together, emotions and cognition interact to facilitate focused attention and making decisions (Barrett et al., 2007).

Brain structures involved in the neural circuitry of cognition influence emotion and vice versa. Young children with healthy social and emotional adjustment tend to achieve higher academic performance in school. Therefore, the frequent distinction made between cognitive and emotional aspects of development is not an accurate representation of how the brain processes information. Temperament plays a significant role in children's expression of emotion. However, emotional expression is also related to communication skills acquired from caregivers (Barrett et al., 2007).

Healthy social-emotional development is based in a supportive social environment established by adults significant to a young child. Young children develop their social skills from the quality and quantity of interactions experienced with adults. Young children build upon the skills learned from their initial relationships with adults. If healthy adult-child interactions are not experienced, a young child has no model for constructing healthy interactions with others (Messinger & Fogel, 2007).

The learning of social skills is a direct product of interactions that take place between adults and young children. These interactions form the basis for all subsequent social interactions. How adults interact with young children is at the very heart of early childhood care and education. Close relationships with adults who provide consistent nurturing strengthen a child's capacity to learn. A healthy relationship with at least one adult caregiver is a vital early learning experience. Relationships influence an infant's emerging sense of self and understanding of others (Schechter, 2012).

Establishing close relationships with adults is crucial for emotional security, a healthy sense of self, and an evolving understanding of social interactions. A young child's social-emotional development includes gaining an understanding of social roles and relationships. Initially, infants express their emotions through facial expressions, vocalizations, and body language. The eventual ability to use words to express emotions gives young children a tool for expressing needs in a socially competent manner. Emotional expression is a by-product of social interactions between infants and adults as they attempt to communicate with each other (Geake, 2009).

Both the understanding and expression of emotion are influenced by what a young child is exposed to. A young child's understanding of the meaning of emotions and learning which emotions are appropriate to display in which situations is a direct product of interactions with caregivers. How young children express emotions plays a significant role in relationship development. The positive expression of emotions enables healthy relationship formation. Whereas, the socially incompetent management of negative emotions leads to difficulty in social relationships. Infants respond more positively to adult vocalizations that have a positive affective tone. Social smiling is a developmental process of neurophysiology that has a cognitive, social, and emotional component (Messinger & Fogel, 2007). Observing caregivers expressing positive emotion is important for the mental health of young children (Quann & Wien, 2006).

Expressing Emotions

The development of the affective domain is a critical aspect of brain architecture. How effectively a person learns healthy ways of expressing emotions has enormous consequences that will last a lifetime. Starting from birth, infants begin developing the ability to express different emotions and the capacity to cope with and manage their emotional responses to stressful situations. The development of these capacities occurs at the same time as skills related to mobility, thinking, and communicating with language (Bayley, 2006).

As a person develops into adulthood, social skills are essential for the formation of emotionally healthy relationships, competent parenting, the ability to hold a job, work well with others, and for becoming a contributing member of society. Disregarding this critical aspect of the developing child can lead to ignoring the foundation that emotions establish for later growth and development. It is essential that a young child's affective domain get the same level of attention as his cognitive domain (Quann & Wien, 2006).

Learning to manage emotions is more difficult for some children than learning to count or read and may be an early warning sign of future psychological problems. The core features of emotional development include the ability to identify and understand one's feelings, to accurately read and understand the feelings others, to manage emotions and express them in a constructive manner, to regulate one's behavior, to develop empathy for others, and to establish and sustain healthy emotional relationships (Tsai et al., 2006).

Emotional development is built into the architecture of the human brain. Emotions are a biologically based aspect of human functioning that is hardwired into the central nervous system. Growing interconnections among brain circuitry support the emergence of emotional expression and socially competent behavior. As young children develop, early emotional experiences become embedded in the architecture of their brains (Fogel et al., 2009).

The emotional experiences of newborns and infants occur during periods of interaction with a caregiver. Infants display distress and cry when they are hungry, cold, and wet and experience positive emotions when they are fed, soothed, and held. During this early period, infants are incapable of modulating the expression of overwhelming feelings and have limited ability to control their emotions (Carter et al., 2009).

Acquiring the capability of managing feelings is one of the most challenging tasks of early childhood. When feelings are not well managed, thinking can be impaired. Throughout early childhood, young children develop an increasing capacity to use language for communicating feelings. The interrelated development of emotions and cognition relies on the emergence, maturation, and interconnection of complex neural circuits in multiple areas of the brain. The circuits that are involved in the regulation of emotion are highly interactive with those that are associated with the executive functions of planning, forming judgments, and making decisions. These functions are intimately involved in the development of problem-solving skills (Dinstein et al., 2008).

In terms of basic brain functioning, emotions support executive functions when they are well regulated but interfere with the ability to pay attention and make decisions when they are inadequately controlled. Differences in temperament are grounded in one's biological makeup. These variations lead to the stimulation of different behavioral pathways for developing strategies to controlling emotional responses (Gilmore et al., 2007).

Nurturing Emotional Development

Findings from brain research indicate nurturing emotional development is crucial to the learning process. A young child's intellectual well-being and emotional well-being are interdependent. In the center of the brain is a set of structures typically referred to as the limbic system. This set of structures has historically been thought of as the emotional center of the brain. Evidence is conclusive that emotions resculpt neural tissue. In situations of high stress or overwhelming fear, social judgment and cognitive performance suffer from compromise to the neural processes of emotional regulation. Some nominal stress is essential to meet challenges and can lead to better cognition and enhanced learning, but beyond a certain level of stress, the opposite effect occurs (Barrett et al., 2007).

Being able to self-regulate emotions is a key element of learning. Self-regulation is one of the most important behavioral and emotional skills that children need to learn. Emotions direct psychological processes, such as the ability to focus attention, solve problems, and relate to others. Neuroscience has identified critical brain regions directly related to the development of self-control (Bogdan, Williamson, & Hariri, 2012).

Healthy emotional development depends on the quality and reliability of a young child's relationships with the important people in his or her life. The development of a child's brain architecture depends on the establishment of these relationships. In early childhood, growth-promoting relationships are based on give-and-take interaction with a significant adult. A young child experiences the world as an environment filled with relationships. These relationships affect all aspects of a child's development. The quality and stability of a child's human relationships in the early years lay the foundation for later developmental outcomes such as:

- Self-confidence
- Mental health
- Motivation
- The ability to control aggressive impulses
- The ability to resolve conflicts in nonviolent ways
- Knowing the difference between right and wrong
- Having the capacity to develop and sustain intimate relationships (Bierman et al., 2008)

Nurturing and stable relationships with caring and responsive adults are essential to healthy social-emotional development in the first three years of life. Secure attachments contribute to a love of learning, healthy self-esteem, positive social skills, understanding of emotions, the ability to make and keep commitments, and a sense of morality. Interaction between an infant and at least one primary caregiver that is responsive, so that when an infant reaches out for interaction through babbling, facial expressions, and gestures, the adult responds with echoing and mirroring the same type of vocalizing and gesturing, is vital for emotional development. A young child who has a healthy relationship with a primary caregiver is more likely to develop sensitivity to the feelings, needs, and thoughts of others. This will tend to form a foundation for cooperative interactions with others and an emerging sense of social consciousness. Responsive adult-infant relationships are associated with stronger cognitive skills in young children and enhanced social competence (Messinger & Fogel, 2007).

Emotional Responses to Others

The most important relationships in life are the first relationships an infant has with the adults that play a significant role in that infant's early care and education. When a young child reaches out for interaction through babbling, smiling, verbal utterances, gestures, or crying and an adult responds by mirroring or echoing the infant's vocalizations or gestures, brain circuitry is stimulated. Decades of research indicate that mutually rewarding interactions are essential prerequisites for the development of brain circuits that will lead to increasingly complex social skills. The important influence of healthy relationships in shaping the architecture of the developing brain indicates that better trained early care and education staff working with young children is vital for providing an emotionally healthy environment conducive to learning social competence (Thompson & Raikes, 2007).

Language acquisition depends on the capacity to link meaning to specific sounds and words. It also depends on the ability to concentrate one's attention on details that facilitate engagement in constructive social interaction. Emotional health, social skills, and cognitive-linguistic capabilities that emerge during early childhood are prerequisites for developing healthy relationships. Brain architecture influences the development of the affective domain in tandem with the psychomotor domain and cognitive domain (Pluess & Belsky, 2011).

Cognitive development is directly tied to social competence, interpersonal sensitivity, and awareness of how the self relates to others. During the first three years of life, young children begin to develop an understanding of how the expression of emotion impacts others. Research suggests that infants and toddlers understand social interaction in direct response to their experiences with the adults in their environment. This includes an infants' understanding of what to expect from others, how to engage in social interactions, and which social interactions are appropriate for which situations (Taumoepeau & Ruffman, 2008).

Development of Empathy

Young children need experiences of empathy to learn how to be empathic toward others. The mirror neuron system plays a critical role in social learning (Geake, 2009). Social learning is important for the development of empathy. Empathy is the ability to experience what another person is feeling and compassionately being able to respond to that person's distress (Mosier, 1987). Empathy is fundamental to interpersonal sensitivity and successful human relationships (Barrett et al., 2007). Evidence of this is often seen in children's pretend play when acting out family roles. Humans are born with the capacity to be empathic. However, a young child needs to experience empathy to establish a neural network for expressing it. A secure attachment relationship between an infant and a primary caregiver, where emotional attunement exists, provides adequate experience to facilitate the learning of empathy (Mosier). The identification of the mirror neuron system validates that social aspects of the environment can affect biological functions such as gene expression (Chong, Cunningham, Williams, Kanwisher, & Mattingly, 2008). These findings provide strong evidence for the social interaction theories of Bandura and Vygotsky.

Empathy reflects a social aspect of emotion. Empathic understanding is being able to link one's feelings to another. Since humans are social animals, a vital function of empathy is to strengthen social bonding. Research demonstrates a strong correlation between empathy and social competence. Prosocial behavior, such as helping, sharing, and comforting another person, illustrates how empathy evolves. The experience of empathy is strongly linked to the development of moral behavior. During the first three years of life, young children begin developing the capacity to understand the emotional expression of others. Adults' modeling empathic behavior leads to young children manifesting the same behavior toward others. The way to support the development of empathy in young children is to create a culture of caring in the child's immediate environment. Helping young children to understand the feelings of others is an essential component of social competence and moral reasoning (Quann & Wien, 2006).

Self-Regulation

Self-regulation is the ability to adapt one's emotional responses, thinking, and behavior according to the appropriateness of the situation. It includes the ability to start or stop doing something even if one doesn't want to (Bogdan et al., 2012). It is a key component of learning. Being able to direct or disrupt attention for problem solving and communicating ideas to others are by-products of self-regulation. Self-regulation is critical to being able to create and maintain positive relationships. It begins to develop during infancy and has long-lasting effects on a child's relationships with others (Saarni et al., 2006). The learning of self-regulation is a primary task during toddlerhood and is only possible within the context of a nurturing relationship. By providing appropriate stimulation in response to an infant's moods and interests, a caregiver can help an infant manage his or her arousal level and build a neuro-network for self-regulation (Thompson & Raikes, 2007).

When a human is born, the brain has relatively few emotional circuits (fear, discomfort, joy, and curiosity) and a limited ability to control them. Control is learned from watching others. In nurturing relationships, an infant's primary caregivers provide experiences that build pathways of neural connections through one-on-one stimulus and response. However, if this process is interrupted by stress or a caregiver's inadequate responses, the neural connections may be weak and compromises the infant's ability to develop self-regulation. Self-regulation is a process of executive function. Executive function processes are the most critical components of emotional development and social competence. Research indicates that half of all children by age five lack socially competent levels of emotional and cognitive self-regulation (Szalavitz & Perry, 2011).

Learning to self-regulate emotions is a vital component of early education. The ability to regulate emotions is important for being able to communicate one's needs in a socially competent manner. Limited ability to regulate one's emotions can impair problem solving and compromise judgment necessary for effective decision making. Emotional regulation involves the interaction of emotions, cognition, and behavior. A young child's skill in the use of language is of vital importance for learning how to use words to express emotions. Helping young children to negotiate socially competent outcomes during emotionally charged situations is a critical adult responsibility. Emotional regulation is strongly influenced by adult role modeling of emotional regulation. The relationship between a young child and her caregiver provides a model for interactions between a young child and other children. Adults can best help young children learn how to manage their emotions by demonstrating socially competent ways of expressing their own emotions (Strathearn et al., 2008).

A young child's capacity for impulse control is important for being able to successfully adapt to social situations that require self-control. As infants mature, they become increasingly capable of exercising voluntary control over their behavior such as waiting for needs to be met or following safety rules. Responsiveness to an infant's signals contributes to the development of healthy emotional regulation (Lipina & Colombo, 2009).

Nurturing Social Competence

The earliest messages that the brain receives have an indelible impact on a child's affective domain. Early brain development is the foundation of human adaptability and resilience. Because experiences have such a powerful impact on brain development, the very young child is especially vulnerable to persistent negative influences during this period. However, on the brighter side, that means experiences that occur during the first three years of life provide an opportunity for positive early experiences to also have a huge effect on a child's coping skills and ability to express emotions in a socially competent manner (Bogdan et al., 2012).

The debate about whether genetic predisposition or nurturing experiences have the greater influence on a young child's development is a moot argument. Brain research indicates that emotion and cognition are profoundly interrelated processes and both are intimately tied to genetic predisposition and environmental stimulation. Social-emotional development is intimately tied to a young child's early experiences, such as how caregivers express feelings and manage their emotional responses to the environment. The ability to establish and maintain emotionally healthy relationships with others involves both intrapersonal and interpersonal processes (Durston & Casey, 2006).

Young children are particularly attuned to social and emotional stimulation. Infants perceive emotions before they can understand them. They learn to recognize emotions by observing adult caregivers. The capacity to express emotions in a socially competent manner is learned by observing the behavior of others. Healthy social-emotional development unfolds within an interpersonal context. Without positive ongoing relationships with nurturing adults, the young child's ability to express emotions in a socially competent manner will be compromised. Healthy emotional development includes the following abilities acquired during early childhood:

- The ability to identify and understand one's own feelings
- The ability to accurately read and understand the emotions expressed by others
- The ability to manage emotional expression in a constructive manner
- The ability to regulate one's own behavior
- The ability to express empathic understanding for others
- The ability to establish and maintain healthy relationships
  (Szalavitz & Perry, 2001)

Play and Emotional Development

Play promotes the healthy development. All learning is accelerated by play. This includes learning in the affective domain. The neurobiological drive to explore sparks play activity. Exploratory play stimulates neural activity and is responsible for the construction of complex neural networks. Play encourages engagement and the repetitive actions that engender confidence, a sense of accomplishment, and mastery. Play engages attention that promotes skill development, creative problem solving, and relationship building. Pretend play nurtures brain development by involving emotions and cognition in executive function, sensorimotor activity, and language expression. Pretend play stimulates the formation of synaptic connections (Szalavitz & Perry, 2011).

A young child pursues skill development through three strategies: trial and error practice, observation, and imitation. Learning through observation and imitation engages a neurophysiological system referred to as mirror neurons. A mirror neuron is a neuron that fires not only when a person performs an action but also when the person observes an action performed by someone else (Chong et al., 2008). The mirror neuron system is involved in the cognitive processes of social cognition and social interaction, the social use of language, understanding of actions, observational learning, theory of the mind, and empathic understanding (Chong et al.).

Neuroscience has found that repeated observation of an action increases brain activity resulting in experience-dependent changes in neuro-clusters (Chong et al., 2008). The mirror neuron system facilitates the ability to understand the actions of others and to imitate their actions (Frey & Gerry, 2006). Because mirror neurons are used to learn from what is observed, these neurons can facilitate learning through imitation rather than relying on learning through trial and error (Chong et al., 2008; Geake, 2009). The human infant has the ability to imitate actions within an hour after birth. For example, a newborn can imitate protruding the tongue, while observing it being demonstrated by an adult. The ability to imitate helps young children learn by observation, without the need for direct instruction (Frey & Gerry).

Young children eventually become selective in what they choose to imitate. If a person being watched makes a mistake or stops before completing an action, a toddler will typically perform an action that he or she thinks was intended, not what was actually done. Toddlers are able to understand the relationship between observed actions and the effects of those actions. They benefit from observation of others' actions to assist organizing their own actions. Because children learn through imitation, antisocial models and events (such as portrayed in the media) are a potentially dangerous source for observational learning (Frey & Gerry, 2006).

The Stress Factor

The development of emotion and cognition both rely on the maturation of the complex neural networks in multiple areas of the brain. The integration of efforts from different areas of the brain results in more efficient functioning necessary for learning. Neuroscience is able to demonstrate how the connections between emotions, memory, and attention improve problem solving and self-control, and how chronic stress can raise chemical levels of stress hormone that interfere with memory, attention, and learning (Thompson & Raikes, 2007).

A young child experiencing consistent, predictable nurturing develops neurobiological capabilities that increase the chance for having stable mental health. However, if there is an absence of nurturing relationships in the first three years of life, long-lasting deficits in neurodevelopment will occur (Szalavitz & Perry, 2011). Infants with a secure attachment to a primary caregiver tend to have lower levels of stress hormone (Wiedenmayer et al., 2006).

If an infant is exposed to persistent chaos and unpredictability, the developing neural system and functional capabilities will reflect this disorganization (Szalavitz & Perry, 2011). Unpredictable environments cause stress. Stress affects emotional development. Children who chronically experience abusive environments develop more defensiveness than children experiencing a nurturing environment (Anda et al., 2006).

Hormonal changes associated with pregnancy and childbirth prime mothering responses to an infant. Neurochemical responses tend to become shaped by caregiver(mother)-infant experience (Amelie et al., 2009; Kringelbach & Berridge, 2010). The process allows biologically based attachment needs to develop between infants and non-maternal caregivers, including fathers, grandparents, and child care providers (Saarni et al., 2006). Competent caregiving functions as a regulator of the stress response (Schechter, 2012). The caregiver-child relationship is a stress buffer. Consistent and responsive attention to an infant helps build the neurobiological capacity to tolerate future stress. Attachment to a caregiver in a secure relationship provides a sense of safety and elicits biological responses important for being able to cope adequately to stress and is critical for forming neural connections related to feeling a sense of belonging and confidence in oneself and developing a sense of the needs and feelings of others, social relatedness, access to autobiographical memory, and the development of self-reflection and narrative (Szalavitz & Perry, 2011).

Stress during early childhood can be either growth-promoting to the brain or damaging to the brain, depending on the intensity and duration of a stressful experience. Individual differences in physiological responsiveness to stress and the extent to which a significant other is available to an infant for providing emotional support during periods of stress will influence how an infant is able to cope with stress. Without adequate nurturing, an infants' ability to cope with stress and develop healthy emotion regulation may not occur (Wiedenmayer et al., 2006).

A young child will alternate from reaching out to the primary caregiver and exploring the environment. A sense of security grows out of a nurturing, predictable environment. Young children who experience a responsive relationship feel more emotionally secure and have greater stress tolerance than young children that have a less emotionally secure relationship. Secure attachment plays a pivotal role in the regulation of the stress responses (Johnston, 2009).

All stress is not equal. Some stress can have a positive effect on development. This is typically the case when exposure to stress hormones is time-limited and related to discovery learning. A positive stress occurs when an infant is attempting to reach a toy that is just barely out of reach. The stress induced by straining to obtain the toy can actually provide the motivation to sustain effort in reaching for the toy until it is secured. This assists an infant in developing coping skills necessary for adapting to change (Schechter, 2012).

A level of stress experience that could be tolerable stress is associated with physiological responses that could possibly disrupt brain architecture if not kept in check. Appropriately supportive relationships can facilitate adaptive coping and restore stress hormone levels to within normal limits. Common early childhood experiences, such as stranger anxiety, separation anxiety, and receiving immunizations, can produce stress. However, these stress-inducing experiences, if short-lived, may not result in enough stress to damage the brain. Stress that occurs within the context of a stable and supportive relationship with a significant adult can be tolerable stress. The support of a responsive adult can facilitate in bringing stress hormone levels back to within a normal range. Stress such as being startled for a prolonged period before being receiving comfort can potentially be tolerated, even though significant levels of stress are involved. A level of stress that could have long-term negative consequences can be tolerable if its occurrence is time-limited by a supportive adult helping to mediate an infant's stress response. Timely intervention allows the brain to recover from the potentially damaging effects of the body's stress management system being overactivated (Wiedenmayer et al., 2006).

The most threatening kind of stress experience is referred to as toxic stress. Toxic stress is associated with an intense and prolonged activation of the body's stress management system in the absence of adult support to provide buffering protection from the release of stress hormones. Precipitants can include chronic depression of an adult significant other who becomes emotionally unavailable, reoccurring physical or emotional abuse, chronic neglect, parental substance abuse, and/or repeated exposure to violence (Lipina & Colombo, 2009).

Toxic stress is associated with effects on the nervous system that can, over time, damage the developing architecture of the brain and lead to negative mental health consequences. Research indicates that remediation interventions that are provided after age eight will tend to produce a less favorable outcome than developmentally appropriate interventions done prior to age three in children who are particularly vulnerable to mental health instability. Activation of the body's stress management system produces elevated levels of stress hormones (e.g., cortisol) and proteins associated with inflammation (e.g., cytokines). These responses prepare the body to deal with threats. They stimulate the "fight or flight" response. The consequence of persistently elevated cortisol levels can be toxic to the developing architecture of the brain. When these physiological responses to stress remain activated at high levels for too long a period of time, they can have a devastating effect on brain development (Wiedenmayer et al., 2006).

The essential feature of toxic stress is the absence of consistent, supportive relationships to help an infant cope with distress so that the body's physiological response to stress remains at dangerously high levels. Chronic elevated levels of stress hormone release brain chemicals that disrupt the healthy architecture of the developing brain. This can lead to difficulties with learning and emotional modulation that affect metabolic regulatory mechanisms leading to a permanently lower threshold for distress. Young children experiencing toxic levels of stress may develop greater susceptibility to stress-related mental health problems (such as depression and anxiety disorders) that persist into adulthood (Schechter, 2012).

Toxic stress can damage the developing brain. Sensitive and responsive caregiving is a requirement for the healthy neurophysiological and psychological development of a child. Young children who experience abuse and neglect will tend to have lifelong problems with emotional regulation, self-concept, social skills, and learning. This can lead to mental health problems (Anda et al., 2006). Young children who have been exposed to violence will be at risk for acting out in violence, under stress, because of adverse effects on their early brain development (Smyke et al., 2012).

Chronic stress during postnatal development has been found to lead to dysregulation of the stress response system, disruption of neural plasticity, and atypical synaptic connectivity (Pluess & Belsky, 2011). Stress can be overwhelming for young children without supportive adult relationships and can lead to changes in brain functioning, including chemical responses, impaired cell growth, changing the kinds of proteins and other molecules produced by the brain, death of neurons, and the interference with the formation of healthy neural networks. Prolonged stress leads to an elevated level of noradrenaline, a hormone that increases arousal and aggression as well as lowering the levels of serotonin (a mood-regulating hormone that affects learning and memory), which can result in depression and low impulse control (Szalavitz & Perry, 2011).

The effects of prolonged stress (persistent altered levels of the impulse-modulating and stress hormones serotonin, cortisol, and noradrenaline) can become a process characterized by hypersensitivity to signs of danger, including hypervigilance and a short fuse for the body's stress response which can lead to lifelong problems with learning, behavior, and mental health by actually changing brain chemistry, as well as interfering with attention and memory (Geake, 2009).

Emotions, learning, and memory are closely linked. Emotions influence a person's capacity to attend, to be involved, and to take action, all of which are essential for learning. A child's motivation is underpinned by having a sense of security that develops from nurturing relationships. If children feel excessively stressed, fearful, or anxious, maintaining engagement can become difficult, and neural processes are compromised (Schechter, 2012).

The Effects of Environmental Deprivation

Neuroscience has provided compelling evidence that brain development in the first three years of life is extremely vulnerable to environmental deprivation. The longer-term negative outcome is a significant decrease in the victim's capacity to trust. Early experiences either enhance or diminish an individual's potential for trust, empathy, efficient problem solving, and rational decision making. All development and learning is significantly impacted, for better or for worse by experiences occurring during the first three years of life. Knowledge from neuroscience, cognitive science, the social and behavioral sciences, and psychology provides a broad understanding of how learning is not just about school readiness. The impact of early experiences on brain architecture and brain function profoundly influences social and emotional development (Anda et al., 2006) (Table 6.1).

The evidence is clear that individualized, consistent human contact can have a profoundly positive therapeutic effect on an infant even after suffering emotional neglect.

Emotional neglect most commonly arises from parental psychiatric conditions, such as a history of major depression and anxiety disorder (both of which are associated with attachment disturbances during infancy) and demonstrate consistent patterns of corticolimbic dysregulation that is visible on neuroimaging. Documented enlarged amygdala volume in young children of a depressed caregiver/parent suggests the

Table 6.1 The first three years of life shape subsequent development

Neuroscience has provided compelling evidence that:
The first three years of life are critical to long-term outcomes for children
Nurturing relationships are critical for optimal brain development
Neglectful and negative relationships damage the developing brain
The strength and quality of the relationship between an infant and a responsive caregiver is fundamental to the development of brain architecture
Children's brains are changed by experience
Most of the brain's development after birth is dependent on experience
Healthy brain development relies on loving, caring, stable, and supportive relationships with important people who respect children
Children's brains adapt to the environment in which they find themselves
Infants with strong, positive, affective attachment to their caregivers have been found to learn better and cope better with stressful situations
Children are social beings who learn most effectively in socially sensitive and responsive environments through interaction with caring adults
Social-emotional development is as important as intellectual development
Infants learn to trust by having a predictable and responsive caregiver
Warm, sensitive interactions are more effective at promoting brain development than any toy, CD, DVD, or TV
All areas of learning and development are connected and depend on each other
Children learn self-control and how to manage their feelings by observing the behavior of the adults around them
Empathy is learned by watching it and experiencing it
If children don't learn to regulate the use of aggression prior to school, aggressive behavior can become a lifelong problem
Unpredictable environments cause unhealthy stress to young children
The earliest messages that the brain receives have an indelible impact on a child's emotional development
Neuroscience provides a well-documented rationale for early intervention

need for further research of the intergenerational transmission of psychopathology to infants raised in such an adverse situation. Neuroscience validates the importance of prompt intervention with a neglected child, ideally within the first three years of life (Bogdan et al., 2012).

Neuroscience provides evidence that early experiences impact mental health and social skills. The longer a child stays in an unhealthy environment, the more difficult it is to apply interventions that can reverse damage to mental health. Attempts at intervention will require more resources, more time, and potentially be less effective for minimizing the damaging effects of an emotionally unhealthy environment when interventions are attempted after the end of early childhood (Smyke et al., 2012).

Neuroscience affirms that all behavior that controls the learning of how to express mood and emotion is mediated through the brain (Levitt & Campbell, 2009; Schechter, 2012). The assertions of neuroscience are deductions made from scientific experiments, descriptive studies of children who have suffered environmental deprivation, and even from neuroimaging and electroencephalograms (EEGs) done on adult brains (Bogdan et al., 2012).

Findings indicate that if, during the first three years of life, a young child experiences neglect that is characterized by inadequate sensory input (i.e., lack of touch, lack of social interaction, and poverty of exposure to language), there will be underdevelopment of the brain (Szalavitz & Perry, 2011). The development of the brain and its functions is severely compromised in an environment that does not have adequate stimulation. Studies are conclusive that the longer children experience environmental deprivation, the more pervasive and resistant to recovery the detrimental effects will be. Hard scientific data collected through brain imaging technology is continually being modified, refined, and built upon to enhance understanding of the negative effects of environmental deprivation. These neuroscience findings complement what has been understood about environmental deprivation for over 30 years (Szalavitz & Perry).

Neuroscience highlights the fundamental importance of early experiences on the developing human brain and the associated risks of environmental deprivation during the first three years of life. The neurosciences have increased our understanding of the genetic factors that interact with the environment contributing to individual outcomes that are favorable for either emotional resilience or psychopathology. Genetic and environmental studies have explored what can be done in an attempt to limit some of the devastating effects of emotional neglect that might occur to a young child in the first three years of life. The hope exists of eventually finding intervention strategies that can foster greater plasticity in the social-emotional life of a child suffering from environmental deprivation. However, a solution is far from easy and not something that will occur in the near future. The more practical pursuit is prevention (Schechter, 2012).

Some individuals may be at risk for heightened symptoms of depression and anxiety by virtue of a genetic predisposition. Other children may have a genetic predisposition for being more resilient in the face of environmental deprivation. Genetic research challenges our thinking of risk versus resilience and gene variants that promote different degrees of plasticity (Gilmore et al., 2007). Young children who suffer more pervasive emotional neglect show clinically significant reductions in the severity of attachment disorder after early psychosocial intervention (Bogdan et al., 2012).

Young children who are grossly neglected display delays in motor development and cognitive ability, and many are never able to catch up, even with remediation. Just as serious is the fact that environmental deprivation can lead to a blunted affect from which the child will tend not to recover. It is clear that children require adequate stimulation to manifest “normal” development. However, research does not provide any evidence that “extra” stimulation is helpful for augmenting what would be in the range of normal development. There is definitive evidence that environmental deprivation will have a devastatingly negative influence on brain development. However, neuroscience does not suggest that adding “extra” stimulation will enhance synapse formation (Szalavitz & Perry, 2011).

Addressing Mental Health Issues

The emotional health of a young child is closely tied to the social and emotional characteristics of the environments in which he resides. A young child growing up in an environment where mental health problems, substance abuse, and family violence are observed on a regular basis faces significant risk of damage to his emotional development. Chronic maltreatment has been documented as producing measurable changes in the brain of a very young child. Although these children are at greater risk for later problems with aggression, they can be helped substantially if provided with early and adequate intervention that must include a reliable and nurturing relationship with a supportive caregiver. Young children who have experienced significant maltreatment exhibit a predictable array of clinical symptoms. Young children can have mental health symptoms such as anxiety and/or depression and demonstrate the same kind of brain changes seen on electroencephalograms in clinically depressed adults (Smyke et al., 2012).

A healthy well-being incorporates the integration of physical, social, emotional, and cognitive aspects of development. Neuroscience provides evidence of the interrelatedness of emotions and cognition. Social and emotional capacities are equally as important as cognitive capacities as indicators of healthy brain development and predictors of academic achievement (Schechter, 2012).

Evidence from neuroscience links a sense of well-being with learning. A healthy sense of well-being is identified as a cognitive characteristic of executive function. The neural networks associated with executive function have been found to be highly interactive with those involved with regulation of emotion. Research has identified a strong connection between emotion and cognition and how they enhance learning through the release of endorphins. Endorphins are the neurochemicals in the brain that contribute to pleasure, feeling positive, and acting with optimism (Geake, 2009).

The fact that significant emotional distress can affect the architecture of a young child's brain is difficult for society to accept. Despite extensive knowledge on the emotional and social development of young children and its underlying neurobiology, the current early childhood focus is on cognition, language development, and early literacy.

The gap between what is known about emotional development of young children and the management of behavioral difficulties demonstrates an uneven availability of support for addressing mental health problems. Limited mental health training for caregivers and early childhood educators on how to deal with children who present significant emotional and/or behavioral problems in early care and education programs is an alarming problem that must be addressed (Lipina & Colombo, 2009).

Minimal expertise in early childhood development and infant mental health within child-welfare agencies that assess and treat children who have been the victims of maltreatment is a major drawback to appropriate intervention. Despite evidence that young children can experience debilitating anxiety and depression from the trauma of parental abuse and neglect or from witnessing violence in their family or neighborhood, there are limited competent resources available to provide treatment. This is the case in spite of the data illustrating that early interventions can significantly moderate the negative effects of these types of trauma (Schechter, 2012).

Neuroscience provides a well-documented rationale for early intervention. There is compelling evidence that all early childhood programs should balance the focus on cognition and literacy with equal attention to emotional and social development. Young children need to develop social competence just as much as they need the cognitive skills required to master reading and math. Services to support parents and child care programs that are struggling to manage the disruptive and aggressive behavior of some young children need to be readily available in order to prevent social and emotional problems from becoming more severe (Thompson & Raikes, 2007).

Providers of early care and education must have sufficient training to help children with behavior problems at the first sign of a problem. Greater emphasis must be placed on the social and emotional development of children in both preservice training programs and through continuing education via in-service training. Additionally, early childhood care and education programs must have direct access to mental health professionals who specialize in working with young children. Expertise in early identification, assessment, and clinical treatment must be incorporated into existing intervention programs to address the needs of young children with mental health problems (Smyke et al., 2012).

Practical Application

The challenge that needs to be addressed is the significant gap in the quality of early childhood care and education, and the responsibility to close that gap is a moral imperative. The difference between what is known from systematic scientific inquiry about what is in the best interest of young children and what is actually practiced is unacceptable from a moral perspective. Neuroscience provides a sound framework for establishing the appropriate actions necessary to meet the emotional needs of young children. All that is lacking is a stronger commitment to acting on the research that is available.

The essence of high-quality early childhood education is embodied in the ability of early care and education practitioners to build positive relationships with young children. A significant shortage of adequately trained early childhood education staff indicates that society does not recognize the importance of having highly trained and highly qualified early childhood professionals working with young children.

Quality in early child care and education programs is often defined in terms of adult-child ratio, group size, physical facilities, and curriculum. But "quality" is perceived differently when viewed as a feature of the relationship a young child develops with an adult. The importance of ensuring that relationships in child care

are nurturing, stimulating, and reliable requires that the emphasis of high-quality child care should be on the skill and personal attributes of caregivers and on improving the wages and benefits that affect staff turnover. Having a better understanding of early childhood education and brain development can provide impetus for the design of early childhood programs that have a more positive impact on the lives of young children.

Unfortunately, the generally poor quality of child care available in America does not support this view. High caregiver turnover, poorly designed programs, inadequate preparation of staff, and low wages are the norm. Research suggests that the amount of time spent in out-of-home care during infancy may be associated with a tendency to display oppositional and aggressive behavior by the time a child enters kindergarten. Other research indicates that a child who develops a warm and positive relationship with her kindergarten teacher is more excited about learning, more positive about coming to school, and more self-confident and displays more academic achievement in the classroom.

Conclusion

Certain major themes consistently emerge from the neuroscience literature in relationship to the affective domain. Knowledge acquired from neuroscience, cognitive science, the social and behavioral sciences, and psychology provides a broad understanding that learning is not just about cognitive development related to school readiness. The impact of early experiences on brain architecture and brain function also has a profound influence on social and emotional development. The intimate interaction between genetic predisposition and experience shapes the architecture of the developing brain. Each child's engagement in relationships with his/her parents, other primary caregivers, and even media exposure will have an indelible impact on his or her developing mind. Emotional, social, and cognitive abilities are inextricably intertwined and cannot be separated; even though rhetoric is often employed to make it seem as if it is possible to isolate cognition from emotion, it is not possible. The brain is an integrated organ and all its functions operate in a coordinated effort. Emotional health and social competence provide the foundation for emerging cognitive abilities. This provides the foundation for what it means to be human.

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Chapter 7
Early Literacy Trends for Children Identified as At Risk for School Failure: Are They Consistent with Contemporary Neuroscience and Learning Theory?

Rae Ann Hirsh

By the time Tara was six years of age, she/he had lived with eight different families. His/her biological mother was incarcerated on cocaine charges and his/her biological father was institutionalized for schizophrenia. Tara was labeled at-risk for academic failure and participated in a variety of early childhood programs that were developed for children like his/her. She/he also attended a kindergarten program in his/her public school district designated for children at-risk.

Children, like Tara, identified as at-risk for school failure often participate in early childhood programs with a specialized focus on early literacy skills. The curricular practices proliferating these programs are heavily influenced by public policy. This chapter will explore the policy trends for children identified as at-risk, analyze early learning standards stemming from those policies, and investigate whether recent developments in neuroscience and learning theory support the current trends in early literacy programs. The chapter will conclude with policy and curricular recommendations influenced by contemporary neuroscience and learning theory.

Early Literacy Policy Trends for Children At-Risk for School Failure

National attention to programs for children considered at-risk for school failure intensified with the passage of the Elementary and Secondary Act (ESEA) of 1965. This act was an effort to combat poverty, inequality, and racism through creating instructional assistance programs for children identified as at risk. Part of the act allowed for federal assistance to create public preschool programs that would

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provide foundational skills for preschool children considered at-risk to succeed academically in later school years. Throughout the decades that followed, variations of the act have emphasized early literacy, particularly learning to read, and have influenced curricula in public early childhood programs. Contemporary approaches to learning to read range from a task orientation model that focuses on decoding and comprehension (Gough & Tunmer, 1986) to a lifespan developmental perspective that focuses on these six principles: (1) recognition of the changing role of reading as communication practices evolve, (2) broadening of the concept of reading beyond word recognition, (3) acknowledgement that growth in reading continues through the lifespan, (4) consideration of students' developing interests and needs, (5) instruction in domain-specific reading practices, and (6) attention to readers' individual differences (Fox & Alexander, 2011, p. 8).

In 2000, The National Reading Panel (NPR) endorsed the task orientation model through its identification of five pillars of reading instruction: (1) phonemic awareness, (2) phonics, (3) fluency, (4) vocabulary, and (5) comprehension. The vast differences in schools of thought regarding learning to read have resulted in policy and practice debates concerning the most appropriate instructional methods to instill literacy skills in youths labeled at-risk. Despite the debates and criticism, the task-and-skills-oriented model of reading has predominated. The Elementary and Secondary Act was revised and reinstituted several times in the last few decades and has perpetuated the task-and-skills model. In 1998, Head Start programs were mandated to address specific language and literacy standards (Kleeck & Schuele, 2010). In 2001, the Elementary and Secondary Act was nicknamed *No Child Left Behind* (NCLB) and introduced accountability and standards-based assessments to its repertoire and reemphasized the importance of early literacy skills (The White House, 2002). In 2002, the Good Start, Grow Smart initiative was launched. This initiative stemmed from NCLB and offered state money in return for preschool early learning standards and policy guidelines that align with state education reading and math standards. In 2008, the National Early Literacy Panel (NELP) published an early literacy report entitled *A Scientific Synthesis of Early Literacy Development and Implications for Intervention*. The NELP's methodology sought to "identify the essential early skills or abilities relevant to later literacy development [through a search] for published scientific studies that could provide correlational evidence showing the relationship between early skill attainment and later literacy growth in decoding, reading comprehension, or spelling". The NELP's entire report sought to find strategies that specifically target the task-and-skills model of reading. Early literacy was limited in the report to decoding, reading comprehension, and spelling. The skills identified as necessary early literacy skills were chosen because "the use of these skills is evident within all literacy practices, and they are readily recognizable as being necessary or useful components of literacy" (NELP, p. vi.). The title of the report *A Scientific Synthesis of Early Literacy Development* is somewhat misleading. The report is not a scientific synthesis but a collection of research that facilitates the task-and-skills model of reading development. The report does not seek to identify or research the skills necessary for literacy to develop; its purpose is to identify strategies that support a specific model of reading development. This is an important distinction as the NELP's report is heavily cited in policies and practices that govern early literacy programs and grants. The skills and strategies mentioned in the report may help some children develop early reading skills; however, a more comprehensive approach that targets the current understanding of the cognitive structures responsible for symbolic thought needs to be addressed and utilized in policy and practice.

The Elementary and Secondary Act, NCLB, and the NELP's report inform policy and practice in curriculum and instruction for young children. The influence can be seen in the creation and execution of early learning standards.

Public Policy's Influence on State Standards

According to the US Department of Education, in 2005 almost half of preschool-aged children attend a part-time or full-day early education program. These programs are often Head Start and/or Even Start programs which are federally funded initiatives currently working under the guidelines of No Child Left Behind Act (NCLB) of 2001 (The White House, 2002) and have adopted early learning standards for the Good Start, Grow Smart (2002) early learning initiative. The policy guidelines adopted in this initiative outline biosocial, psychosocial, and cognitive domains (DellaMattera, 2010). Biosocial development refers to physical growth and brain development, psychosocial development refers to emotions and relationships, and cognitive development refers to mental processes, language, and cognition. All 50 states have early learning standards for preschool-aged children. Thirty-four states have early learning standards for infants and toddlers. Forty-eight states currently have social/emotional standards for preschool-aged children (Dusenbury, Zadrazil, Mart, & Weissberg, 2011). While these states address social/emotional standards, a thorough examination of the early learning standards reveals an extraordinary emphasis on cognitive development. After a study of four states' early learning standards, DellaMattera reports that between 60 and 70 % of the early learning standards address cognitive development, 19–23.5 % address psychosocial development, and a mere 8–10 % address biosocial development.

An examination of K–12 standards has revealed that as of April 2011, only one state, Illinois, has free-standing social/emotional standards in their state standards (Dusenbury et al., 2011). Some states attempt to integrate social/emotional standards into health and other content areas. Recent reform efforts of NCLB have initiated the trend toward national core standards. As of 2011, every state except Texas, Alaska, Virginia, Montana, Minnesota, and Nebraska has adopted the new core standards. The core standards address education from K to 12th grade and have no standards targeting social and emotional development and/or skills (Common Core State Standards Initiative, 2011). From preschool to 12th grade, the majority of the standards target specific math and literacy skills. As DellaMattera cautions, "This sends a clear message about what is regarded as important elements of human development in preparing preschoolers for success in school and life" (2010, p. 38). The message is clear; public policy encourages a cognitive emphasis in early learning programs that target specific literacy skills that focus on decoding and comprehension.

Despite the Act's revisions and emphasis on isolated literacy skills, literacy rates are still a concern in the United States. The curricular trends inspired by NCLB have come under question, particularly the task-and-skills-oriented model of reading development that persists in preschool curricula. The task-and-skills model views reading as an isolated cognitive function that can be learned as decoding and comprehension skills are acquired. Current trends in brain research and learning theory suggest that literacy involves more than simply decoding and comprehension. The rich emotional architecture of the brain reveals that emotions have a significant role in literacy and symbolic development. Contemporary neuroscience (Schore, 2001; Zull, 2006) and developmental learning theory (Greenspan & Shanker, 2004) challenge the task-and-skills model by suggesting that the emotional circuitry of the brain relies on emotional signals to create symbols, language, and problem solving.

Neuroscience and Early Literacy Skills

The field of neuroscience has tremendous implications for the classrooms of young children and learning theory. Zull (2006) defines learning as a change in a behavior, thought, action, or symbol. The internal changes of the brain during learning rely on chemical changes originating from a specific set of neurons in the neocortex. These chemicals were responsible for the evolutionary changes in the brain (Zull). The chemical changes are initiated through social contact with other human beings. "This human capacity to exchange emotional signals with each other begins in early life during an unusually long practice period and leads to symbols, language, abstract thinking, and a variety of complex emotional and social skills that enable social groups to function" (Greenspan & Shanker, 2004, p. 13). Human beings have experienced increasingly complex social and emotional interactions over hundreds of thousands of years that have allowed complex symbolic thinking to emerge. Without the changing rich emotional context of culture, it is doubtful that symbolic thinking would have reached the cognitive milestones of contemporary society.

The neocortex houses other biological components essential to learning which include the processors for sensory input, association, and motor movement. These processors represent the biological structures thought to be responsible for learning. "All regions of the neocortex are enmeshed in networks of other neurons that secrete emotion chemicals" (Zull, 2006, p. 7). Emotions are the primary *contemporary* function of those neurons. Emotion chemicals saturate every cognitive process in the brain associated with learning and provide the very foundation for learning to occur (Feldman, 2007; Greenspan & Shanker, 2004; Jensen, 2005; Zull, 2006). Emotions can be referred to as the *architect of the mind* as they are responsible for building the cognitive constructs in the developing brain (Greenspan & Shanker).

In addition to the chemical structure, emotions play additional roles in brain growth. During the first two years of life, the brain creates nucleic acids that control all developmental processes. "This massive production of both nuclear and mitochondrial genetic material in the infant's brain is directly influenced by events in specifically the social-affective environment" (Schore, 2001, p. 11). Doan (2010) reports that "before children learn that words carry meaning, they understand affect" (p. 1065). Social-affective interactions, nucleic acids, and emotion chemicals work with sensory input, associative processes, and motor movements to develop symbols. For example, a toddler has an affective desire. The toddler uses physical movements to indicate that affective desire to an adult. As the toddler coordinates gestures and desires, he/she begins to develop language to signal a response to the affective desire (Greenspan, 2001). "A child's capacity to connect affect to motor planning and emerging symbols becomes relatively apparent between 9 and 18 months of age as the infant shifts from simple patterns of engagement and reciprocity to complex chains of affective reciprocity that involve problem-solving interactions" (Greenspan, 2001, p. 3).

As symbols develop, our brains have the capacity to understand the emotional meaning of a symbol or stimulus before the symbol/stimulus is even recognized (Greenberg, 2008). Children who have difficulty with this emotional process often times have challenges with language and motor planning as well. This is evident in children with autism and on the autistic spectrum. Typically, children with autism have noticeable breakdowns in emotional development, language, *and* motor planning. Greenspan (2001) points out that "the core psychological deficit in autism may, therefore, involve an inability to connect affect (i.e., intent) to motor planning and sequencing capacities and symbol formation" (p. 3).

Symbolic development requires a purposeful emotional emphasis from infancy (Feldman, 2007) in an environment that nurtures emotional development (Eynde, De Corte, & Verschaffel, 2006; Greenspan, 2001; Gygas, Tapiero, & Carruzzo, 2007; Yeh, 2008). This is evident in the research on affect synchrony and familial relationships. Feldman studied interactions between infants and their mothers at 3 months to determine how emotionally in tune the mother was with his/her infant. This "in-tuneness" can be referred to as affect synchrony (Feldman, 2007). Affect synchrony, "the matching of micro-level affective behavior between parent and child…," (Feldman, 2007, p. 602) at 3 months is a strong predictor of symbolic development in toddlerhood. Greenspan (2001) reports that "family patterns that foster healthy relationships are essential for healthy emotional and intellectual growth. In one study we [he] found that families with four or more risk factors interfering with relationships were 20 times more likely to have marginal IQ scores and behavior problems at age four. This pattern continued and was again documented when the children were 13 years old" (p. 22).

The Academy of Child and Adolescent Psychiatry reports staggering statistics that demonstrate the tremendous number of young children with emotional challenges. Almost 3,500,000 children in the United States are diagnosed with some type of emotional problem (Hansen & Zambo, 2007). In addition to emotional diagnoses, a growing number of children are also diagnosed with disorders that significantly affect emotional development. Autism, Asperger's, and children on the autistic spectrum exhibit significant emotional, cognitive, behavioral, motor, and communicative delays.

Many young children are exposed to a number of emotional stressors that include divorce, violence, poverty, abandonment, and neglect that put them at risk for optimal cognitive development (Hansen & Zambo, 2007). In addition, the US Census Bureau (2001) has identified several risk factors for children that include poverty, welfare dependence, absent parents, single-parent home, unwed mother, and having a parent that did not graduate high school. All of these risk factors have the potential to severely impact the quality of the parent/child relationship which negatively impacts the development and size of the brain.

Much of the work dedicated to social/emotional deprivation studies and cognition revolve around children raised in international orphanages. Emotional deprivation has been specifically correlated with abnormal sizes of specific brain structures such as the hippocampus, amygdala, and corpus callosum (Mehta et al., 2009; Pollak et al., 2010). The hippocampus' primary function is processing memory and creating emotional responses to stimuli. The amygdala is crucial in processing emotions and guiding social behaviors (Adolphs & Pessoa, 2010). The corpus callosum connects both hemispheres of the brain and contains the most white matter. Young children who have experienced significant emotional deprivation have demonstrated 15–18 % decreases in brain matter indicated through images obtained from medical resonance imaging (MRI) and smaller head circumferences than typical children (Mehta et al.). Children raised in institutions where caregivers have significant social and emotional training have increased developmental quotient scores on standardized developmental assessments by as much as 13.5 points (McCall et al., 2010).

Contemporary neuroscience supports the structural intertwining of emotions and cognition (Zull, 2006). Enriched social/emotional environments result in healthier brain development, improved cognition, and the necessary foundation for symbolic thinking and early literacy development (Adophs, 2007; Hanson & Zambo, 2007; McCall et al., 2010; Mehta et al., 2009). Unfortunately, public policy significantly downplays emotion's role in cognitive thought, construction, and development. As a result, early learning standards and curricular practices intended for children at-risk place a significant emphasis on isolated literacy skills to provide a foundation for reading and cognitive development. Social and emotional skills that are addressed are not purposefully intended for literacy development. Public policy and curricular practice need to embrace emotion's role in brain development and respond with standards and practices that encompass the important role emotions have in cognition. Greenspan and Shanker's (2004) developmental evolutionary model of symbolic development provides a contemporary learning theory that can inform policy and practice and takes into account emotion's role in early literacy development.

Developmental Evolutionary Model of Symbolic Development

Greenspan and Shanker's (2004) developmental evolutionary model of symbolic thought provides a learning theory consistent with emotion's role in early literacy development supported by contemporary neuroscience. Symbol systems such as letters and numbers provide the necessary foundation for skills such as reading and mathematics. Symbol systems help to facilitate the development of a child's potential or intelligence. School curricula, most notably in the early years, are focused on recognizing, developing, constructing, communicating, sharing, and utilizing symbols from different disciplines. Symbols provide meaning and transference for different disciplines and for strands of information. Symbol systems exist in different forms across many disciplines (Gardner, 2011). There are linguistic symbols such as letters, words, and genres. Mathematic symbols take the form of numerals, signs, patterns, algorithms, and operations. Bodily/kinesthetic symbols involve movements and gestures that communicate specific physical disciplines such as ballet terminology and movements. Musical symbols consist of notes, staffs, rhythms, and genres. Various art tools, forms, and techniques communicate spatial symbols. Symbols are the necessary tools that facilitate learning and the construction of knowledge (Gardner, 2011).

But how does a child create and assign meaning to these symbols? Theorists such as Piaget provide a developmental hierarchy to the use and sophistication of the development of symbols and symbol systems; however, the processes involved in initial construction and meaning of symbols can be understood by examining the role of emotions in symbol construction (Greenspan & Shanker, 2004; Zull, 2006). Emotions are responsible not only for symbolic thought but for the formation of crucial building blocks necessary for the brain to develop normally and functionally (Feldman, 2007; Greenspan & Shanker, 2004; Jensen, 2005; Zull, 2006). Greenspan and Shanker define the basic unit of intelligence as connection between a feeling and a symbol. This connection introduces the concept of emotion into the learning equation. In order to fully understand emotion's role in the cognition, it is critical to understand emotion's role in the development of symbol systems.

Infancy: The Beginning of Literacy Development

Healthy emotional and symbolic development requires adults who nurture healthy emotional interactions from birth (Greenspan, DeGangi, & Wieder, 2001; Greenspan & Shanker, 2004; Klein, 2007). In order for children to develop a sense of symbols, they need to interact with an adult who is attentive to their needs and individual differences. This attentive, synchronous relationship inspires children to search for meaning in the symbols they see and manipulate. Greenspan et al. explain the synchronous development of emotions and symbols in the first few years of life through the identification of specific emotional milestones.

Navigating the Flood of Sensations

The infant first experiences the world through sensory perceptions. Greenspan et al. (2001) label this initial milestone as *Making Sense of Sensations*. The infant is bombarded with sensory experiences and needs to organize them and decide which sensations are important to attend to. These sensations begin to unlock the complex emotional world for the child as she/he figures which sensations are pleasurable and which are not and which sensations she/he wants repeated and which she/he does not. *We will now return to Tara and examine how his/her early literacy skills were impaired as she/he navigated through the six emotional milestones. Tara experienced more unpleasurable sensations than pleasurable. Signals from his/her parents were confusing. Sometimes unpleasant sensations were responded to by his/her parents and stopped; often times they were not, and occasionally they were brought on by his/her parents. Tara had difficulty making sense of so many uncomfortable and unpleasant sensations. She/he began to respond by completely withdrawing or exhibiting a forceful and lengthy crying episode.*

Falling in Love

The next milestone is referred to as *Intimacy and Relating* (Greenspan et al., 2001). As Greenspan (1997) explains, "Without some degree of this ecstatic wooing by at least one adult who adores his/her, a child may never know the powerful intoxication of human closeness, never abandon herself to the magnetic pull of human relationships, never see other people as full human beings like herself, capable of feeling what she/he feels" (p. 51). The infant first begins to understand social human interaction through *intimacy and relating*. The child begins to recognize and react to the emotional cues and actions from others. This is the beginning of affect synchrony. Affect synchrony develops through attuned interaction between an infant and his/her caregiver and is essential for symbolic development (Feldman, 2007). This synchronicity can predict the success and sophistication of symbolic play in the toddler years. *Tara had a drug-addicted mother and schizophrenic father during the critical time she/he was developing intimacy and relating. His/her first exposure with intimacy resulted in neglect, abandonment, abuse, and mistrust. His/her first relationships in the world were unstable and unhealthy. She/he did not experience a synchronous relationship and therefore did not develop appropriate emotional regulation skills. Affect synchrony is essential for symbolic development, and not experiencing this as an infant caused Tara to develop an unstable foundation for symbols and emotions.*

Buds of Intentionality

The third milestone, *Buds of Intentionality* (Greenspan et al., 2001), is marked with the infant's intentional attempt at two-way communication. The infant begins to use gestures and expressions to initiate and respond to a caregiver. This intentional two-way communication is the infant's first intentional attempts at verbal literacy.

Responding to and encouraging these first attempts is important in developing healthy communication and verbal literacy skills. *Tara's initial attempts at two-way communication were met with inconsistent, limited, and often negative responses from his/her parents. This contributed to an unstable foundation for communicating wants and needs. His/her attempts at early communication were often met with punishment or no response at all. During this stage, Tara was first placed with a foster family. Tara had not experienced healthy intimacy nor had his/her attempts at interaction been recognized and responded to in a healthy way. Tara was irritable and fussy and demonstrated limited attempts at communication.*

Purpose and Interaction

Milestone four, *Purpose and Interaction* (Greenspan et al., 2001), marks the child's ability to understand and use gestures and sounds not only to communicate wants and needs but to communicate intention and purpose. The child begins to fine-tune his/her interactions to learn more about the adults she/he is with, herself, and the world around his/her. *To interact with purpose, the child needs to have his first attempts at two-way communication responded to in a healthy way. Tara's attempts were often not even responded to and his/her interactions at this stage were erratic and irritable. His/her interactions resembled a much younger infant. During this stage she/he was placed with yet another foster family.*

Images, Ideas, and Symbols

The fifth milestone signifies the true beginning of symbolic thought. This milestone is referred to as *Images, Ideas, and Symbols* (Greenspan et al., 2001). A child can give an emotion a name and talk about how they are feeling. The toddler in this stage understands that a symbol can stand for something or someone else and the symbol emerges as the child replaces his/her caregiver's physical presence by a mental image (Feldman, 2007). Communication extends further than wants and needs. The child communicates for fun and pleasure. If a child does not reach this milestone, future reading and writing become an increasingly challenging task. *As a toddler, this stage was challenging for Tara. She/he did not develop a strong sense of purpose and interaction. This contributed to an inferior sense of ideas and symbols. Communication attempts usually resulted in negative responses from adults, and she/he learned that communication was a tool for expressing negative emotions, thoughts, and feelings. Communication was not seen as an attempt for fun and pleasure. She/he didn't consider his/her own intentions at communication important and, therefore, exhibited a delayed attempt at pretending, creating, and using symbols.*

Emotional Thinking

As communication evolves, the child reaches the sixth milestone, *Emotional Thinking* (Greenspan et al., 2001. At this level, the child can link ideas to sequences or emotions. The child can name feelings and explain why they feel a particular way. For example, the child can say, "I am mad because she/he took my toy." The child can also plan, create goals, and follow through on them. This is significant to the development of symbolic representation, because now the child can connect and sequence feelings and ideas. The child can elaborate on thoughts and provide causes for actions and feelings. The child now has the brain constructs necessary for further development of ideas, intelligence, and symbol systems. This is demonstrated through the type of symbolic play and language the older toddler/young preschooler exhibits (Feldman, 2007). Emotions not only help create the symbols a child will use but also give meaning to these symbols once created. The meaning of a symbol changes with experiences and interaction. *Emotional thinking involves the ability to add reasons to feelings and actions. Without strong purpose and interaction and with delayed attempts at pretending and using symbols, Tara demonstrated much difficulty reaching this milestone. She/he was not able to verbalize why she/he felt different emotions and often responded with violent temper tantrums and screaming. His/her violent outbursts and limited self-control were often reasons for different foster home placements. Without this stage fully developed, it was difficult for Tara to express feelings and needs, develop goals, and use symbols in functional ways.*

After children reach the *emotional thinking* milestone, their ability to use and create symbols continues to evolve during the preschool years. The preschooler begins experimenting with symbols through drawing and exploration of print. Children's symbolic representations during the preschool years have tremendous literary considerations. Children's drawings offer a narrative look at the thought processes involved in symbol formation (Kendrick & McKay, 2009). The thought processes usually revolve around experiences that have evoked strong emotional reactions in the preschool child. Without emotional interactions, the symbols used in a child's environment have little meaning or usability.

When preschool children have strong emotional interactions with symbols in their environment, their idea of that symbol is strengthened and their own representations of the symbol become more detailed and authentic (Spendlove, 2007). *Tara's attempts at writing and print awareness were overshadowed by his/her negative behaviors. She/he associated a strong negative emotion with anything school related. His/her foster parents had a very difficult time with his/her, and she/he was placed in another foster care home with a single mother for his/her kindergarten year. Before kindergarten, Tara had very limited awareness and exploration of print due to intensive attention to behavior and his/her negative emotions and outbursts. Tara had formed negative appraisal emotions associated with communication attempts because of his/her experiences as a young child. These negative emotions transferred from verbal communication to reading and writing. Tara's art and writing development reflected scribbling and beginning awareness. This left Tara with a weak foundation for the readiness skills that she/he would need in kindergarten.*

Practical Applications: How Can Early Literacy Initiatives Reflect Contemporary Neuroscience and Learning Theory?

Emotions play a critical role in cognitive development as evidenced in current research in neuroscience (Mehta et al., 2009; Pollak et al., 2010; Zull, 2006). Therefore, it is imperative to facilitate a learning environment that supports the healthy development of emotion if children are expected to be able to use the formal symbol systems of the culture. A call for three distinct approaches is in order to create an early literacy program that incorporates advances in contemporary neuroscience and learning theory:

1. Prenatal and infant programs need to be developed to help mothers develop affect synchrony.
2. Mediated learning/floortime needs to be a part of preschool readiness programs.
3. Social and emotional goals need as much, if not more, attention than cognitive goals in the early childhood curriculum.

Parent Programs

Programs serving young children need to address affect synchrony as early as possible. Children at risk for emotional and/or cognitive challenges should be a part of infant intervention programs that help mothers bond with their babies, respond to emotional cues, and develop affect synchrony through modeling and coaching. Hospitals can implement this type of modeling and coaching into their parenting classes. Child care centers offering mommy-and-me sessions can target young infants and their mothers. Caregivers of infants need specific training on developing affect synchrony with the infants they care for. Early "prevention" programs can be initiated to help mothers and fathers develop intimate bonds with their babies. Foster care programs need to adopt specific training strategies to help foster parents develop affective synchronous behavior with the infants they care for. Readiness programs in school can be developed for parents of new infants in the community. The readiness program can communicate the importance of emotional bonding and the impact it will have on early literacy development. Stronger advocacy for maternal and paternal leave to care for infants needs to occur along with policies that protect the time new parents need to bond with their babies. The media can be called upon to spread the importance of emotional bonding to later cognitive development.

Mediated Learning

Emotional needs can also be approached in the curriculum of infants to preschoolers through mediated learning and specific approaches such as the Developmental, Individual-Difference, Relationship-Based (DIR) Floortime Model. “Mediated learning, as distinct from direct learning through the senses, occurs when the environment is interpreted for the child by another person who understands the child’s needs, interests, and capacities, and who takes an active role in making components of that environment, as well as past and future experiences, compatible with the child” (Klein, 2007, p. 125). Mediating involves focusing, exciting, expanding, encouraging, and regulating the child’s behavior through purposeful interaction that responds to the symbols and experiences in the child’s environment (Klein). Mediation responds to the emotional needs of the child and helps interpret and formulate affective responses into symbolic experiences. The DIR Floortime Model involves a specific mediation strategy that targets six emotional milestones: *making sense of sensations; intimacy and relating; buds of intentionality; purpose and interaction; images, ideas, and symbols; and emotional thinking* (Greenspan & Wieder, 2006). Floortime consists of meeting a child at his developmental level, identifying his strengths, and using those strengths to engage the child on his terms and entice him into healthy interactions and exchanges, helping the child to work through each emotional milestone.

Early Learning Standards

Social and emotional standards need to be as prevalent, if not more, than cognitive standards in early learning programs. Standards targeting curricular practices that support positive, appropriate, healthy relationships with children and adults can facilitate healthy emotional and cognitive development (Amsterlaw, Lagattuta, & Meltzoff, 2009; Croizet & Dutrevis, 2004; Havighurst, Harley, & Prior, 2004; Osborne, 2007; Schutz & Davis, 2000; Zembylas, 2005). The emphasis in the early learning curriculum needs to focus on the relationship between the child and the child’s teacher and developing emotional competencies. Ellen Galinsky (2010) identifies seven essential life skills that all children need: focus and self-control, perspective taking, communicating, making connections, critical thinking, taking on challenges, and self-directed/engaged learning. Each of these life skills requires the partnership of an in-tune, loving adult. Mastering these skills allow the child to develop core executive functioning skills that will provide the cognitive foundation for literacy. Executive functioning skills “manage our attention, our emotions, and our behavior in order to reach our goals” (Galinksy, p. 7). Early learning standards need to reflect contemporary brain research on emotions, cognition, and learning.

Tara’s reading deficits were first addressed through in-class and pull-out intervention programs, direct instruction, reading recovery, small group, and individual reading help. These programs were not effective. Tara’s teacher carefully observed his/her and initiated a mediated learning experience for his/her using his/her interest in puppetry. His/her teacher noticed that the only material in the room that incited a positive emotion in Tara was puppets. Tara loved the puppet corner in the classroom and enjoyed puppet stories told by his/her teacher. Tara enjoyed the *humor of the puppet shows and liked the cuteness of the puppets. Tara began to ask for the sheepdog puppet, a very popular puppet in the classroom. Tara's teacher recognized the puppet as a vehicle for reaching Tara on an emotional level and helping his/her address missed emotional milestones in his/her earlier development. Tara began to express emotions to his/her teacher through the use of the puppet and engaged in dialogue with the puppet. Tara began appropriately conversing through the use of the sheepdog with other students as well. She/he often asked the other children's puppets if she/he was pretty and cute, and if they liked his/her (meaning the sheepdog). She/he liked the responses she/he got and soon began to interact more appropriately with his/her peers. Very slowly, she/he reworked some of the emotional milestones that were so challenging for his/her as a younger child. His/her teacher began to write small scripts down that Tara narrated. Tara began to write his/her own scripts in pictures and letter strings. Tara's work as a reader and writer finally began to grow.*

Conclusion

Current trends in early childhood curriculum for children identified as at-risk for academic school failure need to embrace current neuroscience and learning theory to fully provide a strong cognitive foundation for learning and literacy. Healthy emotional development is a powerful building block in the brain and needs to be addressed in policy and practice as a necessary conduit to cognition. Future research involving brain imaging and other technologies that allow us to delve into the mysteries of the developing brain is imperative to fully understand the processes involved in the structural formation of cognition and early literacy skills.

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Chapter 8
Brain Differences in Children with Autism Spectrum Disorders and Subsequent Impact on Learning

Diane Branson

Introduction

Kara is a 2-year-old with autism spectrum disorder (ASD) who is fascinated with letters of the alphabet and numbers. She can recognize and name all the letters of the alphabet and match and name numbers up to 20. Kara cannot, however, use words to communicate her wants and needs. Kara screams and cries much of the day as her teachers and parents try to understand what she wants.

Pablo is a 4-year-old with ASD. Pablo speaks in long sentences using advanced vocabulary and his teachers call him "the little professor." Pablo tends to become obsessed with particular topics. His latest obsession is with dinosaurs and he has a near encyclopedic knowledge that he tries to share with everyone. Pablo does not have any friends in his preschool; his odd behaviors and poor social skills put the other children off and he prefers playing by himself or with adults anyway.

Darren is a 5-year-old with ASD. He is nonverbal and uses a Picture Exchange Communication System (PECS) to communicate with others. Darren has a paraprofessional assigned to him to due to his tendency to eat inedible objects (e.g., play dough, dirt, and paste) and to engage in self-injurious behaviors (e.g., biting his own hand, pulling out chunks of his own hair, and banging his head against the wall).

The diverse abilities and deficits illustrated in the preceding vignettes demonstrate why early childhood teachers often feel unprepared to meet the needs of children with ASD who are placed in their classes (Barton, Reichow, Wolery, & Chen, 2011). It is important for early childhood teachers to increase their competence in successfully including children with ASD in their classes; however, because the number of children diagnosed with this disorder continues to rise each year.

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Furthermore, recommended educational practices call for the placement of children with ASD in classrooms with typical peers (Ganz & Flores, 2010; Iovannone, Dunlap, Huber, & Kinkaid, 2003; National Research Council, 2001; Simpson, 2005), increasing the likelihood that most early childhood teachers will have the experience of including a child with ASD in their early childhood class at some point in their careers.

This chapter will provide an overview of autism spectrum disorders, with an emphasis on current knowledge about the neurological differences between the brains of children with autism and individuals without ASD. This will be followed by a discussion of cognitive theories used to explain some of the characteristics common in individuals with ASD. Next, there will be a discussion of how early childhood teachers can use their knowledge of the unique learning styles of children with ASD to apply Universal Design for Learning (UDL) principles in their classrooms and individualized adaptations to design supportive learning environments.

Autism Spectrum Disorders

Autism spectrum disorders (ASD) are a group of neurodevelopmental disorders characterized by abnormalities in social interactions and relationships, delayed or nonexistent use of language for communication, and restrictive, repetitive, and/or stereotypic behaviors. This disorder was once considered to be rare, but now is believed to affect as many as 1 in 88 individuals (CDC, 2012). The definitive cause of ASD has not yet been determined, but current research points to a combination of genetic vulnerability along with an environmental trigger (Geschwind & Levitt, 2007; Muhle, Trentacoste, & Rapin, 2004). An identical twin of a child with ASD has a 60–90 % chance of also being affected (Volkmar, Chawarska, & Klin, 2005). Genetic testing of multiplex families (i.e., families with more than one child with ASD) has identified several differences on a number of chromosomes, including 2, 5, 7, 11, and 17, which may contribute to the disorder. Researchers suspect that there could be dozens of different genes involved in causing different variations of ASD (Abrahams & Geschwind, 2008; Rutter, 2005).

In addition to investigating the role that genes play in ASD, researchers have used neurocognitive testing to learn more about the developmental disruptions in brain development that might cause ASD and how particular brain structures might lead to the symptoms associated with ASD.

Current Knowledge on Brain Differences in ASD

Researchers have studied the brains of individuals diagnosed with autism to try to understand what anatomical differences could explain the characteristics associated with the disorder. Early anatomical studies of autistic brains described the anatomical differences based on postmortem studies of adolescents and adults diagnosed with the disorder (Bailey et al., 1998; Bauman & Kemper, 2004). Advances in the field of cognitive neuroscience in recent years have helped researchers begin to understand the neurodevelopmental differences in the brain structure and function of young children with ASD soon after they begin to show clinical signs of the disorder (Courchesne et al., 2007; Dawson et al., 2007; Dinstein et al., 2011; Just, Cherkassy, Keller, Kana, & Minshew, 2007; Sparks et al., 2002). Neurocognitive testing across the lifespan in autism has revealed age-related brain abnormalities. Several researchers have identified overgrowth during the early years of life, followed by declining growth during adolescence and adulthood (Courchesne, Campbell, & Solso, 2011; Courchesne, Redcay, Morgan, & Kennedy, 2005; Pierce, Glatt, Liptak, & McIntyre, 2009).

Several of the consistent neurobiological findings will be discussed later in the chapter. A complete review of all the findings is beyond the scope of this chapter. To read more on this topic, see, (e.g., Courchesne, Redcay, and Kennedy (2004), DiCicco-Bloom et al. (2006), and Stigler, McDonald, Anand, Saykin, and McDougle (2011)).

Use of noninvasive brain imaging techniques has greatly advanced our understanding of brain anatomy and function. Magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI) technologies are two technologies that are frequently used and have improved our understanding of the autistic brain. MRI uses radiofrequency waves to define body tissue structure and function without exposing the body to ionizing radiation used in more invasive imaging techniques (e.g., positron emission tomography). fMRI is particularly useful in showing the brain in action. This kind of testing can be used to show which areas of the brain are activated during specific cognitive or motor tasks. fMRI measures changes in cerebral blood flow and metabolism in regional brain areas. For example, this kind of testing identified that individuals with autism do not use the fusiform gyrus area when processing faces as compared to individuals without autism (Pierce & Redcay, 2008). Electroencephalography (EEG) measures the electrical activity produced by neurons as measured by electrodes placed along a person's scalp. This technology is frequently used in tandem with fMRI to measure both global and regional brain activity during cognitive tasks.

Neuroimaging studies have been used to help us understand both the neuroanatomical difference in the brain's physical structure (e.g., size of different lobes in the brain) and the brain's function (e.g., under-connectivity of neural networks during a cognitive task like reading a sentence). An effort was made to only report the most consistent brain differences identified in the literature; however, it must be acknowledged that neurocognitive research in autism is an ever-evolving field of study with new findings frequently changing our current understanding of brain differences.

Structural Brain Differences in ASD

One of the most consistent findings regarding the brain structure of children with ASD is that brain size is normal at birth and then increases dramatically during the first two years of life. This early overgrowth is followed by slowed or arrested brain growth in early childhood. Structural MRI studies have shown the frontal and temporal lobes as primary sites for overgrowth in 2–4-year-olds with ASD, while the parietal and occipital areas are relatively unaffected (Courchesne et al., 2007; Hazlett et al., 2005; Minshew & Keller, 2010; Minshew, Sweeney, Bauman, & Webb, 2005; Redcay & Courchesne, 2005). Courchesne et al. explain that during the first two years of life, the neural circuitry for higher-order language, social, emotional, and communication skills are being formed. This is also the period when brain overgrowth in autism is at its maximum and the first signs of autism typically appear. Abnormalities in the development of this circuitry may lead to the characteristics of autism. Another key finding is that both white and gray brain matter abnormalities have been found throughout the brain, demonstrating the distributed rather than focal brain abnormalities in ASD (Stigler et al., 2011). There have been inconsistencies regarding whether volume was increased or decreased in various brain structures, and this has been attributed to the heterogeneity of the disorder, to the age when subjects were scanned, as well as to other differences in research methods (Amaral, 2008; Courchesne et al., 2011).

Abnormalities have been found in several areas of the brain, including the frontal lobe (Bloss & Courchesne, 2007; Carper & Courchesne, 2005; Hazlett et al., 2005), temporal lobe (Carper, Moses, Tigue, & Courchesne, 2002; Hazlett et al., 2005), amygdala (Munson et al., 2006; Sparks et al., 2002), corpus callosum (Boger-Megiddo et al., 2006; Piven, Bailey, Ranson, & Arndt, 1997; Rice et al., 2005), and cerebellum (Bauman & Kemper, 2004; Vargas, Nascimbene, Krishnan, Zimmerman, & Pardo, 2005). A summary of the purpose of each brain area, the structural abnormalities noted in the literature, and the suspected result on behavior in ASD is presented in Table 8.1.

Functional Connectivity Differences in ASD

According to Minshew and Keller (2010), fMRI studies have established that autism is a "disorder of under-connectivity among brain regions participating in cortical networks" (p. 124) or a "disconnection syndrome" (Williams & Minshew, 2010). Regions of the brain that should function together efficiently to perform information-processing tasks are affected, and in many cases individuals with ASD rely on local processing networks in one brain area to accomplish tasks that are normally handled by coordination of two or more brain areas (Williams & Minshew, 2010).

Functional connectivity refers to how activity in one brain area correlates to activity in another area or to the temporal synchronization of activation of two brain areas during a task (Waas, 2010). Functional connectivity is typically measured by fMRI data, looking at activation patterns during tasks that require coordination of different brain areas. EEG has also been used to provide indices of connectivity.

A number of fMRI studies have demonstrated medium- and long-distance functional under-connectivity in children and adults with ASD during rest and during task completion (Belmonte et al., 2004; Courchesne & Pierce, 2005; Minshew & Williams, 2007; Waas, 2010). One of the most replicated findings has been underactivation of the fusiform gyrus and reduced connectivity between the

Table 8.1 Anatomical differences of the autistic brain

Brain difference	Purpose of this brain area	Suspected result	Researchers
Excess frontal lobe growth in the early years followed by arrested growth in adolescence	Responsible for executive function brain activities: reasoning, planning, and organizing	Excess white matter interferes with the brains ability to develop long-distance connectivity between different areas of the brain which are needed for higher-order cognitive functions	Carper and Courchesne (2005), Courchesne et al. (2011), Courchesne and Schumann et al. (2007), Hazlett et al. (2005), Redcay and Courchesne (2005)
Increased volume in the amygdala during infancy but smaller number of neurons in the mature brain	Responsible for social and emotional functioning. Helps coordinate body's physiological response to cognitive information (e.g., "fight or flight" response)	Increased anxiety levels, lack of empathy, and deficits in recognizing emotions. The degree of overgrowth has been linked to severity of ASD symptoms and poorer development of language and social skills	Munson et al. (2006) and Sparks et al. (2002)
Enlarged temporal lobe	Important for language processing and social communication skills	Excess neurons leading to reduced long-distance functional connectivity which would impact higher-order language and social skill development	Bloss and Courchesne (2007), Carper et al. (2002), and Hazlett et al. (2005)
Undersized corpus callosum	Connects the left and right hemispheres of the brain in order to transfer sensory and cognitive information	Poor coordination between the left and right sides of the brain impacting higher-order language and social skill development	Boger-Megiddo et al. (2006), Piven et al. (1997), and Rice et al. (2005)
Abnormal cerebellum and decreased number of Purkinje cells	Responsible for physical coordination	Poor motor planning and coordination	Bauman and Kemper (2004) and Vargas et al. (2005)

fusiform gyrus and the left amygdala, posterior cingulate, and thalamus during face-processing tasks (Critchley et al., 2000; Kleinhaus et al., 2008; Pelphrey, Adolphs, & Morris, 2004). Just et al. (2007) measured functional connectivity between frontal-parietal brain areas during a Tower of London (TOL) task. The TOL task has been used to test executive function in individuals without disabilities and reliably evokes activation in the prefrontal and parietal areas of the brain (Velazquez et al., 2009). Just et al. found reduced coordination in the frontoparietal in subjects with ASD as compared to controls during the TOL task. In addition, there was a relationship between the size of the genu of the corpus callosum and functional connectivity. The corpus callosum mediates communication among cortical areas responsible for higher-level cognitive function, such as executive function tasks. Reduced functional connectivity between the frontoparietal lobes was associated with smaller genu of the corpus callosum in individuals with ASD (Just et al., 2007; Velazquez et al., 2009). Other studies have found long-distance functional under-connectivity between Broca's and Wernicke's and the dorsolateral prefrontal cortex during sentence comprehension tasks (Just, Cherkassy, Keller, & Minshew, 2004) and between the medial, temporal lobe, and other cortical structures during emotion recognition tasks (Welchew et al., 2005). Dinstein et al. (2011) used fMRI to compare neural synchronization in toddlers with ASD, toddlers with language delays, and normal toddlers during natural sleep. The results of their study showed that toddlers with ASD exhibited weaker interhemispheric synchronization in the inferior frontal gyrus (IFG) and superior temporal gyrus (STG), two areas of the brain commonly associated with language production and comprehension. Furthermore, there was a positive correlation between reduced interhemispheric synchronization, delayed language scores, and more severe autistic symptoms with the toddlers with ASD. The toddlers with language delay did not show the same pattern of reduced interhemispheric synchronization as those diagnosed with ASD, even though both groups showed language delays.

Cognitive Theories of Autism Spectrum Disorders

Neurocognitive studies such as those described above help us understand how ASD develops over time and may eventually help us pinpoint biological markers that could be used to diagnose ASD, even before the first signs of the disorder are visible. Cognitive psychologists and researchers have approached the disorder from a different vantage point by studying the association between cognition and behavior. ASD is a heterogeneous disorder marked by variations in the known causes and presentation of characteristics. Researchers continue to search, however, for cognitive explanations or theories of some of the unique behaviors associated with ASD. The hope is that identifying cognitive subgroups of individuals who have deficits in particular cognitive areas could help design targeted interventions where additional practice is provided in the areas of deficits or compensatory strategies are identified to compensate for missing skills (Charman et al., 2011).

Cognitive theories have been proposed to describe both the deficits and the strengths that characterize autism spectrum disorders. Three recognized cognitive theories will be discussed: weak central coherence, lack of theory of mind, and poor executive function.

Uta Frith (1989) was the first researcher to assert that both the deficits in social interactions and the unusual skill 1 in 10 individuals with autism shows in music, art, calculation, and memory (Miller, 1999) come from the same type of information processing, which she labeled “weak central coherence.” *Central coherence*, according to Frith, refers to our tendency to process incoming information globally, taking in all the available information together searching for higher-level meaning. Individuals with autism, on the other hand, use detail-focused processing in which specific features are perceived and remembered at the expense of real understanding. This cognitive processing style is advantageous for some tasks and explains why individuals with autism have been shown to be superior at the Embedded Figures Test (Wechsler Intelligence Scale), in which individuals must locate a part within the global picture, when compared to matched non-ASD controls (Jolliffe & Baron-Cohen, 1997). Conversely, piecemeal or detail-focused processing can result in children with ASD focusing on individual parts of a toy, such as spinning the wheels of a car, rather than driving the car along the carpet path. Weak central coherence may also be related to stimulus overselectivity, which is a common trait in some children with ASD (Koegel et al., 2005). Stimulus overselectivity describes the tendency of individuals with ASD to focus on only one attribute of an object or environment while ignoring other attributes (Waas, 2010). For example, when meeting a new person, an individual with ASD may focus on the shirt the person is wearing instead of their facial features. Consequently, when the person is wearing a different shirt, the individual with ASD may not recognize the person. Stimulus overselectivity has been identified as a possible explanation for the reason individuals with ASD frequently fail to observe cues in the environment or respond to irrelevant cues rather than cues that could provide important information. For example, a child who is an English-language learner may not understand the teacher’s verbal directions to get his/her jacket and line up to go outside, but this child can observe the other children’s behaviors and glean the meaning of the teacher’s verbal direction. A child with ASD, on the other hand, may focus solely on the car that was taken away from him in preparation for going outside and become angry because he does not understand what is going to happen next or what he is expected to do.

Theory of Mind (ToM) refers to one’s ability to understand the views and beliefs of another person (Baron-Cohen, 1988, 1995). ToM is a cognitive construct that begins at age 1 year and continues to develop in complexity up to ages 9–11 years in children with typical development (Brune & Brune-Cohrs, 2005).

This construct is commonly measured using a false-belief paradigm, such as the classic Sally-and-Anne test (Baron-Cohen, Leslie, & Frith, 1985). In this scenario, Sally has a basket and Anne has a box and Sally places her marble in the basket. When Sally leaves the room to go for a walk, Anne moves the marble into her box. To test for ToM, researchers asked subjects where Sally would look for the marble when she returned. Children with typical development and children with Down syndrome with mental ages above 3 years old correctly identified that Sally would look for the marble in her basket when she returned, because she did not see Anne’s actions and therefore did not know that Anne had moved the marble. In their classic research study, Baron-Cohen, Leslie & Frith (1985) found even children with ASD with higher mental ages than the children with typical development and Down syndrome controls were unable to understand this false-belief paradigm.

Lack of ToM may be the root of language, social, and symbolic play deficits in ASD, according to Ute Frith (2012). The ability to share attention is a precursor skill for learning to communicate using language. The inability to read social cues and understand unwritten social rules interferes with social competence.

Executive function is an umbrella term for brain functions such as planning, working memory, initiation, and monitoring of action. The Wisconsin Card Sorting Task (WCST) and Tower of Hanoi/London are frequently used in examining executive function. Russell, Jarrold, and Hood (1999) reported that poor performance on tests of executive functioning is more consistent in autism than in any other childhood disorder. Other researchers have found differences in executive function abilities between individuals with autism and those with Asperger's syndrome, a higher-functioning disorder on the autism spectrum, with those individuals with Asperger's syndrome performing better on tasks of executive function.

Disruptions within the orbitofrontal region of the frontal cortex have been identified as a potential cause of deficits in executive function found in individuals with ASD. Specific behavioral characteristics associated with ASD may be explained by deficits in executive function, including the need for sameness, circumscribed interests, impulsivity, lack of planning, and difficulties with self-regulation and self-monitoring (Rinehart, 2006).

Practical Applications for Teachers

Knowing the neurobiological bases for ASD and cognitive theories behind the unique strengths and deficits associated with ASD can help teachers understand why children with ASD might struggle with certain activities and display certain behaviors. Considering both the deficits and strengths associated with ASD can help teachers create classrooms where children with this disorder can be successful. This next section will describe how teachers can increase access and active engagement in classroom activities for individuals with ASD by following the principles of Universal Design for Learning, along with implementing individual accommodations using an ecological planning process.

Universal Design for Learning

Universal Design for Learning concepts originated in the field of architecture as a means of creating physical structures designed to accommodate the physical needs of a variety of users from the beginning, rather than going back later to add features to improve accessibility (Center for Applied Special Technology [CAST], 2012; Dolan & Hall, 2001). The framework for *Universal Design for Learning* (*UDL*) is based on concepts from several disciplines including education, developmental psychology, cognitive science, and cognitive neuroscience (Rose & Gravel, 2010).

UDL is based on three principles that are related to three sets of interconnected networks, each responsible for a different role in learning: (a) recognition network responsible for receiving and processing information – the "what" of learning; (b) strategic network designed to plan and execute action – the "how" of learning; and (c) affective network involved in evaluating and setting priorities – the "why" of learning (Dolan & Hall, 2001; Ralabate, 2011; Rose & Gravel, 2010).

Rose and Gravel (2010) describe the match between UDL and cognitive neuroscience as follows:

> It is by design that the three principles of UDL match up well with this framework from neuroscience – addressing in turn the perceptual learning of the posterior cortex, the strategic and motor learning of the anterior cortex, and the affective or emotional learning of the medial and orbital frontal cortex – in order to be systematic in considering learning differences. (p. 2)

While UDL was not specifically designed to address the needs of individuals with ASD, it is easy to see how the principles of UDL could be beneficial since brain imaging studies have documented differences in the three networks involved in learning identified above (posterior and anterior cortex and medial and orbital frontal cortex) in individuals with ASD (Courchesne et al., 2007; Dawson et al., 2005).

Based on an understanding of these three networks involved in learning, UDL guidelines seek to improve how information is presented to the learner, how the learner can demonstrate what he or she has learned, and the process by which learners are engaged in learning through:

1. Providing multiple means of representation
2. Providing multiple means of expression
3. Providing multiple means of engagement

Multiple Means of Representation

Providing multiple means of representation refers to presenting information in different modalities (e.g., vision, hearing, touch) and different levels of complexity (e.g., vocabulary use, levels of abstractness) or using scaffolding strategies to ensure comprehension (e.g., adding pictures to illustrate spoken words). Children with ASD have difficulty with auditory processing skills, shifting attention between speakers and objects, and integrating information (Quill, 1998; Tissot & Evans, 2003). Adding visual supports to spoken words provides a static, concrete representation that can help improve comprehension of language, prepare the child for

Fig. 8.1 Cue cards provide visual supports for behavior expectations (Lentini, Vaughn, & Fox, 2009. Used with permission by authors)

changes to their schedule, and assist in task completion for children with ASD (Hart & Whalon, 2008; Meadan, Ostrosky, Triplett, Michna, & Fettig, 2011).

A variety of visual representations can be used, including real objects, photographs, or line drawings, and these representations can come in different forms or modes: (a) static – print or object based; (b) dynamic – multimedia sources in addition to visual (e.g., sound); or (c) interactive – multimedia input that requires child involvement.

Several different types of visual supports have proven effective for use with children with ASD, including visual schedules, visuals to structure the environment, visual scripts, cue cards, and visual task analysis. Visual schedules can be used to help the child with ASD anticipate the order of the daily schedule as well as to increase their independence during routine activities. Visual schedules can reinforce what activity is currently taking place, what activity will happen next, when an activity is finished, and to alert the child to any changes in their schedule. Visuals to structure the environment might include pictures on the shelves to show where toys belong or tasks that are completed in specific areas of the classroom. Visual scripts can be used to support communication, social interactions, and appropriate behavior. For example, a visual script could help a child with autism understand the role of the cashier in a McDonald's Restaurant dramatic play scheme and provide support for social interactions and communication during the play scheme. Cue cards are visual reminders of behavior expectations. Some researchers recommend taking pictures of children in the classroom "following the rules" to serve as a model for the child with ASD (Kabot & Reeve, 2010; Meadan et al., 2011). Visual schedules and visual task analysis provide support for the child to complete routines or tasks independently (e.g., washing hands, cleaning up after lunch). Figure 8.1 shows cue cards to support a child in following class behavior expectations.

Figure 8.2 shows a visual class schedule used to help a child understand the sequence of daily activities.

Fig. 8.2 Mini-schedule for a morning routine at preschool visually shows a child the sequence of activities during this routine (Lentini et al., 2009. Used with permission by authors)

Multiple Means of Expression

Demonstrating what you have learned requires both organizational and communication skills. UDL guidelines call for teachers to provide supports and scaffolds to assist all learners in setting learning goals and monitoring their progress toward those goals and in providing multiple modalities (e.g., verbal, pictures, written, multimedia) to communicate what they have learned.

Children with ASD have documented deficits in executive function and in communication skills (Ahmed & Miller, 2011; Carlson, Mandell, & Williams, 2004; Charman & Stone, 2006; Weisner, Lord, & Esler, 2010) which could impact their ability to complete class routines and activities as well as to demonstrate what they have learned. Many of the visual supports listed under the multiple representations section can also assist children with ASD in planning, organizing, and completing tasks, skills that are impacted by executive function deficits (Ahmed & Miller, 2011; Carlson et al., 2004). Visual schedules, visual task analysis, and visual scripts could all be used to support a child with ASD in independently planning and completing tasks.

Communication deficits in ASD range from complete absence of functional verbal language, estimated to be 25 % of the population of individuals with ASD, (Volkmar, Lord, Bailey, Schultz, & Klin, 2004) to completely verbal with slight problems with the pragmatics of language (e.g., difficulties with conversational turn-taking, understanding and using gestures and facial expressions, and making inappropriate social comments; Philofsky and Fidler (2007)). It is important for teachers to provide alternative methods for children with ASD to communicate preferences throughout the day and to demonstrate what they have learned.

Several alternative modes of communication have been used effectively with children with ASD. Alternative modes of communication are described as either unaided, meaning nothing external is added to the person's body (e.g., gestures, manual signs), or aided, where an external device is used (e.g., pictures, VOCA). There is substantial research showing that both unaided and aided communication modes can be used effectively by individuals with ASD, although the research has not always met evidence-based standards and therefore is considered "suggestive" rather than "conclusive" (Schlosser & Raghavendra, 2004). Little research is available comparing the effectiveness of unaided and aided communication modes with any disability group, including individuals with ASD (Mirenda, 2003). According to Mirenda, the following considerations should be made when considering which alternative communication mode to provide to children with ASD:

- *Manual signs* – consider the child's fine motor, imitation, and memory skills as these skills are important for learning to use this mode. Understand that signs may not be recognized by everyone, thereby limiting their effectiveness with all communication partners.
- *Picture communication* – informally test the child's understanding of different kinds of symbols before choosing line drawings, clip art pictures, or photographs. If the child is unable to understand picture symbols, you may need to use real objects. Consider using the Picture Exchange Communication System (PECS) which has proven easy to teach children with ASD to initiate communication with others (Frost & Bondy, 1994).
- *Voice Output Communication Aid* (*VOCA*) – consider the portability of the device and the ease by which the device can be programmed.

Other considerations when choosing alternative communication mode options is child preference. The best course of action may be to provide multiple options until the child demonstrates a preference for either aided or unaided options. Once the child's preference is apparent, the use of that particular option can be encouraged. Alternatively, all options can remain available, as it is common for people to use a combination of both unaided and aided communication devices when they are available (Beukelman & Mirenda, 2005).

Multiple Forms of Engagement

McWilliam and Casey (2006) define engagement as "the amount of time children spend involved with the environment (with teachers, peers, and materials) in a way that is appropriate for the children's age, abilities, and surroundings" (p. 4). Child engagement is a necessary first step for learning to occur. The amount of time a child with autism is actively engaged in activities and social interactions is one of the best predictors of long-term positive outcomes (Iovannone et al., 2003). Unfortunately, characteristics associated with ASD make active engagement difficult. Poor receptive and expressive communication skills make it hard for a child with ASD to attend during group activities. Deficits in executive function make it a challenge for a child with ASD to organize himself/herself and his materials in order to participate in class activities. In addition, it is common for children with ASD to have restricted or circumscribed interests which might impact a child's motivation to become engaged in class activities (Hume & Reynolds, 2010).

Several strategies can be used to promote engagement of children with ASD in early childhood education activities. Priming is a strategy where the child is exposed to content or activities individually before they are expected to engage in the activity with peers (Hart & Whalon, 2008). Sending home song cards of songs that will be sung during circle and books that will be read can prepare the child with autism for participation. Embedding highly preferred materials and activities during class activities can also be used to increase a child with autism's engagement. If a child is highly interested in letters of the alphabet, finding ways to include alphabet letters in several classroom centers, such as dramatic play, blocks, and sensory, can increase the child's engagement in those centers, and according to some researchers, the child's developmental progress as well (Boyd, Conroy, Mancil, Nakao, & Alter, 2007; Dunst, Trivette, & Masiello, 2011; Lieber, Horn, Palmer & Fleming 2008). Finally, a simple but effective strategy for increasing a child with ASD's engagement is by embedding a variety of choices into classroom activities (Barton et al., 2011; Cole & Levinson, 2002).

Individualized Adaptations to Support Children with ASD

Even when a classroom is set up based on the principles of Universal Design for Learning, there may be specific routines or class activities during which a child with ASD requires individualized adaptations in order to successfully participate. The first step in identifying potential adaptations is to assess the child's current participation during each routine and activity compared to the behavioral, social, and educational expectations of the child's peers in the classroom (Leiber, Horn, Palmer & Fleming 2008; McCormick & Noonan, 2002).

There are several tools that can be used to assess a child's current level of functioning within specific routines and activities, including CARA's Checklist of Priorities and Concerns (Milbourne & Campbell, 2007), Child Assessment Worksheet (Sandall & Schwartz, 2008), and the Ecological Congruence Assessment (McCormick & Noonan, 2002; Wolery, Brashers, & Neitzel, 2002). McCormick and Noonan (p. 51) list the following steps to use during the ecological assessment and planning process:

1. List all the daily routines and activities.
2. List the major behavioral expectation for each routine or activity.
3. Evaluate the child's present performance on each of the behavioral expectations (e.g., "can do" or "needs to learn").
4. Write objectives that will allow the child to participate more independently during each routine and activity.
5. Plan for each adaptation or support that will allow the child to learn and practice the target behaviors (e.g., scaffolding and practice, adapting the task or modifying materials, changing the task expectations, arranging for peer assistance).
6. Identify the staff member who will provide the adaptations and supports.
7. Plan for data collection to evaluate the child's progress.

Table 8.2 illustrates how an ecological congruence planning process could be used to make decisions about the individualized adaptations that might be needed to

Table 8.2 Ecological congruence assessment and planning form

Activity: Playing a musical instrument during circle time

Behavior expectations for all children	Can do/needs to learn	Types of supports needed	Comments
Walk to the circle rug and sit down	Can do		Keeping the schedule consistent helps
Sit next to peers	Needs to learn	Seat next to preferred peer Use carpet squares	
Wait for his turn to choose an instrument	Needs to learn	Give child a "wait" card to hold until his turn	
Choose an instrument out of a field of 6	Needs to learn	Limit choices to a field of two	
Play the instrument independently	Needs to learn	Use peer modeling and support	
Stop playing the instrument at the end of circle	Needs to learn	Give warning when there are 2 min left Exchange highly preferred object when child returns instrument to basket	
Put instrument back in the basket	Can do		
Transition to next activity	Needs help	Use visual schedule Schedule a highly preferred activity following circle	

This figure shows a process for deciding which skills a child with autism might need help with during a specific activity

support a child with ASD's participation during a musical instrument-playing activity done during circle time. The only way to determine if the adaptations and supports are working is to monitor the child's participation during each routine and activity. If the individualized adaptations are successful, teachers should see a decrease in challenging behaviors and an increase in the amount and the complexity of the child's engagement during the activity. Monitoring can also help teachers decrease supports and fade adaptations over time as the child becomes able to participate more independently (Barton et al., 2011).

Summary

Advances in neurocognitive testing have established that ASD is a neurodevelopmental disorder affecting many different brain areas. There is evidence that ASD is a disorder of under-connectivity among brain regions that would typically work together in cortical networks to accomplish higher-order cognitive tasks, including language processing and production, social interactions, and goal-directed planning and monitoring. What is not clear at this point is whether brain under-connectivity is a *result* of ASD or the *cause* (Just et al., 2007). The fact that early intervention produces better outcomes for children with ASD (e.g., use of verbal language, more likely to be placed in an inclusive setting) seems to point to the fact that brain activity can be improved following intervention (Iovannone et al., 2003). Few studies have documented neural changes following specific interventions. One study of changes to activation of the fusiform gyrus shows the potential of focused interventions. Perlman, Hudac, Pegors, Minshew, and Pelphrey (2011) were able to demonstrate "normalization" of activity in the fusiform gyrus when individuals with ASD completed an intervention that compelled the participants to fixate their eyes on a fearful face. Use of targeted interventions to improve brain function shows promise, but much more research is needed.

Learning the neurocognitive basis for ASD can help early childhood teachers appreciate that many children with ASD will learn differently than children with typical development. Structural and functional brain differences in ASD affect all facets of learning and participation in the early childhood classroom. Teachers can support learning for children with ASD by implementing UDL guidelines to make sure their classroom is accessible to all learners and by creating individualized adaptations that take into consideration each child's strengths and deficits during daily routines and activities.

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Chapter 9
The Twice-Exceptional Young Learner

Leslie Haley Wasserman

Introduction

Sarah went to kindergarten when she was 4 years old because the preschool that she attended was beginning a charter school with a different kindergarten curriculum than the local public school. Her parents thought that this would enhance the educational background of their precocious young girl. Her parents were both right and wrong. The charter kindergarten did indeed enhance her learning, but it also excelled her to a place where going to the local kindergarten when she turned five was now out of the question. Sarah, as it turns out, is academically gifted. She was on an accelerated path in her education and began first grade as a 5-year-old. As she progressed in her education, she would become identified as gifted—qualifying with superior cognitive abilities.

Sarah talked at a young age and had an unbelievable memory about places that she had gone to and about conversations that had taken place days and weeks ago, but she could not remember what was being asked of her less than 5 min ago. Her parents had always known that their youngest of three children was bright and was gifted like their other two children, but she was also very different from them. Playtime was a flurry of activity where she flitted from one thing to another never staying for more then 5–6 min at each activity. She never napped and talked nonstop. She was dubbed the "Queen of Interruptions" by her siblings. She was a whirlwind of motion for more than 16 h a day. It was exhausting just watching her go from one activity to another.

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What made Sarah so different from her siblings? Sarah was bright and curious and questioned everything just as children do. She exhibited the same interest in all things like her older brother and sister did at that age but she was still not like they were when they were younger. They could carry on conversations without interrupting, they could attend to tasks for short periods of time, and they could entertain themselves through play with their favorite toys. Sarah could not do any of these things. Sarah's mom knew from the time that Sarah was very little that she exhibited the signs of attention deficit hyperactivity disorder. Since Sarah was young and many of her characteristics were developmental, the diagnosis was difficult to get as such an early age. Sarah's mom is also a special education teacher and did many different types of modifications and accommodations for her to help her be more successful.

Sarah was officially diagnosed in first grade with attention deficit hyperactivity disorder (ADHD) with scores that were off of the chart. Her severe diagnosis of ADHD made it difficult to attend to task, sit still, and be quiet for even small periods of time, and she had no ability to organize herself personally and academically at home or at school. According to the Americans with Disabilities Act, better known as the ADA, Sarah is disabled. How can a child with an IQ well above 100 also be disabled?

Sarah is twice exceptional—gifted with a disability. She is not alone. Twice-exceptional learners are the most underserved population in our schools today. According to Whitmore and Maker (1985), "gifted individuals with specific learning disabilities are the most misjudged, misunderstood, and neglected segment of the student population" (p. 204). With No Child Left Behind (NCLB), how could this be? The reasons why will be discussed in this chapter. One of the reasons this is happening is that twice-exceptional students' strengths and weaknesses often cancels each other out in the classroom so the students are harder to identify. Another reason is that twice-exceptional learners are atypical. They do not learn the same way as their typically developing peers do.

According to Beckley (1998) there are three different subgroups of twice-exceptional (2E) students that still remain unacknowledged. The first group consists of students who work at grade level and fly under the radar of the screening tools. They can also be categorized as underachievers or lazy. The second group consists of students who have been identified with learning disabilities and their giftedness has still not been discovered. The third group is the largest unserved population—the students who appear to not qualify for services either for disabilities or for giftedness. They perform at grade level but are also performing below their potential (Beckley).

Throughout this chapter, I will discuss the students identified as twice exceptional and the implications for these students in our classrooms today. A brief overview of gifted education and special needs will be provided as background knowledge for the reader so that the information provided about twice-exceptional learners will be clearer, and the reader will be better able to identify who twice-exceptional students really are. I will also discuss the relationship between twice-exceptional young learners and the role neuroscience plays in making their lives and the lives of those who live and work with them more successful.

The Gifted and Talented Learner

What is gifted? According to the National Association for Gifted Children (NAGC), each state has its own definition of giftedness. Since I live in Ohio, I will report specifically how Ohio identifies gifted students. Each state has its own specific guidelines for who qualifies and how they qualify. According to Ohio: "Gifted" means students who perform or show potential for performing at remarkably high levels of accomplishment when compared to others of their age, experience or environment and who are identified under division (A), (B), (C), or (D) of section 3324.03 of the Revised Code as of 8/22/2010 (NAGC, 2012). According to Ohio Revised Code 3324.01-07 (law) and Ohio Administrative Code 3301-51-15 (rule), there are four different categories that children can be identified: superior cognitive ability, specific academic ability, creative thinking ability, and visual or performing arts ability. Here is an explanation of the four different categories according to the Ohio Department of Education (ODE):

Superior cognitive ability is for students who score two standard deviations above the mean minus the standard error of measurement on an intelligence test, perform at or above the 95th percentile on a basic or composite battery of a nationally normed achievement test, or attain an approved score on an above grade-level standardized, nationally normed test.

Specific academic ability in a field is for the students who perform at or above the 95th percentile at the national level on a standardized achievement test of a specific academic ability in that field. A child may be identified as gifted in more than one specific academic ability field.

Creative thinking ability is for the student who scores one standard deviation above the means minus the standard error of measurement on an intelligence test and attains a sufficient score, as established by the Department, on a test of creative ability or a checklist of creative behavior.

Visual or performing arts ability is for the students who demonstrate to a trained individual through a display of work, an audition, or other performance or exhibition, superior ability in a visual or performing arts area and attains a sufficient score, as established by the Department, on a checklist of behaviors related to a specific arts area.

There are specific standardized tests that are used to identify the students with different areas of giftedness. Some examples are the Cognitive Abilities Test (CogAT), Woodcock-Johnson III (WJIII), Wechsler Intelligence Scale for Children (WISC-IV), ACT Test, Scholastic Aptitude Test (SAT), and the EXPLORE Test just to name a few (ODE, 2012). With each standardized test, there are different composite scores that are used for qualification purposes. Generally, an IQ score from standardized tests of 130–140 qualifies a student for gifted services (Crepeau-Hobson & Bianco, 2011).

In 2010, gifted standards were restructured by the National Association for Gifted Children (NAGC) with help from the Council for Exceptional Children (CEC) and a variety of other stakeholders (NAGC, 2012). These standards have an increased focus on diversity and collaboration. The 2010 standards use student outcomes for goals instead of teacher practices. There are six gifted programming standards:

- Learning and Development
- Assessment
- Curriculum Planning and Instruction
- Learning Environments
- Programming
- Professional Development
(NAGC, 2012)

These standards along with the common core state standards help to create a curriculum that is challenging and teaches the skills and concepts necessary for the twenty-first century.

> In the U.S., education decisions occur mainly at the state and local level. Although certain programs (e.g., Title I schools, students with disabilities) are intertwined with federal policy, the vast majority of programs and services that students receive are determined by state laws and local policies and are funded through a combination of state and local funds.
>
> For gifted learners, all program and service decisions are made at the state and local levels. In the absence of federal minimum standards, there is wide variability between states, and in many cases, an even wider unevenness between districts in the same state. (NAGC, 2012)

According to the Ohio Department of Education (ODE), school districts are required to identify gifted students but are not mandated to provide any services for gifted students. School districts must provide two different opportunities each school year to be screened for possible identification of giftedness. “While districts are not required to provide services for gifted students, the majority of districts choose to provide some level of service for gifted students, although few districts currently provide a comprehensive K-12 continuum of gifted services. Districts that choose to provide gifted services must do so in conformance with Ohio Administrative Code (OAC) 3301-51-15.” For the students who do qualify and for the school districts that do provide gifted services, a written education plan (WEP) is written for the goals of each student. The purpose of the WEP is to provide modifications for the gifted student for each class that the student qualifies for such as: reading, creative thinking ability, math, writing, science, social studies, drama, dance, music, and/or visual arts. This WEP is a legal binding document and the teacher is held accountable for assisting the student to reach the goals created for him on the WEP. It is the “tool that drives services for identified gifted students” (ODE, 2012).

The Brain and Giftedness

What makes a brain gifted? Once teachers know the differences in what causes a student to be gifted, the better that student can learn. According to Jensen (2006), there are four distinct categories of brain differences:

- *Morphology*—size, quantity, and shape of brain structures
- *Operations*—neural efficiency and speed of internal connectivity in the brain
- *Real-estate*—strategic differences in which or how many brain areas are used
- *Electro-chemical cellular function*—differences in electrical and chemical activity (p. 154)

In the first category, brain morphology, the total brain volume accounts for 16 % in general intelligence. Bigger head size does in fact increase chances of higher IQ (Jensen, 2006). Interestingly, people who have been diagnosed with ADD or ADHD have been found to have lower IQ scores and have a smaller brain volume by 3–4 % (Jensen). It has also been found that gifted brains also include a larger proportional number of extreme neurons. Extreme neurons are important for creating the connections for processing capacity. In postmortem studies, it was found that gifted brains contain more glial cells than a typical brain (Jensen). Glial cells are the supportive cells in the central nervous system. Unlike neurons, glial cells do not conduct electrical impulses. The glial cells surround neurons and provide support for and insulation between them. Glial cells are the most abundant cell types in the central nervous system.

Operations are when our brains do what we want them to do. Almost all people, regardless of level of intelligence, are capable of this. Strategic operations are done faster by those who are considered gifted. The brain consists of somewhere between seventy-five and one hundred billion neurons with nearly a trillion glial cells (Jensen, 2006). Connectivity to these synapses enables us to integrate information. The more gifted the learner, the faster the connectivity occurs.

According to Jensen (2006) “efficiencies in the gifted brain help it use the right areas, use the areas that it is good at, and use the smallest amount brain real estate necessary to do the task” (p. 160). The focus of the brain for gifted learners often shows the following differences:

- Greater focus skills (frontal lobe function)
- Greater global connectivity (more overall brain usage)
- Greater alpha brain wave pattern (supports concentration and input)
- Better brain chemistry balance (supports attention, mood, and memory) (Jensen, p. 161)

The gifted brain is more complex and is believed that gifted learners use the spatial-temporal areas to support higher-level thinking and functioning (Jensen).

Differing levels of hormone levels have been found to have different effects on the brain. Higher levels of cortisol, a hormone related to stress, are less likely to have curious behavior, and those individuals with lower levels of cortisol have been found to be more competent intellectually (Jensen, 2006). It was found that testosterone levels also played a part in giftedness. The lower the salivary testosterone level found in both in males and females, the higher the level of student achievement (Jensen). Dopamine is found in the frontal lobe and needs the right amount of dopamine for it to produce greater intellectual performance. Dopamine is much like a stimulant in the brain that makes it work effectively. Another hormone that is found in the brain is serotonin that affects mood, memory, and attention (Jensen). Creative problem solving is increased when the correct level of serotonin is present. Serotonin can be found in teas and different types of food such as turkey, milk, bananas, and avocados. When the dopamine level and serotonin level are increased, the brain is able to process more quickly and increases attention. Serotonin is known to increase flexibility to achieve "maximum cognitive achievement" (p. 166).

Some characteristics that can be found in gifted learners are creativity, sensitivity, intensity, and also perfectionism. They can process advanced, complex thoughts. They have an increased vocabulary and are curious learners. Motivation and interest levels in achieving are high. Many gifted learners have a talent, specific interest, or musical ability. It is important for teachers, parents, and the school system to meet the needs of the gifted learners by allowing flexibility in the school curriculum to challenge the gifted learner so that he can get the education that he deserves. The term differentiation has been mostly associated with changing the curriculum for students when they are struggling, but it also should mean changing the curriculum for the gifted learner as well (Manning, Stanford, & Reeves, 2010). Curriculum should match the child's interests as well as his ability level.

Gifted learners can also have special needs that need to be addressed as well. Having a full understanding of each learner's strengths and weaknesses is imperative to reaching each child's educational needs.

Special Needs: Who Qualifies?

The Individuals with Disabilities Education Act (IDEA) was restructured in 1990. IDEA is the federal special education law that aids with special education services in your local area school system. It was again restructured in 2004 and is now referred to as IDEIA (Individuals with Disabilities Improvement Act). To qualify for special education services, a student must meet very specific criteria for one of the disability categories that have been defined by the federal government in IDEIA 2004. A student can qualify in one or more deficit areas. The IDEIA's disability terms and definitions guide how states define disability and who is eligible for a free appropriate public education (FAPE) under special education law. In order to fully meet the definition (and eligibility for special education and related services) as a child's educational performance must be adversely affected due to the disability (nichy.org). The 14 areas that are considered to be a disability as of 2012 are autism, deaf-blindness, deafness, developmental delay, emotional disturbance, hearing impairment, intellectual disability, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, traumatic brain injury (TBI), and visual impairment (nichy.org).

Children aged 3–22 can receive special services once they are identified with a disability or multiple disabilities. The most common type of disabilities associated with twice-exceptional learners are students who are considered to have a learning disability such as in math or reading or both; students on the high functioning end of the autistic spectrum; and those who qualify as other health impairment.

In order for this chapter to explain the role disabilities play in twice-exceptional learners, I must define the importance of "other health impairment." Other health impairment means:

> having limited strength, vitality, or alertness, including a heightened alertness to environmental stimuli, that results in limited alertness with respect to the educational environment, that-
>
> (a) Is due to chronic or acute health problems such as asthma, attention deficit disorder or attention deficit hyperactivity disorder, diabetes, epilepsy, a heart conditions, hemophilia, lead poisoning, leukemia, nephritis, rheumatic fever, sickle cell anemia, and Tourette syndrome; and
> (b) *Adversely affects* a child's educational performance
>
> (nichny.org)

The phrase "adversely affects educational performance" appears in most of the disability definitions. This does not mean, however, that a child has to be failing in school to receive special education and related services. According to IDEA (2004), states must make a free and appropriate public education (FAPE) available to "any individual child with a disability who needs special education related services, even if the child has not failed or been retained in a course or grade, and is advancing from grade to grade" [IDEA 300.101(c)(1)].

Depending on the nature of the disability, students can qualify for an IEP (Individualized Education Plan) or a 504 plan. Both plans are based on a student's instructional needs and each provides protection under Federal Guidelines. In order to qualify for an IEP, the student must meet the state's eligibility requirements. The IEP falls under the federal law of IDEIA where intervention specialists (special education teachers) work closely with the students and the classroom teacher to assist the student to meet his educational goals. This is for the student who qualifies for the IEP after extensive testing. There may be other professionals involved in the student's care based on his needs such as speech-language pathologist (SLP), an orthopedic therapist, a physical therapist, an adaptive physical education teacher, a psychologist, an interpreter, and any other services that will assist the student with his needs. The student is to be educated in his least restrictive environment (LRE). The LRE could be the classroom, a resource room, or a combination of both in the regular school system. In more extreme cases, inclusion into the regular classroom may not be the child's LRE, and a special placement in a facility for developmental delays may be more appropriate.

The 504 plan is for students who do not qualify for an IEP due to the nature of their disability but are still affected adversely by their disability in their educational environment. Unlike the IEP, students on 504 plans are not monitored by intervention specialists. There is a specific coordinator in each school district or each building that monitors the students' 504 plans. The Office of Civil Rights enforces the Americans with Disabilities Act (ADA) and is the federal governing body responsible for the 504 plan. The 504 plan is used for one of the 14 specific disabilities identified by the ADA that is a medical condition, and which is getting in the way of learning.

Now that I have provided background information about gifted students and special needs, I would like to delve into twice-exceptional learners and the importance of identification of this unique group of learners.

The Brain and Special Needs

Identifying differences in the brain for students with special needs is much different from identifying differences for gifted learners. The term "special needs" is a broad category that encompasses so many different types of disabilities: motor, social/emotional, cognitive, physical, health related, and so on. Because of this, students with special needs have different diagnoses and so the differences are not easily pinpointed as specific differences in the brains. Each student has strengths and weaknesses and even if a student has the same disability as another student, the differences in the brain will not be the same. Some learning disabilities (cognitive functioning) can be identified as easily as giving the student an IQ test. Generally, the IQ cutoff score is 70 (with the mean score being 100) for a public school type educational setting. Under 70, the student usually receives special services at a Facility for Developmentally Delayed that caters to those with lower IQs. This is just one example of a special need. Depending on the score and the area(s) of weaknesses, the student can receive a diagnosis of learning disabled (LD) in a specific content area of math, writing, or reading or any combination of the three. Once diagnosed LD, the student will receive services in either the special education/resource room or in the regular classroom with the help of an intervention specialist—whichever is the student's least restrictive environment (LRE).

A new study (Courchesne et al.) published in the November 9th (2011) issue in the *Journal of the American Medical Association* has found an interesting development in the study of the brain in autistic children (postmortem brain tissue from seven boys with autism and seven boys without, aged 2–16). There has been found that autistic children have too many brain cells. They have more neurons in the prefrontal cortex than children who do not. This is the area of the brain that is key to communication, complex thoughts, decision-making, and social behaviors. Typically developing children have about 1.6 billion neurons in the prefrontal cortex, whereas autistic children were found to have approximately 1.94 billion. This new information could lead to a real advancement in the research of the autistic spectrum and what causes it.

Autism is a disability that can affect children in various ways. Students can be identified as "high functioning" or "low functioning" or somewhere in between. Students with autism are often referred to as "being on the spectrum." Oftentimes, students with autism have other disabilities as well. The highest functioning autistic students are capable of being mainstreamed into the inclusive classroom. Students with Asperger's syndrome can also be successful in the inclusive classroom. These students are bright but have social deficiencies and do not interact in a typical way with their peers.

Students who have been identified with attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD) need modifications and adaptations made to differentiate their learning. There are more students being identified with some type of attention disorder each year, and it is important for teachers and parents to know what they can do to assist the learners how to be successful in school and in life. Many students need to have accommodations made for them for various reasons. This will be addressed later in this chapter.

Children with physical disabilities have their needs met by occupational and/or physical therapists. In most cases, students who have physical limitations usually do not have cognitive difficulties and can be educated in the regular classroom environment.

Learning, emotional, and behavioral issues are connected, and so many learners who have learning disabilities begin acting out due to frustrations for not having their needs being met (Jensen, 2006). Each child also brings with him different experiences and backgrounds such as differing levels of parenting, environmental toxins, differing prior knowledge, and home environments that can be nurturing or dysfunctional. These all make an impact on our brains, and, therefore, no two are ever exactly the same. Identification and remediation is what is best for assisting students with all levels of abilities.

The Importance of Identification for Twice-Exceptional Learners

The “gifted handicapped” movement began in the 1970s with students who had identified physical or sensory disabilities (Lovett & Lewandowski, 2006). It was not long before the students who were identified as learning disabled (LD) were also considered to be a part of this group. At first, the gifted handicapped students were placed into the self-contained special education class where they wasted their abilities and did not learn anything beyond the special education curriculum. In the 1980s, many scholars began advocating for the students’ rights to be in the environment that was suitable for their educational abilities (Lovett & Lewandowski). It was found that both giftedness and a learning disability or disabilities can simultaneously exist with the same child (Baum & Owen, 1988; Fox, Brody, & Tobin, 1983; Whitmore & Maker, 1985).

Twice-exceptional learners are characterized as students with learning disabilities who have “outstanding talents in some areas and debilitating weakness in others” (Ruban & Reis, 2005, p. 2). In order to be identified as twice exceptional, students must meet the eligibility requirements for both giftedness and for a learning disability or learning disabilities. According to Whitmore (1981), a twice-exceptional student is one who has accommodations given for the disability or disabilities while promoting the students’ giftedness and potential for learning. Due to the fact that there are so many different combinations as to what makes up the twice-exceptional learner, the characteristics are hard to define. Because of this fact, this makes identifying the students so much harder. The characteristics often mask the giftedness or the disability (Maker & Udall, 1985). Often, only one is identified and the students are not getting the education that they deserve. "Gifted children with disabilities often use their intelligence to try to circumvent the disability. This may cause both exceptionalities to appear less extreme; the disability may appear less severe because the child is using the intellect to cope, while the efforts expanded in that area may hinder other expressions of giftedness" (Willard-Holt, 1999).

According to the Idaho State Department of Education (2010), there are several twice-exceptional combinations. The differing combinations are listed along with some examples of each:

- Gifts outweigh challenges (academic/intellectual vs. learning disabled)
- Gifts and challenges outweigh each other (intellectual/leadership vs. sensory integration disorder)
- Challenges outweigh gifts (creativity/performance vs. bipolar or ADHD)

There is much more research available for the twice-exceptional learner with LD and with ADHD and not much research about those students who have emotional/behavioral disabilities (EBD). "The profile of the student labeled EBD has been negative, and leads the individual working with these students to believe in one-dimensional view that focuses on negative behaviors that often overshadow potential G/T behaviors of the person" (Morrison, 2001, p. 426). All students who are identified as twice exceptional have behaviors of extreme opposites. In the case of EBD students, it is difficult to identify them as twice exceptional since there appears to be three core characteristics that can be found in both EBD and gifted populations. Academic ability and creative thought are the first two characteristics and are easier to identify. The third characteristic is more difficult to assess due to the EBD characteristics displayed by the student. These negative behaviors include poor impulse control, intense emotions, isolation from peers, and polarized and hierarchical value systems (Morrison). It is important for educators to be aware of these characteristics to be able to reach all students and meet all of their needs.

Characteristics of Twice-Exceptional Learners

Even though I stated earlier that the characteristics of twice-exceptional learners can be varied, there can be some characteristics that can be found in many of the twice-exceptional learners. Since twice-exceptional students are atypical learners, many find themselves becoming easily frustrated, with themselves or with others and with the work that they are to be doing. They are often unorganized, messy, and easily distracted. They have a fast rate of learning and become bored easily. They have wonderful retention of material. Their oral communication skills are better than their written communication skills. They are persistent. They have a thirst for knowledge and are motivated to learn on their own. They are creative. They are imaginative. They are curious. They understand higher level thinking skills. They are insightful. They are early readers. They are good problem solvers. They are good in math—especially in geometry and spatial relationships. They are sensitive. They have a good sense of humor. They rapidly grasp ideas. They have difficulty with sequential steps. They fail to complete assignments. They are daydreamers. Their judgment lags behind their developmental growth (Willard-Holt, 1999). They can be immature socially compared to their peers. They can be impulsive. They can talk incessantly. They can be disruptive to others and to teaching. They can be a wonderful addition to your classroom.

As you can see, the twice-exceptional learner can be many things. How does the classroom teacher teach this type of learner? A specific change in the way the teacher teaches is a key component to the success of the twice-exceptional learner. The problem with twice-exceptional learners is that everything in school is either too easy or too difficult and it is never "just right" (Warshaw, 2006). Accommodations are necessary component for teaching twice-exceptional learners.

Accommodations and Modifications for Twice-Exceptional Learners

The Response-to-Intervention (RtI) Model should be used to assist twice-exceptional learners (and all learners). RtI is a framework for continuous improvement on standards-based instruction based on research-based interventions that are matched to the students' needs whether they are academic or behavioral or both. There are three tiers to the RtI Model that apply to academic and behavioral needs. The majority of the students should respond well to Tier 1. Tier 1 is successful for about 80 % of students. Tier 2 is successful for approximately 15 % of the students and Tier 3 is for the 5 % of students who need extensive intervention.

In order to begin the RtI Model, there are several things that must be put into place first. The teacher(s) need to define the problem. There should be an RtI team in place in the school. The teacher then goes to the team and discusses the identified problems. The team will then complete a problem analysis. The team will then come up with a plan and the teacher will go back to the classroom and implement the plan. After several weeks, the team will convene again and evaluate how the plan is working. If it is successful, the teacher will continue the plan. If not, the team will implement a new plan and the cycle will continue until it is successful.

Tier 1 is team based and provides differentiating instruction for each child with emphasis on prevention of reading failure for lowest achieving/performing students. Assessments and instruction is integrated with continuous progress monitoring. The goal is for quality instruction for all students. Tier 2 is supplemental intervention and continuous progress monitoring for students who have not meet the goals of Tier 1. Tier 3 intensifies instruction, and progress monitoring is more frequent and is for the students who have not met the goals of Tier 1 or Tier 2.

The benefits of RtI include enhanced student performance, accountability, greater staff involvement, greater parent involvement, and greater student involvement. The "cornerstone of an effective RtI model is the ability to identify students who are struggling early so that intervening strategies can be measured and student responsiveness can be assessed through ongoing progress monitoring" (Crepeau-Hobson & Bianco, 2011, p. 105). The goal for meeting the needs of the twice-exceptional learner is to provide challenging curriculum while meeting their needs in the deficit areas and strengthening their assets (Baum, Cooper, & Neu, 2001).

It is important to collaborate with all teachers: special, gifted, and the school psychologists to get resources to assist one another to make the most of the expertise to aid the twice-exceptional learner. Having this topic as a part of professional development goals will assist all who works with 2E students (Assouline, Nicpon, & Huber, 2006; Bianco & Leech, 2010). Helping parents understand the importance of nurturing their own twice-exceptional children will assist all in creating a meaningful learning environment. By doing this, parents can help develop a "growth mindset" instead of a fixed mindset for their children. Whitson (2011) has devised seven ways to assist gifted children:

- Play up personal strengths
- Play down competitions
- Provide opportunities to try out new things
- Encourage practice
- Celebrate mistakes
- Idealize improvement
- Praise hard work and effort
  (p. 189–190)

It is important for parents to be involved in the education of their twice-exceptional learner, and by having communication regularly with the school and the teachers, they can help make the most of their child's educational journey. Parents need to be advocates for their children to be sure that their child's needs are being met. Going through this process with the school system is not easy. It can be confusing and difficult to understand what the rights of the parents and the students are. Parents can look to other parents to assist them along with parent groups or other organizations that will give support and advice to parents. Having contact with others involved in the same situation can help to lessen the confusion and can strengthen awareness (Maker & Udall, 1985).

Strategies for School Success

Educators should think carefully about what they are assigning children. Will all of the students be able to successfully complete the assignment? If the answer is no, then teachers need to start thinking outside of the box. They should think about the abilities of the students in the class. Utilizing Gardner's Multiple Intelligences (MI) within the classroom would be beneficial for twice-exceptional students. Let the students use their creativity, their outside talents, and their abilities to complete the assignment. There are many ways to do this. Some examples include: Writing a poem about the topic, singing a song or composing music, painting something to do with the topic, or doing anything else that enables students to show their understanding of the topic should be acceptable. Not every assessment need be paper/pencil work or written tests to show that they have learned the material presented. That is not to say that these types of assessments do not have a place because they do, but not every time. Let the students make those connections in their own way (Jensen, 2005).

According to Baum (1990) there are curricular needs that need to be addressed that will benefit all twice-exceptional learners:

- Focus attention on the development of the gift
- Provide a nurturing environment that values individual differences
- Encourage compensation strategies
- Encourage awareness of individual strengths and weaknesses (p. 2–3)

By sticking to these guidelines, students will be more successful. Some strategies can be done for whole classes or just for individual students. Based on the needs of the students, teachers need to make modifications. Some more strategies that can help individual students are:

- Access to a computer when needed
- Compact/pace/test out of curriculum or required classes
- Break assignments into parts with completion checks
- Preferential seating
- Organization checks
- Copies of notes
- Differentiated assignments
- Opt out of daily assignments if tests are at mastery level
- Provide concrete cues
- Test grades weighted higher than daily work
- Extended time on assignments
- Work or test in quiet room (Collins, 2008, p. 4)

Scaffolding and making connections to prior learning is essential to teaching. Making the connections with familiar ideas helps make connections across the learning for students. Teachers need to use novelty to their advantage and use this as attention grabbers for the students. By demanding respect for all students and celebrating all differences, students will become a community of learners and will be accepting of all differences.

Differentiation and the Classroom Practical Application

What is differentiation? Differentiation is quickly becoming a new "buzz word" in education, but why is it important? Differentiated instruction means adapting instructional strategies to meet the needs of the students. All students learn differently. Students can be auditory learners, by hearing; visual learners, by seeing; tactile learners, by doing; or a combination of learning styles. The term differentiation means change. Differentiation should take place each day in the classroom. Differentiation can also mean that changes should take place not only in the curriculum but in other aspects of the child's education. The mindset of the teacher is very important for this to be successful.

The teacher must have the correct mindset. According to Sousa and Tomlinson (2011), mindset is "assumptions, expectations, and beliefs that guide our behavior and our interactions with others" (p. 18). For teachers, having a growth mindset is important for the learning environment in differentiated classrooms. If the teacher is unable to have a "growth mindset," then differentiation will not be successful.

The classroom environment also makes a big impact on learning. According to Schiller and Willis (2008), it is important to create conditions for success. Safe environments are essential. There should be nothing in the classroom that scares the child. Some examples could be having certain pets in your classroom or decorations that are too scary at Halloween. Keeping to a routine is comforting to a child and so it should be followed as closely as possible each day. Children need to feel as though they are safe. "Students must feel safe and emotionally secure before they can focus on the curriculum" (Sousa & Tomlinson, 2011, p. 20). By creating a relaxing environment, children feel at ease and are apt to learn more. It is in this type of environment that children learn about empathy and build a sense of community. This gives the students a sense of belonging which increases learning. When students feel a part of a group, there can be much less classroom management issues and students feel responsible for their own actions.

Another aspect of differentiation is allowing children to express themselves through their emotions. Children enjoy singing and listening to music, so it would make sense to incorporate it into the classroom (Schiller & Willis, 2008). Chanting and putting words or poems to music is helpful to the learning process. By using multisensory approaches, it assists students to learn since you are using more than one modality.

The interests of the students should also be taken into account when planning curriculum. It is easy to differentiate learning when students are eager to learn specific topics. The use of trade books at different ability levels in differing genres makes teaching reading much easier when students are engaged. This allows for differentiating for differing levels of readiness and can make assessment be more developmentally appropriate.

By knowing each child's interests and learning style, the classroom teacher is able to differentiate the curriculum and learning to make the teaching environment a pleasant, nurturing atmosphere for learning to take place. "What students learn will shape who they become, how they view learning itself, and how they interact with the world around them" (Sousa & Tomlinson, 2011, p. 46).

Conclusion

Society favors those who are gifted and can misunderstand those with special needs (Nicpon, Allmon, Sieck, & Stinson, 2011). As if the twice-exceptional student does not have enough difficulty understanding where they fit in, they also have to navigate both of these worlds. This is not easy, and many times, twice-exceptional students are not successful doing so on their own. Support from the school, teachers, and parents is necessary so that the students' strengths will be recognized and nurtured and their weaknesses strengthened through accommodations and modifications. Each child is a unique learner and thus each personality, learning style, temperament, and ability to learn needs to be taken into account when planning lessons and for how the presentation of information will be taught. Providing experiences that promote success will increase self-esteem, will teach students to become more effective thinkers and learners, and will enable all to celebrate the strengths of every child.

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Chapter 10
Making a Case for Early Intervention: The Role of Developmental Neuroscience

Niamh Stack

Introduction

> Nought to three is the really explosive bit of brain growth. If you can help at that point, it's so much more effective, so much cheaper than at any other time. (Graham Allen, UK Member for Parliament, interview in Gentleman, 2011, para 13)

The above quote epitomises contemporary discussions which compound early intervention, economics and neuroscience and which provide the impetus for this chapter. Contained within these two sentences are a series of assumptions and claims about our understanding of the brain, the critical nature of early development, the potential impact of interventions during this stage and the economic motivations for these interventions. The aim of this chapter is to deconstruct these assumptions and claims and to provide an informed and evidenced discussion of early intervention and the potential role of developmental neuroscience in this area.

The Case for Early Intervention

In the past 50 years educators, psychologists and researchers have put forward compelling arguments for the long-term importance of our earliest experiences and from this work convinced policy makers internationally as to the potential benefits of early intervention (cf. Dunst, 2007; Heckman & Masterov, 2004; OECD, 2009; UNICEF, 2008; Wave Trust, 2010). The success of these arguments is

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demonstrated by the range of early intervention programmes which are currently delivered internationally.

> The importance of early childhood development remains profound … the prenatal and postnatal periods are the most critical time in a child's development, laying the foundation for physical, emotional, and intellectual wellbeing … interventions directed at the poorest children can provide enormous returns on investment. For example, home and community-based parenting and family support programmes significantly benefit the youngest children by promoting physical, cognitive, and emotional development, especially when they are integrated with other health, nutrition, and child-protection interventions. For children aged 3—6 years, organised early childhood learning centres not only improve school readiness but also school attainment. (Anthony Lake, Executive Director of UNICEF, 2011, p. 1277)

This understanding of intervention incorporates the full gamut of provision. To name just a few: the *Harlem Children's Zone*, a large-scale community-based organisation serving over 17,000 children in a 100-city block in New York through progressive systems of support programmes from before birth through to college (Dobbie, Fryer, & Fryer, 2011), or targeted programmes such as the *Special Supplemental Nutrition Programme for Women, Infants and Children* which is a US federally funded programme for supplemental foods, health care referrals and nutrition education for low-income pregnant, breastfeeding and non-breastfeeding postpartum women and for infants and children up to age 5 who are found to be at nutritional risk. Prenatal nutrition programmes such as this address the need for early intervention to assist pregnant women in vulnerable life situations, such as homelessness, and to reduce the incidence of low birth weights and subsequent potential developmental difficulties (Richards, Merrill, Baksh, & McGarry, 2011). There are also early interventions for specific developmental disabilities, such as the *Early Start Denver Model*, a developmental behavioural intervention for young children (aged 18–30 months) diagnosed with autistic spectrum disorder (ASD) that aims to improve cognitive and adaptive behaviour and reduce the severity of ASD diagnosis (Rogers & Dawson, 2010).

What is understood as 'early' is also open to interpretation and can include prenatal interventions such as the nutritional programme above, legislative and policy definitions of varying ranges from 0–2 years to 0–8 years, to an understanding that early intervention can occur at any time in development across the lifespan as a preventive or quick response remedial programme such as interventions which are effective in the early stages of dementia (Prince, Bryce, & Ferri, 2011). However given the focus of this text on young children, this chapter will not extend across the lifespan but rather also focus on this early developmental stage. However in contrast and in complement to some other chapters in the text that focus their discussions on issues within preschool age children, this chapter will include interventions, and the potential role of neuroscience, in the first two to three years of life. Even with this more focused emphasis, it would be impossible to provide a comprehensive discussion of all internationally available early intervention programmes within one chapter; consequently the emphasis will be on a number of examples which have been chosen to illustrate the diversity of provision internationally and the potential relevance of neuroscience in designing and evaluating these programmes. Our understanding of the role of both biological and environmental factors on early development cannot be traced to one date, one incident or one study but rather reflects the historical contexts of the time and an increasing amalgamation of interdisciplinary findings across the globe. Contemporary international acceptance of the importance of early intervention in young children's development was not always so, and to understand how it has become so universally pervasive, it is important to return to its early beginnings and consider from where it emerged.

In 1945 in the first week after the end of the Second World War, the men and women of a small village called Villa Cella in Northern Italy decided that the proceeds from the sale of an abandoned German war tank, a few trucks and some horses should be prioritised to build a school for young children. This school was for the children of local farmers, day labourers and factory workers. This community, which had been decimated by war, believed a sustainable and peaceful future for their children was only possible if they intervened early and freed their children from social disadvantage through the power of knowledge and education (Barazzoni, 2005). This school is part of the history of the now more than 30 *Nidi* (infant toddler centres for children from 3 months to 3 years) and the *Scuole dell'infanzia* (for children from 3 years to the compulsory school age of six) of Reggio Emilia. Embedded within the ethos of these infant and toddler centres are elements, extensions and experimentations with the theories of Dewey, Piaget, Vygotsky and Bruner, but no single pedagogical approach is adopted; rather they consider Reggio an experience rather than an approach (Rinaldi, 2006). This early childhood system incorporating aspects of both care and education for children under six which continues today is so valued by its community that it receives more than 14 % of the city budget, and, perhaps more importantly, parents and the wider community remain committed to the ideal of education as a communal activity in the daily practice within the centres (Edwards, Gandini, & Forman, 2012). In 1991, the American magazine *Newsweek* described one of the nurseries in Reggio as the best in the world, which led to an influx of researchers, developmentalists and educators trying to interpret and import the approach. This raises an important point about early intervention programmes; their success (or failure) is deeply rooted in the context in which they are situated, and they cannot simply be transplanted wholesale from one context, country or culture to another; where appropriate it may be possible to interpret and adapt, but there are no simple solutions or quick fixes. This issue of the continuing importance of culture and context will become relevant again later when we progress to discussing the contribution of neuroscience in this area.

A second issue raised by the Reggio experience worth consideration is their focus on early development for its own sake. Although they are fully committed to inclusive pedagogies with respect to all aspects of diversity, and with children with disability receiving first priority and full mainstreaming, it is not a deficit approach focusing on ameliorating perceived risks or preventive actions but rather a universally positive appreciation of the intellectual curiosity and creativity of young children identifying and focusing on their strengths rather than their weaknesses (Rinaldi, 2006). It's under six provision aims to support and celebrate the young children's present rather than predict their future. Educators in Reggio are resistant to the need for longitudinal evidence, outcome measurements and efficacy evaluations based on external criteria and instead see research as the daily critical questioning and co-construction of knowledge in which they engage with the children under six in their care (Dodd-Nufrio, 2011). As we will see later in the chapter, this emphasis on pedagogy and development is not always evident in the rhetoric associated with early intervention, and often children's development, health and well-being appear to be a secondary aim to labour market productivity (Heckman & Masterov, 2004). In 2011, the Secretary General of the UN issued a follow-up report on a special session on the promotion and protection of children. This document reminded Member States of the rights of young children to play, learning and education as universal and as beginning from birth, a right that is strongly connected to the child's right to survival and development, and which is epitomised in the Reggio experience, rather than secondary societal and economic demands.

In his State of the Union Speech in 1964, President Johnson declared a 'War on Poverty' in the USA. The choice of weapons in this war was in part influenced by the work of psychologists such as J. McVicker Hunt and Benjamin Bloom. Hunt's (1961) seminal book *Intelligence and Experience* challenged the prevailing opinion that cognitive ability was innate and argued for the importance of early experiences on children's psychological development and malleable intelligence. Similarly, Bloom's (1964) key text *Stability and Change in Human Characteristics* demonstrated that early experiences in the home shaped learning ability. As in Villa Cella 20 years earlier, these findings and discussions lead to the belief that there was a need for early intervention programmes to break the cycle of poverty. From these discussions the internationally renowned Head Start programme emerged. What began as an 8-week experimental school readiness programme for disadvantaged children has grown exponentially, and to date nearly 30 million children have participated in Head Start since 1965, and in this time it has grown from an 8-week project to include all year round services, a diverse range of programme options and a prolific research base.

Head Start and its proponents were part of a movement which progressed understanding from what *is* human development to envisioning what human development *could be* through collaboration with communities, politicians, policy makers, educators and practitioners (Lerner, 2005). Bronfenbrenner (1967), one of founding contributors to Head Start, emphasised the importance of community involvement in the intervention; for the programme to be successful, it had to be more than a federal financial injection, and the communities in which the programmes were situated also needed to invest in them through the contribution of time and parental commitment. Head Start's aim was to help break the poverty cycle by providing a comprehensive programme for preschool children from disadvantaged families which would ensure that their emotional, social, health, nutritional and psychological needs were met. This commitment to perceiving effective investment in early childhood as '*critical to children's ability to reach their full potential and the Nation's future economic health*' (p. 83) has become deeply embedded in American social policy as is demonstrated by the allocation of $8.1 billion for Head Start and Early Head Start in the 2012 budget to serve 968,000 children and families nationwide

(US Department of Health and Human Services, 2012). Research has demonstrated the potentially positive outcomes for this form of early intervention in the form of, for example, less grade repetition and greater educational achievements in older graduates of the programmes (Chazon-Cohen, Halle, & Barton, 2012). However the efficacy and effectiveness of the intervention has been a source of debate since its inception.

> Like all programs that receive taxpayers' hard-earned money, Head Start must be held accountable. A lack of clarity over exactly what it should be held accountable for has allowed the controversy over whether the program works or not to rage without answer even after all these years … Certainly Head Start never had and never will have the power to equalize the incomes of poor and middle-class parents, provide the health care and social services that poor children may need for all their growing years, clean up the drug- and crime-infested neighborhoods where many families in poverty live, or ameliorate the litany of privations that affect children in low-income families.
>
> (Zigler & Styfco, 2010, pp. 316–317)

Here Zigler, one of the founding fathers of Head Start, emphasises the need to be clear and realistic about the intentions and expectations of early intervention. He argues that a significant proportion of the criticism directed at early intervention programmes in general, and Head Start in particular, reflects these unrealistic ambitions and lack of funding for both provision and high-quality training for the educators on the programme. Lewis (1998) has also questioned the predictive ability of early intervention programmes. He recounts a visit to an early intervention programme designed to foster the socio-emotional development of children of teenage inner city mothers by placing the naked newborn on the mother's naked belly to encourage early bonding. Lewis questions the ability of this temporal act to inoculate the child against future experiences in a poverty environment with possible exposure to violence and drugs. He calls for an acknowledgement of the 'radical discontinuities' that even graduates of early intervention programmes may encounter. Graduating from an early intervention programme unfortunately does not provide you with an invincibility shield against all negative experiences for the rest of your life.

A second issue raised by early intervention programmes like Head Start is the question of targeted versus universal programmes. In the 2010 UNICEF league tables for child well-being in economically advanced countries based on their average ranking, countries such as the USA and Italy were ranked at the bottom of the league table and were argued to be allowing their children to fall furthest behind. Of the countries included in the top rankings of the tables, many are characterised by investment in universal early intervention approaches. For example, in the Netherlands all mothers are entitled to the support of a nurse to take care of other household duties for a week after the birth of their child to allow them to focus on the needs of the child. In Finland, the focus in the early years is on 'a way of preparing children for life', with children encouraged 'to play and interact' and develop their social skills, and the state provides care and education from birth.

Similarly, in Sweden extended periods of maternity and parental leave are available to support and facilitate the needs of the child in their earliest months, and early parent training is provided for a high proportion of the population, not just 'at-risk' populations. In 1970, Bronfenbrenner wrote a minority report, setting forth his differences as chairman from the agreed Forum 15 White House Conference report on children and parents. The crux of the disagreement lay in the assumption of the appropriateness of targeted intervention. Bronfenbrenner vigorously disagreed that children were only at risk in situations of poverty and deprivation and arguing that 'Children suffer when their parents neglect them, whether because of the distresses of unemployment of from long hours of rewarding work' (Bronfenbrenner, 1970, p. 210).

Targeted interventions pose problems because it can often be difficult in practice to identify those most in need reliably. UNICEF's Report Card 8 highlights research indicating that targeted programmes for disadvantaged children, such as Head Start and Sure Start programmes in the USA and UK, in fact may reach only between one third and a half of their intended target groups. The European Commission's Communication on Early Childhood Education and Care [COM (2011) 66] called for 'generalised equitable access' to early childhood education and care, arguing that targeted interventions can stigmatise participants, as families are defined by their disadvantage and their failings. Arguing for universal early intervention provision asks us to avoid generalisations and assumptions about children and their experiences and contexts and rather to allow the opportunity to support and improve all children's early years' experiences appropriate to their needs and circumstances.

The rationale for the previous discussion on the historical contexts of early intervention and questioning of their purpose and ability in predicting children's future is to provide a critical perspective on some of the certainty in which these issues are currently discussed. Irrespective of a focus on targeted or universal provision, early intervention is expensive. For example, US federal funding, significant as it is, covers fewer than one in every four children who qualify for the programme. Funding is a perpetual issue for all early intervention programmes, and outcomes must be convincing in their justification for public financial support. To be sure of the value of investment at this stage, we must be certain of the importance of the timing and the implications for development. Our increased understanding of brain development and recent findings from neuroscience have played an increasingly significant role in these discussions.

The Role of Neuroscience in the Case for Early Intervention

Governments across the globe are being encouraged to invest more money on children in the first six years of their lives to reduce social inequality (Lake, 2011). Human capital theory seeks to take full advantage of the fiscal yield of individuals and has 'contributed to a rethinking of macroeconomic policies for education, and in particular for early education' (Penn, 2010, p. 51). Heckman's (2007) work has been hugely influential in this regard. He argues that intervention in the early years will improve the life chances of the most vulnerable thus leading to sizeable economic savings in later years. These arguments are premised upon the critical nature of this early stage of development, and significant emphasis is placed on our increased understanding of the role of the brain and neuroscientific findings in the justifications. The First Five Years Fund in the USA together with their philanthropic partners, including the Gates and Kellogg Foundations, recognises early learning as a particularly influential and cost-effective investment. An example of their activity is the *Invest in US* project, which is a multimedia, interactive exhibit that makes the case for investing and intervening early for at-risk children. In making this case, the exhibit emphasises the importance of early experiences in shaping the brain. It includes a set of core developmental concepts that have emerged from neuroscience, developmental psychology and the economies of human capital formation:

- Getting things right the first time is easier and more effective than trying to fix them later.
- Early childhood matters because experiences early in life can have a lasting impact on later learning, behaviour and health.
- Highly specialised interventions are needed as early as possible for children experiencing toxic stress, which occurs when prolonged exposure to adverse experiences triggers abnormal levels of stress hormones that can disrupt developing brain circuits.
- All of society benefits from investments in early childhood programmes (http://www.investinus.org/understand-science-early-experiences-shape-brain).

Similarly in the UK, a joint report by the Centre for Social Justice and the Smith Institute in 2008 entitled *Early Intervention: Good Parents, Great Kids and Better Citizens* emphasised the critical nature of the development during this time and in particular the role of the brain. They cite the fact that the large size of the human brain and therefore head means that human infants need to be born before other mammals. This means that brain development, which might occur within the protective of the womb for other mammals, occurs rapidly outside the womb in the first three years of life for infants. Justifying the need for early intervention they argue that:

> It is in that delicate and vulnerable period [0–3 years] that our lives can be made or not. It is there that private competences and public policy must ensure that parents administer the best three years of emotional and cognitive 'intensive care' to every child.
>
> (Allen & Duncan-Smith, 2008, p. 17)

The next section will consider what evidence there is for a critical period in early development, and specifically in brain development, to support these claims.

The average adult human brain contains somewhere in the region of 100 billion active nerve cells called neurons. These are highly specialised nerve cells responsible for communicating information in both chemical and electrical forms in the human body. Sensory neurons carry information from the sensory receptor cells throughout the body to the brain. Motor neurons transmit information from the brain to the muscles of the body. Interneurons are responsible for communicating information between neurons in the body. Messages are communicated between neurons using axons, dendrites and synapses. The axon or tail is the conduit for transmitting information from the neuron. The dendrites are a large number of branching structures from the neuron that are the receptors for information from other cells, and the connection point between an axon from one neuron to the dendrite of another is called the synapse. Research indicates that, with a small number of exceptions, the vast majority of neurons are formed during the prenatal period and are present at birth. However, while the number of neurons remains relatively static after birth, the connections between them see dramatic changes as considerable postnatal growth occurs in the axons, dendrites and synapses. This increase in synapses is called synaptogenesis. Prenatal and early postnatal development is a time of incredible neurological change in synaptogenesis, for instance, from gestational week 34 through to 24 months postpartum, there is an increase of 40,000 synapses per second (Sandman, Davis, Buss, & Glynn, 2011). This rapid period of growth means that any potential disruption during this period could be very damaging. It also appears that synaptogenesis may occur in different regions of the brain at different stages of development. For example, in the visual cortex there is a rapid burst of growth in the synapses between 4 and 12 months; in contrast, synaptogenesis occurs more slowly in the prefrontal cortex which develops later in life (Johnson & de Haan, 2011). During the passage of the life course, this asynchronous pattern of growth is complemented by a pruning process, which works in response to environmental stimuli in removing unnecessary connections with the result that the number of synapses in adults is actually lower than in children. In addition to synaptogenesis and pruning, another important developmental process is myelination. This involves an increase in the fatty shield that surrounds neuronal pathways, and this increased insulation increases the efficiency of the information transmission. This highly developed and robust capacity of the brain to change across the course of development as a consequence of and in response to experience is a process called plasticity. How much change occurs depends on the type of learning, and extended periods of learning result in greater changes. Plasticity is a central feature of the brain throughout life, but the nature of the change can be dependent on the stage of development, and infancy and early development are characterised by quite a dramatic period of synaptogenesis. Brain development and neuroscience feature so significantly in debates about early intervention because this growth spurt is perceived as a 'critical or sensitive period' during which our primary aim should be to ensure that the environment and experiences of young children facilitate rather than inhibit this growth spurt (Sandman et al., 2011).

A primary focus within neuroscientific research has been on investigating the optimal environments for learning during periods of enhanced plasticity and ways of remediating for negative experiences that may occur during this time and hinder development. The earliest studies in this area were conducted around the same time as the first nursery school was being established in Reggio Emilia, and in parallel to the perceived social need, emerging technology has increased our access to, and understanding of, the brain, and acknowledgement of the potential for neuroscience to contribute to the design and evaluation of early intervention programmes has grown. Research in this area began with animal studies. In the early 1960s, Mark Rosenzweig and his colleagues conducted a series of experiments to test the comparative impact of enriched and impoverished environments on the brains of rats. They concluded that the enriched environment had a positive impact on synaptogenesis and learning (cf. Renner & Rosenzweig, 1987). Wiesel and Hubel (1965) studied the impact of visual deprivation on synaptogenesis and pruning by fixing the eye of a newborn kitten shut for the first three months of their life. The results indicated that even after the eye was reopened, the brain had already rewired itself to receive information from the eye which had remained open throughout demonstrating the impact of pruning due to lack of stimulation. The same result was not found when the visual deprivation was applied for the same period of time to adult cats leading to the conclusion that there is a critical period when sensory input is required to stimulate visual development. However, aside from the ethical issues, there are limitations to how much we can extrapolate from animal research to understanding human development. In addition, Howard-Jones (2007) argues that the rats in the 'enriched environments' would have had equally enriched natural habitats and that the real focus of the research is the impoverished rats in cages with no stimulus. Consequently he concludes that there is evidence to suggest that impoverished environments inhibit neural development but little evidence from these studies to demonstrate that enriched environments enhance it.

More recently, centres of excellence in such as the Center on the Developing Child in Harvard University have been demonstrating that although remediation to negative experiences is possible, early development is a sensitive period subject to developmental disruption as a consequence of negative experiences or under-stimulating environments. For example, research at the centre has demonstrated that chronic stress can be toxic to developing brains. While a little stress can have a positive impact in motivating us into action and teaching us how to cope with anxiety, constant high levels of stress from which there is no relief and where no support is provided such as in cases of extreme poverty or abuse can have deleterious effects. Toxic stress can negatively impact upon the developing brain architecture as well as on the chemical and physiological systems that help an individual adapt to stressful events (Sandman et al., 2011). Research has also demonstrated the critical importance of the child's early relationships on the developing brain structures during early development. The findings have extended our understanding of the necessity and role of these relationships for social and emotional development to demonstrating how these relationships directly shape brain architecture and impact upon a range of later developmental outcomes (National Scientific Council on the Developing Child, 2010). Governmental policies such as parental leave and child care services often fail to take the importance of these relationships and the time required to build them into account. Earlier in the chapter we discussed the UNICEF report on child well-being. Countries such as Sweden where extended periods of maternity and parental leave are available to support and facilitate the needs of the child in their earliest months have the highest rankings on indicators for child well-being. This would appear to support the neuroscientific claims, discussed above, as to the importance of this early intervention.

The preceding discussion reflects just a very small selection of the neuroscientific research which has been conducted investigating if early development is a critical (irreversible) period or a sensitive (malleable) period and the type of environment which best facilitates learning at this time. From the body of work available, it would be fair to conclude that although the overt changes in brain connectivity during early development make it a good time to learn, it is more appropriate to consider these as sensitive rather than critical periods. Research has now progressed to demonstrating how the building work on the architecture of the brain continues throughout the life course with some other important periods of accelerated activity such as puberty (Howard-Jones, 2007). A final point on the concepts of critical and sensitive periods in relation to early intervention, Cunha and Heckman (2007) argue that our current definitions of these concepts in this context require extension. They argue that although the research may demonstrate that remediation is possible later in development, it is more costly then. Consequently from an economic perspective, critical and sensitive periods should be defined in terms of the potential costs and returns of remediation and not solely in terms of developmental possibilities. The question we need to ask ourselves as a society is which lens will drive us to providing support when it is required.

As extensive as the increase in our understanding of the brain has become from neuroscientific findings, there is still a considerable degree of uncertainty about the relationships between biological and environmental factors in influencing both the brain systems and architecture and subsequent behaviour. Research continues to try to uncover the answers. For example, drawing inspiration from the Human Genome Project, the current groundbreaking NIH Human Connectome Project is an ambitious effort to map the neural pathways that underlie human brain function (www.humanconnectomeproject.org/). The overarching purpose of the project is to acquire and share data about the structural and functional connectivity of the human brain. It hopes to lead to major advances in our understanding of what makes us uniquely human and help provide a better understanding of abnormal brain circuits in many neurological and psychiatric disorders. From these kinds of developments, it is evident that neuroscience is well placed to continue to enhance our understanding of our early development.

Practical Applications

Plutarch said that ‘The mind is not a vessel to be filled but a fire to be kindled’; therefore, the purpose of early intervention must not be to attempt to fill up a space that has been left empty, as the glass will always need topping up, but rather to ignite the skills and capabilities of young learners so they become empowered within their own development. Knowledge is static but the skills in obtaining and understanding it are dynamic and lifelong.

In the future, a dialogue between neuroscience, policy makers and early intervention providers will be critical in supporting the development, application and evaluation of these programmes based on a sound scientific understanding of the brain. Research in this area will play a key role in understanding the why, how, when and how long for of early intervention. Currently however we are still at an early stage in our understanding of the brain. Most of what we know arises from scientific experimentation with animals or in environments that differ greatly from everyday learning experiences and contexts, and there are a number of limitations and considerations. Howard-Jones (2010) has identified two problems in the relationship between neuroscience and education that are equally pertinent to a discussion of early interventions and the issues raised within this chapter:

- Risk of raising false hopes and expectations of prescriptive solutions
- Risk of ignoring other important research

As discussed earlier Zigler felt that it was not possible for Head Start to ever live up to the ambitious expectations that it could narrow the gap between socioeconomic groups. A sense of the same anxiety is associated with arguments for early intervention which are grounded so firmly within neuroscientific arguments about brain development during this stage. Just as neuroscience is informing our understanding of early development, it is equally demonstrating that the plasticity of the brain continues throughout the lifespan, and so many other events and experiences have the potential for both positive and negative effect, for remediation and for destruction. Science is often accompanied by a sense of certainty that fails to account for the vagrancies of the human spirit. It is not sufficient to say early intervention is justified based on findings from neuroscience; our current understanding of the brain is not extensive enough to justify this claim. That is the land of neuromyth, and it fails to acknowledge the extensive array of other important research that can usefully contribute to the discussion such as the understanding of context as provided by Bronfenbrenner's bioecological model. Equally to ignore our increasing understanding of how the brain's systems and structures develop during this time and to fail to consider its implications in the design and evaluation of programmes would be short sighted.

In order to avoid the pitfalls outlined above, we need to ensure that as early years practitioners, student teachers and lifelong learners, we continue to be informed by, but constructively critical of, emerging research and policy. In our daily practice in the nursery or classroom, in our undergraduate education studies or as part of our continuing professional development, we need to keep in mind that education is a 'long game' and that there are no prescriptive worksheets or classroom activities that provide miracle answers even if they are embedded in the perceived authenticity of neuroscientific research. Knowledge is a powerful ally, and there is a clear need for the integration of findings from neuroscience into our portfolio of understanding about children's early development to enhance our holistic picture of child development. However understanding how a child's brain works will only ever be part of understanding how a child works and of understanding their worlds. We need to use the knowledge from brain research in collaboration with, and in complement to, all the other skills and research knowledge we have as educators or are learning as future educators. You may read extensively within the research about what the potential outcome of certain circumstances is for children's brains, but you will never be able to open up the brains of the children in front of you to check this is the case so you will always be in the situation of making considered judgments based on the knowledge you have of the research (both neuroscientific and educational) and the knowledge you have of each individual and unique child.

In relation to early intervention, the arguments from neuroscience are clear about the potential benefits to intervening early, and they reinforce the existing body of research in this field. But what neuroscience is also increasingly telling us is that early intervention does not have to stop in the early years and that the plasticity of the brain provides us with opportunities for 'early intervention' to ameliorate difficulties in later development as well. This means that there is never any reason to give up on children and see them as victims of circumstances and early experiences, but rather there is always potential for development and change. A belief in the potential for development and change is the ultimate philosophy for education and childcare, and findings from neuroscientific research provide us with another tool in achieving that aim.

Conclusion

> the condition of pedagogical practice is 'an infinite attention to the other'….It is to think besides each other and ourselves to explore an open network of obligation that keeps the question of meaning open as a locus for debate.
>
> (Readings, 1996, pp. 161–165)

The quote above emphasises the importance of listening, the importance of pausing and examining the space between, not rushing to make difference the same. In considering the effectiveness of early intervention, we must always keep an open and critical mind continuously assessing why are we intervening, to whose benefit and what are the implications? The question is not how relevant the findings from neuroscience to early intervention are, but rather, as Howard-Jones (2010) argues, how neuroscientists, educators and policy makers develop a meaningful dialogue and a research process that builds on other established fields of literature relevant to the field and allows the disciplines, including both theorists and practitioners, to co-construct knowledge and understanding. Having reviewed the historical underpinnings of early intervention programmes and the debates surrounding them and seeing how neuroscientific findings fit within this, we now need to work in collaboration to find ways of making often complex findings accessible and useful for parents and children. For example, we may know about the outcomes of stress on brain development or structure, and we may know about the potential benefits of intervening early, but how then do we provide support or develop early intervention programmes that address the toxic effects of stress in a meaningful and sustainable way? How can we, as educators, input into the design of neuroscientific research to ask the questions we are faced within our daily practice in helping us to find answers? To move forward we must become critical consumers of the research knowledge and experienced testers of its practical applications.

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Chapter 11
Effective Strategies to Help Teachers Learn About Brain Development

Billie Enz and Jill Stamm

Introduction

We're living in an exciting age of discovery about brain development and function. New technologies have allowed child development researchers to match information from careful, long-term observations of external behavior with noninvasive brain imaging techniques that allow researchers to graphically record and simultaneously display three-dimensional, color-enhanced images of a living brain as it processes information. The dual data sources provide researchers with a highly effective approach to more deeply understand the organization and functional operations of the brain and how this influences a child's cognitive, emotional, and physical development.

As with all things associated with teaching and learning, there is a debate concerning the ability of neuroscience to inform prekindergarten–12 teaching practice. Sharing accurate information and subsequent practical application of this information has created both debate and frustration in the field of learning and teacher preparation. At one end of the continuum, some argue that the "mechanistic issues that concern neuroscientists are too far removed from the classroom context to be able to effectively inform practice" (Dubinsky, 2010, p. 8057), while on the other side are neuroscientists who are "attempting to apply the techniques of cognitive neuroscience to educationally relevant issues" (Hirsh-Pasek & Bruer, 2007, p. 1293). In the meantime, business entrepreneurs view neuroscience as something that can be profitably marketed as educational products and services—often without substantial research support (Willingham, 2008).

In his book *Consilience*: *The Unity of Knowledge* (1998), physicist E. O. Wilson brought to our attention the term "consilience" which in practical terms means a bringing together, from distinctly different disciplines, information that *when*

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considered together gives power to the combined knowledge that could not be achieved singly. Behavioral/psychological research and neuroscience research must now be combined with the vast experiential base from classroom teachers. Yes, there is a growing belief that educators can learn a lot from neuroscience. But, in building the bridge between neuroscience and education, we need to remember that this process is not unidirectional, coming *from* neuroscientists directly *to* teachers, but rather it is bidirectional, with teachers providing a critical component from theory to praxis (Illes et al., 2010).

However, another equally important aspect of our relationship with neuroscientists is helping to guide the research by asking the important and relevant questions. The scientists are anxious to find out from teachers what they want to know after all the years of their experience so that their neuroscience investigations can help provide some answers. Asking the "right questions" is a critical aspect of successful research in neuroscience, just as much as it has always been in traditional experimental research (Immordino-Yang, 2011).

But to play these critical roles, teachers must be grounded in what one might call *Brain Basics 101*. This chapter brings clarity to what basic brain information teachers should know and how knowing this information changes their thinking about learning processes in their students, and finally how these changes in teacher behaviors can be reflected in their environments (Brandt, 1999; Hall, 2005). The past decade has revealed that this information, used in conjunction with knowledge from other sources including cognitive science, educational research, and a teacher's own professional experience, is helping children learn more successfully (Wolfe, 2010).

New Technologies: Windows into the Living Brain

For thousands of years philosophers, physicians, and educators had to infer the origins of behavior and brain activity from careful, long-term observations of external behavior. However, in the past three decades, brain imaging techniques have allowed researchers to graphically record and simultaneously display three-dimensional, color-enhanced images of a living brain as it processes information (Racine, Bar-Ilan, & Illes, 2006). These data provide researchers with a better way to understand the organization and functional operations of the brain. The research in this area has virtually exploded, and thousands of studies on how the brain develops, processes, organizes, connects, stores, and retrieves information have been conducted and have added greatly to our understanding of how humans develop and learn (Immordino-Yang, 2011; Racine, Bar-Ilan, & Illes, 2005).

Currently, computerized brain imaging technologies typically use the color spectrum gradations to represent the activity levels of the various brain areas in a scan (the red end of the spectrum representing a high level of activity in a brain area, the purple end representing low activity, and the other colors representing intermediate levels). A scan of a slice of brain thus graphically indicates which brain areas were active and inactive during the time interval of the scan. It is important to note that educational researchers are just beginning to use imaging technologies, but this use will dramatically increase in the coming years. Here are some facts about neuroimaging that teachers need to know:

- Initially, imaging technology was primarily used in medical diagnosis, but it is being increasingly used in pure neuroscience and psychological research.
- Each form of brain imaging technology has strengths and weaknesses, and new developments are continually making the technology faster, more powerful, less invasive, and less expensive. Special Feature 10.1, Brain Imaging Technologies offers a list of common technologies.

Special Feature 10.1 Brain Imaging Technologies

- *Computed axial tomography* (*CAT*)—Developed in 1972, this diagnostic technique uses hundreds of X-rays that are passed through the body at different angles to produce clear cross-sectional images, called slices, of the organ being examined. This first technology opened the door for seeing the living brain in real time.
- *Positron emission tomography* (*PET*)—Patients are injected with radioactive tagged glucose prior to this procedure. Since glucose is the brain's principal energy source, the PET scans of subjects will reveal the brain areas that are the most active (those with the most glucose). However, because they are invasive, PET scans are generally limited to medical investigation, for instance, detecting tumors.
- *Functional magnetic resonance imaging* (*fMRI*)—*fMRI* can be used to measure changes in the oxygen/blood flow patterns which allows for functional mapping of the human brain. Investigations in the fields of vision, language, motor function, memory, emotion, and pain have been greatly assisted by fMRI technology. This new ability to directly observe brain function opens an array of new opportunities to advance our understanding of brain organization, as well as a potential new technique for assessing neurological health and cognitive development.
- *Electroencephalography* (*EEG*)—EEG measures the electrical activity of neurons by recording from electrodes placed on the scalp (looking somewhat like a swimming cap) resulting in images of electrical patterns of activity in the brain over time. Since this technology is the least invasive and least expensive of the imaging technologies, it may provide a potential venue for educational researchers in the near future.

It has become common in the popular media to use images of the brain and to report on new research. It is important therefore for teachers to have a basic grasp of terminology, to understand diagrams of brain regions and brain functions associated with each region, and to be familiar with brain areas that are specifically associated with learning and memory. The *Brain Basics 101 Tutorial* that follows is useful for teachers to learn in order to be informed consumers of both popular and educational publications.

Basic Brain Organization

The brain is not a mass of neural cells; instead, it is a highly organized, complex, multifunctional organ. The brain is divided into two hemispheres that are connected by the *corpus callosum*, a band of nerve fibers which carries messages between the left and right hemispheres (see Fig. 11.1).

Each hemisphere is divided into lobes. While each lobe has been associated with specific tasks, they are subdivided into interlocking networks of neurons (brain cells) that coordinate overlapping and complex tasks such as talking which simultaneously requires memory, forethought, and motor coordination of tongue and lips. All four lobes comprise what is referred to as the cerebral cortex (Fig. 11.2) (Goldberg, 2009).

At the base of the brain is the cerebellum which is also comprised of small lobes and receives information from the balance system of the inner ear, spinal cord, sensory nerves, and the auditory and visual systems. The cerebellum integrates this information to coordinate and fine-tune motor activity. It is also involved in motor memory and

Fig. 11.1 The hemispheres

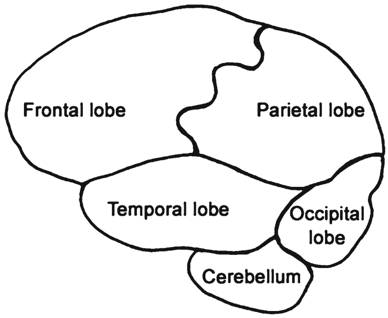

Fig. 11.2 The lobes of the brain

learning and learning simple tasks such as the motor coordination in managing a fork or chopsticks to complex ballet or basketball maneuvers (Timmann & Daum, 2007). Recent research has also demonstrated that highly autonomic motor skills, such as typing, are also housed in the cerebellum.

Frontal lobes	Parietal lobes	Temporal lobes	Occipital lobes
Concerned with emotions, reasoning, planning, movement, and parts of speech Frontal lobes are also involved in purposeful acts such as creativity, judgment, problem solving, planning, and impulse control	Concerned with processing of input from the senses and are responsible for sensory integration, such as touch, pain, taste, pressure, temperature, and spatial relations	Responsible for hearing, memory, meaning, and language The temporal lobes are concerned with interpreting/processing primarily auditory stimuli	Responsible for primary visual processing which includes perception of light, line, curve, color, and secondary processing of vision, which entails recognizing objects

Deep within our brain is the limbic system. The limbic system is responsible for memory and emotion, motivation, behavior, and various autonomic functions, such as the sensation of hunger and thirst and the ability to smell through the olfactory bulbs (Fig. 11.3).

This simple diagram of the limbic system gives emphasis to the four structures known to make up this brain region (Sporns, 2010). Structures with stars* are critical for teachers to learn about and understand because teachers have some influence over the use and continued development of these structures.

The thalamus is about the size of a walnut, and it serves as a primary processor of most incoming information entering the brain. It functions like a relay station, deciding where to send incoming information for further processing. The thalamus is continuously monitoring the *external* environment for input. As a regulator of sensory information, the thalamus also controls sleep and plays a major role in regulating arousal, level of awareness, and activity (Leonard, 2006).

The hypothalamus is about the size of an olive and is constantly monitoring the body's *internal* environment for input. The hypothalamus produces hormones that control thirst, hunger, body temperature, sleep, moods, sex drive, and the release of hormones from various glands, primarily the pituitary gland. The hypothalamus regulates homeostasis in the human body, meaning it is in charge of making sure that everything in our bodies is always in balance. For example, if you have had too many salty foods, the hypothalamus "tells" you and gives you a thirst sensation—therefore causing you to drink some water to put your system back in balance.

*The amygdala** is about the size of an almond. We have two amygdales, one in each hemisphere. The amygdales perform a primary role in the formation and storage of memories associated with *emotional events*.

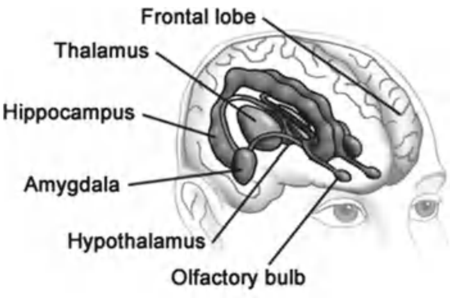

Fig. 11.3 The limbic system

These structures are constantly monitoring the environment for any threat to our survival. The amygdala is the seat of the flight, fight, or freeze decisions that are made in the face of threat. Once activated, it takes a primary position in the way the body allocates energy. To teach this information, we offer the following examples:

> Imagine you are driving home late at night from work and pull up to a convenience store to get refreshments. As you pull up to the store you see several individuals loitering around the front of the building. You suddenly decide you are not so hungry after all and drive away. Whether the threat is real or perceived, your amygdala function has made this decision already by responding to a potential threat to your safety!

When a child has been neglected or abused, these structures (notably the amygdala and hippocampus) are often smaller and do not function properly. Such children frequently become hypervigilant—they constantly monitor their environment for things that might harm them or for ways to satisfy their basic human needs for food, comfort, and companionship. They sacrifice the ability to learn new information because their energies are, naturally, so focused on having these more essential safety needs met (Murray, Izquierdo, Malkova, & Elizabeth, 2009; Perry, 2003).

Helping teachers to understand the important role the amygdala plays in learning is essential. Our ability to learn relies on our ability to focus our attention. However, if our emotional state is being diverted because we feel our safety is threatened, we are unable to channel our attention (Phelps, 2004; Sylwester, 1994). The following vignette provides an example:

> Billie is participating in a graduate class. The internationally renowned instructor asks a question. Billie offers an answer. The teacher responds with "well, that's stupid!" At that point in the class Billie felt unsafe and stupid, as did a majority of the class. During the remainder of the class no one participated and after class, neither Billie nor her classmates could recall the exact content of the lecture.

As Robert Sylwester (1994, p. 60) observed, "emotionally stressful classroom environments are counterproductive because they reduce students' ability to learn."

*The hippocampus** is critical to the storage of memory. The hippocampus works like a filing system, determining *if* something is worth remembering and then determining *where to file it* so that this particular memory can be found again. The hippocampus is essential in forming new memories and connecting emotions and senses, such as smell and sound, to memories. It acts as a memory indexer by sending memories out to the appropriate part of the cerebral hemisphere for long-term

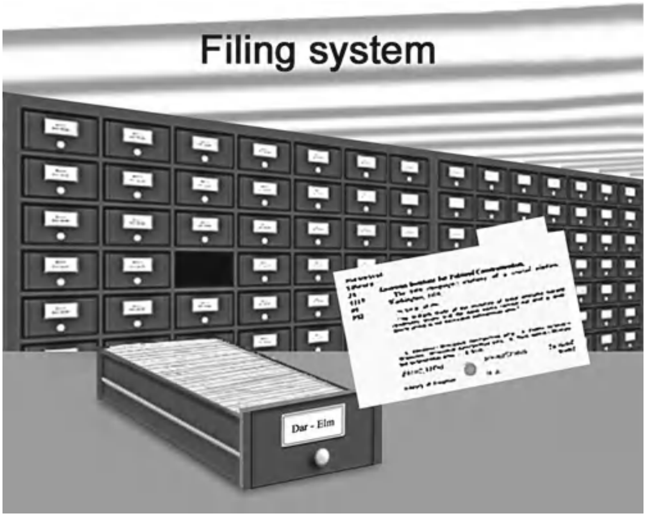

Fig. 11.4 Filing system

storage and retrieving them when necessary. In addition, the hippocampus also appears to serve as a cognitive map that helps humans and other mammals with spatial orientation—in other words helping humans know where they are and how to get there (Kandel, 2007; Rolls & Xiang, 2006).

To illustrate how the hippocampus functions, we offer this activity. Ask teachers to recall the old-fashioned card catalogs in the school library. To help stimulate their memories, you may wish to display Fig. 11.4, the filing system illustration. Ask them to think about the cards. What information is on the cards that would help them to locate the desired text? The content, the title, the author? But most importantly it contains the code that helps us know where to find that particular text in the library! In addition, each card has a small hole at the bottom of the card with a metal rod running through it. The metal rod that holds these cards in place is also a critical piece of the filing/memory system. Imagine what would happen if the box fell over and the rod wasn't there! The hippocampus is like the cards as well as the metal rod, which holds together all the cards in an organized order. The hippocampus has large numbers of stress receptors, and, therefore, the memory systems are vulnerable to the impact of stress on learning.

Just as the purpose of a library is to store books, magazines, music, and other material, one significant purpose of the hippocampus is to store memories, emotions, maps, etc. Like a library that has a system of filing and categorizing so the materials can be retrieved later, the hippocampus develops unique systems for organizing the information that it later receives. It also cross-references and connects ideas, images, and emotions. However, while librarians categorize and integrate new texts monthly, the hippocampus does this process daily. One hypothesis that scientists have been testing is that one of the critical functions of sleep is that during sleep our "filing system" of the day's learnings is being consolidated and updated.

Brain stem. Finally, extending from the spinal cord and underneath the limbic system is the brain stem. This structure is responsible for basic vital life functions such as breathing, heartbeat, blood pressure, digestion, and temperature regulation and is also involved with alertness and arousal. The brain stem functions by relaying information between the nerves and spinal cord to the limbic system, cerebellum, and cerebrum.

Brain Development

The brain's growth and development is not uniform; that is, not all parts of the brain develop at the same time. Brain growth takes place in three different directions in a predictable way (see Fig. 11.5). This progression of growth happens simultaneously: from back to front, from inside-out, and from bottom-up.

Understanding this progression helps to explain human growth both emotionally, cognitively, and physically (Sporns, 2010). For example, in order for a baby to survive outside of their mother's womb, the brain stem (at the bottom of the brain) must be fully functional. The heart must maintain a regular beat, the lungs must breathe automatically, and the baby's body must be able to maintain a normal temperature. So therefore what CAT scans reveal is that the brain stem is nearly fully developed upon birth and the rest of the cerebral cortex continues to develop quite a lot after birth (and this development proceeds from the bottom-up). One system to develop after birth (or often called wire-up) is vision. In utero the baby is developing in darkness. Upon birth light stimulates the cells in the eyes, and, thus, the occipital lobe (sometimes called the visual cortex) begins to develop rapidly. This is an example of back-to-front brain development.

Another part of the brain that is developing rapidly in the first five years of life is the limbic system (from the inside-out) (see Fig. 11.6). The structures in this system work together to help a child pay attention, manage emotional impulses and behaviors, form and retrieve memories, and make rational decisions and carry out

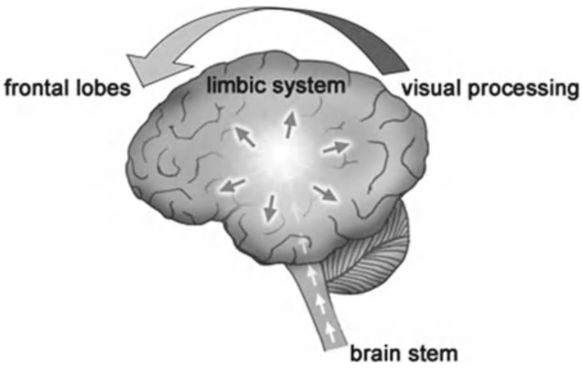

Fig. 11.5 Brain growth

Fig. 11.6 Brain development

actions (Stamm, 2007; Zelazo, 2004). All of these abilities have been given an umbrella term—executive function (Center on the Developing Child at Harvard University, 2011). Problems in the development of these structures in the limbic system in the early years can create later problems for a child in academic learning environments (Goldberg, 2001).

Brain development and brain change is a lifelong process. One of the most important concepts about the timing and sequence of brain development can be stated thusly; "The earlier a system wires up, the more resistant it is to change" (Stamm, 2007). The major difference between brain development linked to learning in a child versus learning in an adult is a matter of degree: the brain is far more impressionable (neuroscientists use the term plastic) in early life than in maturity. This plasticity has both a positive and a negative impact. From a positive perspective, it means that young children's brains are more open to learning and environmental influences. On the negative side, it also means that young children's brains are more vulnerable to environmental challenges such as neglect or abuse, either emotional or physical.

How to Teach This Information

To teach this information in a simple concrete way, we have found using the following visual (adapted from Dr. Robert Sylwester, Professor Emeritus at University of Oregon) to be most effective (see Fig. 11.7, visual mnemonic for the parts of the brain). Use a bagel, pencil, and six layers of colored tissue paper to represent different brain areas and relative amounts of neural tissue to help students make visual connections.

The pencil, at the base, represents the relative amount of neural tissue dedicated to the *brain stem*, which manages vital life functions such as breathing, heartbeat, blood pressure, and digestion.

The bagel, sitting on top of the pencil, represents *the limbic system*. The limbic system consists of separate yet interconnected structures that process the emotional nature of all incoming information. When functioning well, the limbic system allows a person to monitor, detect, and distinguish real threat from imagined threat and to remember to a greater degree those experiences that are important to us. When we feel secure and safe (threat-free), we are able to pay attention and learn new information.

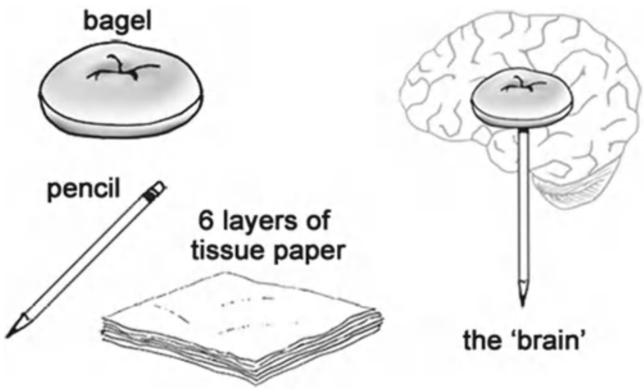

Fig. 11.7 Visual mnemonic for the parts of the brain

The tissue papers represent the neural tissue in the six layers of the *neocortex* (also called the *cortex*), which is the outermost area of the brain. The neocortex is part of the cerebral cortex, and it is involved in higher functions such as sensory perception, generation of motor commands, spatial reasoning, conscious thought, and, in humans, language.

Mold the six sheets into a rough brain shape around the bagel, as demonstrated in the illustration. The neocortex is the gray, highly folded outer surface of the brain. These folds serve to increase the area of the neocortex considerably. If one were to flatten out the folded mass, it would be about the size of an extra-large pizza and, in humans, accounts for about 76 % of the brain's volume. It's a substantial amount of matter because the cortex is the part of the brain where incoming information is both processed and stored and is involved in all school learning.

Notice how these layers of tissue paper are crumpled closely around the bagel. Essential communication occurs between the densely connected neocortex and limbic area, starting with the thalamus. The thalamus deep within the limbic system receives most of the information coming into the brain through the senses (except for smell). The thalamus then relays this data for further processing to the proper area of the neocortex, such as the occipital lobe for visual processing.

The ability of the neocortex to function optimally depends on the healthy formation of the limbic system beneath. Because it is involved in a child's social and emotional development, a healthy limbic system also influences the child's later ability to:

- Pay attention and more easily absorb information
- Retain more of the information she learns
- Be better able to control her own behavior and emotional reactions to others (Liston, McEwen, & Casey, 2009)

The Brain Is

Once again this is where the term consilience is essential, and the work from developmental and educational psychology now must connect with neuroscience. We have learned a great deal about the brain in the past quarter century. Educators and neuroscientists have been trying to put this knowledge to work by transforming main messages into real insights for the classroom. “All learning is brain-based—through the process of living, we are being educated” (Perry, 2000, p. 34). In school, on the most fundamental level, teachers are trying to change the brain (Wolfe, 2010). Indeed, education is practical application of neuroscience, and teachers can become more effective with some knowledge of how the brain senses, processes, stores, and retrieves information. What we have learned about the structures and functions of the brain has helped us to understand the strategies teachers can utilize to help the brain learn. The brain’s main function is to keep us alive; hence, the brain is a *survival organ*. The brain’s job is to adapt to and thrive in ever-changing environments and through life events. To accomplish the ultimate goal of survival, the brain has developed multiple competencies, including:

The Brain Is a Pattern-Seeking Organ

Only when the brain recognizes relationships between new and prior knowledge can it easily retain or connect new information, i.e., learn. When new input enters working memory, this sets off a search (initiated by the hippocampus) throughout the brain’s memory storage areas for stored memory with related patterns. When there is a match, a link to the related pattern is created to secure that new input, and the new input is physically encoded into a brain network with the related memory (Timmann & Daum, 2007).

To illustrate how the brain is a pattern-seeking organ, display the picture/slide (Fig. 11.8) and ask the audience to write down what they see. Now ask them to share with another person what they wrote. The purpose of the activity is not to have convergence but rather to demonstrate that our brains are primed to look for recognizable patterns; what we see often depends upon our prior experiences and current interests. It is interesting to note that due to the current conversation about the brain, many individuals will “see” the brain in the image.

A second activity illustrates how easily the humans are able to sort and label items based upon our brains ability to find patterns. Ask the audience to begin to consider how they would begin to sort the set of keys shown on the slide (see Fig. 11.9). Very quickly the audience is forming categories to organize the set of keys, and the categories and labels that are derived again depend upon prior knowledge and experience.

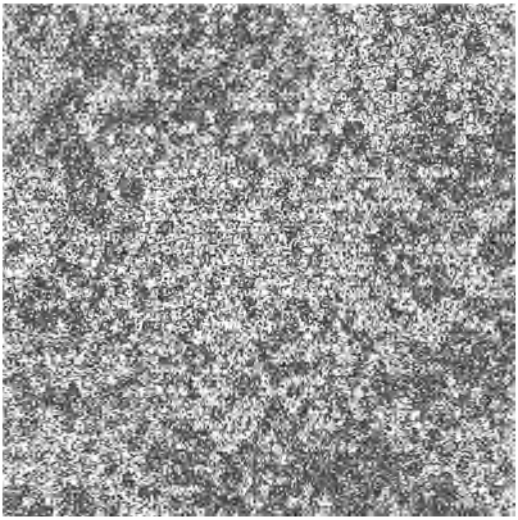

Fig. 11.8 Seeing patterns

Fig. 11.9 The keys

The Brain Is a Pleasure-Seeking Organ

Our brains are actually designed to seek pleasure to feel reward (thanks largely to a structure called the nucleus accumbens, a neural circuit between the limbic system and frontal cortex). This is critical to our survival; hence, we feel pleasure when we eat, sleep, play, etc. We also feel pleasure and satisfaction when we achieve a challenge, for instance, when we learn to walk, climb a mountain, or learn a new skill. When the brain solves a satisfying problem with appropriate challenge, the brain chemical dopamine is released and we feel pleasure and intrinsic satisfaction. Because the brain is a pleasure-seeking organ, it will look for more opportunities to get that same satisfaction and pleasure. However, the reverse is also true if we experience failure or become fearful, we will avoid the situation(s) that presents risk (Kringelbach, 2009). To teach this concept we will often relate this vignette.

> Three-year-old Bree loves to sing. She sings in the bath, the car, and while she plays. Every time she sings her family praises her beautiful voice and creative lyrics. These pleasurable feelings generated by Bree when she sings and by the comments of her family encourage Bree to sing more. Consequently the more Bree sings the better she becomes.

Bree's nucleus accumbens (the pleasure center of the brain) "lights up" when she sings. She wants to repeat the pleasurable feeling! The outcome is that the activity is repeated. Learning to sing, stack blocks, and ride a bike, for example, through play, is what gives pleasure. And it is that pleasure sensation that causes them to repeat the activity countless times. It is actually *repetition* that causes the learning. Our job as teachers is to find ways to make learning pleasurable so that repetition will continue to be rewarding.

The Brain Is a Novelty-Seeking Organ

For survival, the attention systems in the brain are activated when novel or unexpected stimuli appear. We become more alert and attend more carefully to the new incoming information. The evolutionary basis for this is obvious: those who did not become more alert when novel or unexpected stimuli appeared did not survive to pass along their genes; therefore, the brain invests considerable resources/energy in paying attention to novelty and change. However, once the brain assesses that the stimuli are safe, the biological process of habituation begins. Our brains allow us to become familiar with new circumstances through the process of "habituation," in which its response to a sensory stimulus (smells, sounds, feelings, e.g., the feel of contacts in our eyes) gradually decreases in intensity as the stimulus continues. After becoming habituated to the object/person, the child's (or adult's) brain is again ready to learn about something new. In general, the brain is primed to focus on what changes, rather than what remains in a steady state. This is why, for example, we can actually lose sensitivity to odors, so the newest advance in air fresheners is rotating aromas.

Learning requires attention, yet neural systems fatigue quickly. Research and your own experiences as learners have demonstrated that only 4–8 min of fact-driven lecture can be tolerated before the brain begins to daydream or the body begins to move (Perry, 2000; Wolfe, 2010; Geake & Cooper, 2003). If the teacher is not providing sufficient novelty, the brain will go elsewhere. However, the following example demonstrates how a kindergarten teacher has designed a lesson to keep brains and bodies engaged in the learning process. Notice that while the teacher builds the children's concepts, she is frequently adjusting the parameters of learning by slightly changing activities. By using this approach she is able to sustain interest, engagement, and learning.

- Students come into the class. They see the teacher has put an egg, a plastic cup, paper, and a magnifying glass at each student's desk. Each of the tables also has a jug of water.
- The teacher has written question on the board. *What do you know about eggs?* She asks her class this question. The students begin to answer and as they do the teacher writes their responses on the board. *Eggs are smooth, can be eaten, can grow into little chicks. Have yolks, whites.*
- The teacher now draws the student's attention to the materials on the student's desk. The teacher asks the students to take the magnifying glass to examine the shell of the egg.
- The teacher asks the students to draw what they see and share that information with a partner. The students quickly discover that the egg is not smooth as they initially predicted, rather it has tiny little holes. The teacher asks, "Why do you think the egg has holes?" The students suggest that the eggs have holes to let light in the shell or to let air in the shell.
- The teacher tells the students to fill their cups half full with water and to place their eggs into the cup. Then asks them to observe what happens. As they watch the teacher continues to guides their observations with questions. "Does the egg float or sink to the bottom of the glass? What does the egg look like in the water? Do you see little bubbles? Which part of the egg is giving off bubbles? What are the bubbles telling us?"
- The students are beginning to change their perceptions and knowledge about eggs and their structures. The many questions the teacher is posing are helping the students to reshape and refine their prior knowledge of eggs. The discussion between the students and the writing down and sharing their information with the group are also helping this new knowledge go from short-term memory to long-term memory.
- The talking and writing and exploring serve as a part of the physical actions that continue to motivate new learning and encourage the student's retention of this information.

  Adapted from Enz, Bergeron, and Wolfe (2007).

The Brain Is an Energy-Conserving Organ

Our bodies are a closed energy system, that means that when more energy is going one place, there is, by definition, less energy available to go elsewhere. The brain is the most metabolically active organ in the body. Therefore, it is highly dependent on a continuous supply of fuel—blood glucose. To meet this high demand, the brain which is 1/40 of the body's weight possesses relatively high blood flow and glucose consumption, equal in amount to one-fifth of the body total consumption (Dwyer, 2002).

Being alert to new or unexpected sensations is not only essential for our survival; it's an example of energy conservation. The brain also reallocates the precious resources of space and energy when a stimulus that once was novel becomes familiar; for example:

> Think about how much energy and effort you first spent when you were learning to drive. Remember getting in the car and consciously thinking through turning on the key, looking in the mirrors, putting the car into drive or reverse? Carefully backing out of the driveway? How about driving now? Is it easy? Do you even remember backing the car out of the garage today?

The goal of the brain is to put as many things on "autopilot" as possible (remember the cerebellum?). This saves energy and allows us to put our efforts on learning new and ever more important skills. Recent research on the cerebellum, which controls a variety of sensory, motor, and cognitive functions, has a volume about 5 % larger in musicians than in nonmusicians of the same age (Hutchinson, Lee, Gaab, & Schlaug, 2003). Scientists theorize that the since musicians have automatically mastered the skills of playing hundreds of songs their cerebellums reflect this accomplishment.

Another way to share this information with teachers is the following exercise. Count the number of f's.

> Even though I had no formal training, I was fairly well versed in many styles of playing having feverishly practiced during my free time on four different instruments for many years.

Did you count 5 or 7 f's? The brain, in an effort to conserve energy, looks for the gist or the essential point or meaning of the activity. So we typically only attend to the parts we think are important! So we literally do not process the f's in "of" or "for."

Teachers can utilize the concept of energy conservation by creating games/drills that help students translate certain types of information, such as math facts, word recognition, and spelling rules, into automatic response, thus freeing energy and effort to comprehend, learn new information, and to apply this information (Cialdini, 2001; Rawson, 2007).

The Brain Is a Meaning-Seeking Organ

Human beings are meaning makers. We actively engage in figuring out why. The search for cause and effect begins to become active in the second half of a child's first year of life. Humans construct meaning by reflecting on our experiences; we build our own understanding of the world we live in. Each of us generates our own "rules" and "mental models" which we use to make sense of our experiences (Schunk, 2003). Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences. The following is an example of how rules Annie "named" her Grandfather.

> When Annie was ten months old, she began to call her Daddy "Dada" and her Mommy "Mama." Annie also imitated what her family called her Grandma, "Gi-Gi." Though her family called her Grandpa "Papa," Annie refused to call him by that name, instead she

called him Da-Gi (the Daddy that was linked to Gi-Gi). Annie's personal construction of Da-Gi for Grandpa is an example of a personal mental model based on rules/patterns Annie observed and determined.

Facts learned in isolation are soon forgotten; facts which are part of a coherent whole, which have meaning, are retained. Making meaning goes beyond seeking patterns, it involves examining relationships and relating stimuli to other stimuli and categories of stimuli, and finally, like Annie, we construct conceptual models.

When children reach the age of 2, the need to know the how and why goes into high gear. Children from all cultures ask the question "why" as they seek the cause for whatever is happening in their environment, whether that environment be it an apartment in New York City or a hut in Kenya.

No human being is alone. We are all a part of a social system—a culture. We can take culture to be a large set of meanings shared by a group of people. To be a member of a culture means to have the ability to make meaning with other people. Interaction with others is critical for the establishment of "shared meaning." Shared meaning is more powerful than isolated thought (Kövecses, 2006), hence the importance of classroom teaching. Many teachers behave in many consistent ways when they are engaged in instructions, regardless of grade level. Table 11.1 presents some examples of common teacher behaviors, things that highly effective teachers just naturally "do."

Summary

A close examination of what learning principles motivate these teacher actions shows that there are solid, well-researched principles that underlie the behaviors. The real reason however why effective teachers do what they do is actually because of the ways in which the brain works. Knowing some brain basics helps us as teachers to look deeper than our behaviors to then be able to understand *why* learning occurs more successfully when we behave in one way versus another.

Sharing new understandings about the brain and brain function has become essential to the preparation of teachers. There is little doubt that the organ of learning should be a staple in teacher education.

Practical Applications

This chapter had a number of practical applications that will help teachers, parents, and other interested professional learn about the functions of the brain. Researcher and classroom teacher Judy Willis (2006) offers a few more suggestions for making learning even more for the students in our classrooms.

Table 11.1 Teacher strategies

Actions by teachers	Learning principles	Why
Introduce students to new objects, new words, new concepts	Prior knowledge is critical to future learning and connecting new to old helps student retain information	Neurons connect in ways that link similar ideas into networks of neurons that then fire in patterns
Conduct review sessions, practice through homework, repeating main ideas frequently	Repetition improves memory	Repetition speeds up the brain's energy flow by reducing resistance and therefore improving efficiency
Create positive environments that emphasize positive verbal statements, building of trust, relaxed and calm atmosphere, etc.	Emotion → attention → memory	The brain constantly monitors the outside environment to maintain a sense of security and safety
Incorporate fun and excitement into their lessons and into classroom activities	Emotion → attention → memory	The brain seeks pleasure and seeks to repeat pleasurable experiences
Plan instruction to provide multiple experiences with information (listening, reading, acting out, talking, moving)	Active participation improves one's retention of info; multiple modes of encoding improves retention	Information encoded redundantly has multiple retrieval routes (more ways to *find* information later)
Organize new information by giving outlines, logically sequencing information	Organizing information helps to store it efficiently	The brain has processing limitations that can be overcome by chunking/grouping information during storage
School curriculum is *sequenced* to introduce different kinds of experiences and different types of learning at different ages	"Readiness" is an important consideration for skill acquisition	The brain develops dynamically and follows a progression (back to front, inside-out, bottom to top) that influences capabilities
Utilize routines and create rituals when organizing expectations for their classroom	Routines "free up" the system to focus on new information	The brain is constantly seeking to find a pattern in experiences
Use pictures, diagrams, charts, maps, and symbols to teach many concepts	Visual images aid memory	Images help overcome processing limitations. It is easier to recall images than written words as many parts of an image can be grouped together as one
Present information in multiple ways and help learners to create connections to prior experiences	Learners construct their own meaning and, therefore, knowledge	Brains develop uniquely in response to incoming stimuli, based on prior connections Brains search for cause and effect explanations. Humans *create* meaning when necessary

- Relevance—learning is the activation of existing connections in neural networks. It relates to something the learner already knows some information about. The more relevance the topic has to the learner, the greater the meaning. The teacher's job is to help create the connection between the new and the known.
- Emotion—when the learner's emotions are engaged, the brain triggers the release of chemicals that code the experience as important and meaningful. Building emotional connections requires teaching more than facts.
- Pattern—isolated information has little meaning information should be presented in context to help the learner connect to the new information. Context helps the memory connect to larger, overall patterns or prior experience.

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Chapter 12
Metaphors of Developmental Process for Brain-Savvy Teachers

George G. Hruby

> A little learning is a dangerous thing;
> drink deep, or taste not the Pierian spring:
> there shallow draughts intoxicate the brain,
> (but) drinking (deeply) sobers us again.
>
> Alexander Pope

Introduction

The neurosciences are complex. The dynamic interrelationship of physiology, cytology, biochemistry, genetics, and systemic process under investigation across the numerous fields involved in the study of the nervous and endocrine systems is challenging the best-honed skills of the world's top neuroscientists, biochemists, neuropsychologists, neurotheorists, statisticians, and philosophers. Nonetheless, brain science has proven an immensely fascinating area for popular speculation in the mainstream and online media, including in books for the general reader on topics ranging from art appreciation to economics to literary criticism to political analysis (e.g., Arden, 2010; Harris, 2010; Lehrer, 2012). For some time, and increasingly, it is turning up in educational circles in forms ranging from teacher-friendly *brain-based education* (colorful but simplistic; e.g., Jensen, 2008; Sprenger, 2010) to research-grounded *educational neuroscience* (serious but often daunting; e.g., Frederickson, Laurillard, & Tolmie, in press; Patten & Campbell, 2011).

A review of current neuroscience-oriented educational volumes reveals a range of credibility and quality. Some of the neuro-education efforts are fatuous; some are sincere but confused; some are diligent but arguable; some are clearly reserved for

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the use of psychological researchers and educational philosophers (cf., Poole, September 6, 2012). Teachers and teacher educators need to be able to tell the difference and make intelligent use of the more credible offerings.

In this chapter, I will argue that to make good use of educational neuroscience, and to contribute effectively to the conversation about its application in schools, teachers require more than a smattering of brain facts, scientific-sounding rhetoric, and overconfident commandments about what is now known about the brain. Teachers, and early childhood educators in particular, need to know a lot more about life science itself, and about the dynamics of biological development, to make sense of brain transformation through experience and instruction.

But, to begin, teachers and teacher educators need a cohering metaphor to make sense together of the brain, bioecological processes, student learning, and effective teaching. From such a metaphor, easily grasped narratives of how such things work and work together could emerge to inform high-quality teacher professional development. From this, a compelling picture should emerge of what student achievement and effective instruction might look like from the purview of educational neuroscience.

Teachers as Educational Neuroscientists

As the growth of educational neuroscience and brain-based education over the past 20 years might suggest, there is increasing interest among educators in how learning operates at the level of brain anatomy and neurological process. There is also a widespread belief that teachers would be more effective if they knew this information. Although this supposition may seem intuitive, there is no apparent research to demonstrate its validity, and close analysis of the logical warrants for it comes up short on several counts (Hirsh-Pasek et al., 2007; Hruby, 2012; Willingham, 2012).

Given the complexity of the neurosciences, and the issues surrounding the application of their findings to education, it is hard to see how early childhood educators will make use of the science directly. It would certainly require serious re-envisioning in educator professional preparation and development. Yet, it would be helpful if teachers and teacher educators were more conversant in current theoretical models of development generally, including neural systems development, and could use this knowledge to make sense of classroom practices and student achievement. This would be particularly valuable in early childhood contexts given the enormous variability, diversity, and plasticity of young children's development, as would be illuminated by current theories in developmental neuroscience.

The developmental dynamics of neural function is of more immediate use to educators than knowledge of brain structure itself. Educators are not responsible for how students' brains have evolved. They are responsible, however, for how brain functionality changes over time; in other words, how students' brains develop. In fact, increasingly, teachers are being held accountable for "value-added" measures of student achievement that track precisely that change over time in students' knowledge and skills. Thus, development should be the lens by which the neurosciences are focused for educational purposes, not cognitive task processing, which articulate theoretical details of less immediate significance for teachers (cf. Hruby, 2009).

Disturbingly, only a few educational professionals have any interest in or understanding of the nervous and endocrine systems; the majority does not. Too many teachers and administrators who claim an appreciation for the educational value of brain science turn out to be captivated more by media-amplified neuro-myths and simplistic if vibrant visuals than by well-replicated findings or broadly accepted theoretical models. It is not surprising that neuroscience is unfamiliar and its principles are not intuitively obvious to most teachers. It is a technically and conceptually difficult suite of disciplines within biological and medical inquiry. To assume that teachers need the expertise of neuroscientists to be good teachers seems both unreasonable and unlikely. But, to believe that better teachers are made through myths, cartoons, and tidbits makes a mockery of the idea of scientifically grounded professional development on behalf of more effective instruction.

Most professional development booklets about neuroscience set forth basics about brain anatomy, neurons, and synapses, replete with elementary-level diagrams; they map cortical physiology with color-coded functional categories; and they often parade a laundry list of neuro-factoids to startle and amaze. But, untethered from any larger frame of reference, such bits and pieces are less significant than they may at first appear. And too often they are confusing – or sometimes quite wrong (as with neuro-myths claiming that some people are right-brained and others left-brained, that we only use 10 % of our brain, that the brain is hardwired, that functional brain images are photographs of the brain in action, and so on (Helmuth, 2011) – what Poole (2012) felicitously describes as "neurobollocks"). The educational advice of some of this work is equally fabulistic.

Instead of this higgledy-piggledy pop-neuroscience, teachers require a theoretically coherent and thus intellectually supportive framework for informed and intelligent use of neuro-insights. I therefore argue that early childhood educators and teacher educators need (1) a resonant metaphor for making sense of neurological processes that could also apply to teaching and learning and, by way of that, (2) an introductory understanding of the dynamics of developmental biology (the brain is a biological system, after all). They may also require (3) a better understanding of the scientific method in order to distinguish science from educational product marketing. If these new foundations could be combined with what educators already know about effective classroom instruction based on educational research, historical example, and professional expertise, there would be some chance of incorporating neuroscience as a useful idiom in educational practice. Without these foundations and motifs, realizing a neuroscience of education is unlikely.

Toward a Bioecological Metaphor for Brain-Savvy Teachers

Within developmental science, growth in complex biological organisms is understood to demonstrate the dynamics of complex systems (Gottlieb, Wahlsten, & Likliter, 2006; Lickliter & Honeycutt, 2003, 2010; Thelen & Smith, 2006). Thus, to better understand the nature of learning and development in biological systems, such as the nervous or endocrine system, teachers would do well to understand dynamical systems theory. Neuroscience happily provides a window on these dynamics, and one with a view of those processes directly related to the biology of learning, from the genetic to the systemic levels.

Unfortunately, dynamical systems theory in biology is every bit as challenging as the particulars of neuroscience. Grasping dynamical systems theory requires a good bit of intellectual stretching. Still, if neural processes in learning and development are to be grasped scientifically and integrated with what we understand about effective instruction and supportive environments, the dynamics of biological development should be emphasized, because it is the dynamics, or algorithms, of systemic development that reiterate across scales of analysis, from the genetic to the neurological to the systemic, and could potentially be employed at the level of classroom practice as well.

To introduce these dynamics into educational parlance, it might be helpful to employ an operative metaphor as a thematic motif to conjoin what we know about neural, developmental, and instructional process. The metaphor must be broad enough to be encompassing, flexible enough to extend to related topics, such as learning, and have the potential to become intuitive to users. As Aristotle noted in the *Poetics* (2011), we use metaphors to shed light on things we do not understand very well by comparing them to things we do understand well. The analog must be familiar, part of our general world knowledge, or it will not be useful as a metaphor for improving our comprehension. So, claiming that the mind is structured like a software program would be a useful metaphor if we understand how software programs are structured; if not, not. Of course, I assume that any such metaphor would be thoughtfully grounded in current scientific knowledge and assumption about biological process.

Understanding foundational constructs from the biology of development could make a difference in how we understand the changes taking place in our students as a result of our instruction, and could make a big difference in how we formatively interpret our student assessment data. The ubiquity of variation in biological systems, for instance, renders an emphasis on standardized student outcomes particularly problematic. Variability of form and outcome is not only ubiquitous in biological kinds, it is absolutely necessary; it is the basis for adaptation in behavior, development, and even the evolution of species-specific traits.

Such variation can be illustrated by analogy to how newborns vary in litters of kittens or broods of chicks, or how a packet of flower seeds, even under optimal conditions, sprout, grow, and blossom from plant to plant at differing rates. For that matter, the ubiquity of variation in human populations should be manifestly obvious to teachers in the faces and behaviors of the students they teach. The political impulse to standardize and reduce or punish variance in our schools requires serious re-interrogation. Neurologically adept educational specialists could helpfully contribute to intelligent discussion of this issue.

More complex theoretical constructs may require more distant analogies, but ones that can at least be gleaned from the pages of a major newspaper or popular website. Take, as an example, the confusions around using population averages to evaluate and make predictions about an individual's performance and needs. Our current crop of educational benchmarks and standards are calculated on the assumption of such means. Students do not typically match the norms, of course, because students vary and their developmental time course will vary. Yet, students who are found significantly below expectations are quickly declared in need of special instructional regimens or interventions. Is this justified?

Let us review the statistics called on here and the currently popular metaphor they inform. The supposed logic of special interventions for early subpopulations is illustrated by recourse to an arguably freighted metaphor, that of a "gap." If the scores of those below an accepted cut-off are averaged and the resulting mean score is compared to the mean of the remainder or the general population, an "achievement gap" appears. Over a period of years, this gap between means appears to widen. From this, it is claimed that if the students in the subgroup are not all given special assistance as early as possible, they will fall further behind. This all seems to make sense and is taken at face value by policy makers.

The problem is that averages drawn from a population tell us little about individuals within it (standard deviations, when they are included in such data reports, signify little to nonspecialists). It is the individual that does the learning and developing, after all, not the group. And it is the individual that must be taught. The group average is just a statistical abstraction. When these averages are disaggregated to reveal the individual developmental trajectories they are made of, what is first seen is that there is no gap at all but a fairly normal distribution of variance in ability across the population at any point in time. That normal distribution of variance increases over the years, which is to say variance increases as a population ages; the variability *spreads* (this is what anyone conversant with the dynamics of living systems would expect), but there is no widening *gap*. The rhetorically powerful but misleading segregating metaphor of a "gap" (implicitly echoing the metaphor of a deficit, and thus of crisis, and thus of a need for precipitous action) is being visualized by the way that the underlying data has been artificially grouped and averaged as an abstract statistic.

Additionally, when comparing these subaverages, there is no assurance that the students in the low-achieving group in time point 1 are the same students being averaged as low achieving in time point 2. Disaggregating the averaged data reveals that quite a few are not. Experienced elementary teachers are well acquainted with students who begin the year with great promise but end much further down in the pack or who begin at the bottom only to surge into the top tier. Recent longitudinal neuroscience research reveals that this holds true even in the case of adolescents' brain development and IQ (Ramsden et al., 2011). Again, this should not really be surprising, because the variability of individual development trajectories at any scale of analysis is well known to scholars of developmental systems.

Rushing to label students as being in need of remediation on the basis of crude rubrics or statistics does them no service and could well do harm. When too wide a net gets thrown, too many valuable resources get misdirected and too easily entrenched. (Most calculated success rates for interventions include students who would have developmentally self-corrected anyway.) A more nuanced grasp of developmental variation could guard against rash judgments and unnecessary "remediations." An understanding of the dynamics of neural development would require just such nuance and stand as a useful analogy for supporting more nuanced thinking about student development and variation.

Explaining the statistical issues to teachers and other nonspecialists is difficult at best (Hruby, 2011). Metaphors can provide useful shorthand. For although understanding the complexity of human variation is challenging, metaphors from life can reflect them. It is not so difficult to grasp the nature of horse races, for instance, where favored horses often come in last, long shots win, and the lead gets handed off back and forth in the span of the *curriculum* (a word that means race course). Horse races are not games of chance; they are demonstrations of ability, just like standardized tests. But many a splendid thoroughbred has come in last – a poor finish is hardly evidence of disability.

The predictive usefulness of a city's average temperature might be another easily grasped analogy. The average temperature of Chicago in April is 48° Fahrenheit. As anyone who has visited Chicago in April knows, this provides scant guidance about what kind of weather to expect on a particular day. (Chicago's record high for April: 91 °F; the record low: 11 °F!) Just as monthly averages are poor indicators of what one should wear on a given day, population averages are poor indicators of what to expect from a given child.

It is not as if no one has ever noticed the disjunction between individual measures and group measures before. To recount a textbook example, Piaget (1937/1957) relied on case-based research on individual children to inform his theory of stages of cognitive development. In his model, children are said to go through stages marked by sudden transitions in cognitive performance, followed by more stable plateaus. Behaviorists once refuted Piaget's claims by citing population averages of cognitive performance across age cohorts. Such averages seemed to show development occurring in a generally smooth upward arc, without any jumps or growth spurts. Trends identified from large population samples were certainly more statistically reliable than anecdotal case-based evidence. Thus, Piaget was said to have been proven wrong.

Anyone who has ever raised children knows that children do indeed go through growth spurts, in behavior and cognitive ability as much as in stature. The statisticians' mistake was to rely on averages: populations do not develop – individuals do. But they do so at variable schedules, not the same number of weeks from birth. As a result, their individual differences disappear when averaged by year-cohort producing a nicely smooth trajectory that describes a social phenomenon, for whatever that is worth, but not a psychological or developmental one. When individual trajectories are disaggregated from such mean scores, they do indeed show jumps and plateaus, growth spurts, and spans of consistency. Piaget was correct.

This reminds us to stay focused on who is being taught, whose development is being tracked. Policy makers, pundits, and politicians presume we teach "the children," and think of education as an institutionally mediated public service delivery system. They thus attend to statistics that reflect population averages. Teachers, by contrast, must teach each child and do so in a way that will be most optimally effective, something that, because of student variance, is determined and assessed on a case-by-case basis, time point by time point. Teachers therefore attend to the scores and trajectories of individual children.

A better appreciation for variance in populations and in the natural world could lead to a more nuanced grasp of the challenges inherent in applying statistical abstractions to tracking and predicting the developmental outcomes of individuals. Curricula, instruction, assessments, or standards that defy what we know about the *nature* of development and learning, particularly regarding its variation, are unreasonable and should be modified in accord *with nature*.

Most practiced educators have a strong intuition about the natural tendencies that regularly manifest themselves in their classrooms. A grasp of the dynamics of change in living systems could allow them to articulate their intuitions with greater nuance. Rather than mistaking educational standards as industrial benchmarks, and student variation in performance as proof of breakdowns in the industrial production process, variation should be acknowledged and accepted for what it is: a propensity in nature we should work with rather than against.

Foundations of Development for Brain-Savvy Teachers

With a powerful and encapsulating metaphor to act as a focusing idiom, brain-savvy teachers and their professional development facilitators may begin to grasp the dynamics of biological development as articulated widely across the life sciences, including the neurosciences (American Association for the Advancement of Science [AAAS], 1990; Gottlieb et al., 2006). This knowledge may have useful application for parsing students' cognitive, social, and emotional development in classrooms. I am not suggesting that development is only a biological process; it is also a social and cultural process, but the underlying strata that are developing in the brain during learning are certainly biological in nature and need to be understood as such to be understood at all. These bioecologically specific concepts might be distilled to statements and inferences such as the following:

1. Growth is an individual phenomenon, not a group phenomenon.
2. Growth does not typically proceed in smoothly linear trajectories.
3. Growth varies – both within and between individuals; developmental trajectories also vary (and our attempts to prognosticate them may be at the peril of our students).
4. Growth is due to biological processes directed by chemical, structural, and ecological (physical, social, economic) conditions (growth is not predetermined; it is probabilistic and highly adaptive to environmental contingency even at the level of genetic expression [e.g., Lickliter & Honeycutt, 2010; Tung et al., 2012]).
5. The causes of growth and its unique characteristics per individual are not singular but distributed across multiple scales of organization, both spatial and temporal

(claiming only one level, or a single variable, in the neocortex, in the classroom, or in the genome, as *the* cause of an effect is simply wrong).

6. Although the structures and functions of the biological system are scale-specific, the general dynamics of biological development can be found at work across scales of organization, from that of proteins (such as neurotransmitters and hormones) to cell structures (such as synapses) to cells (such as neurons) to cellular tissue (such as the layered and columned nature of brain tissue in the cortex) to systems (such as the hypothalamic-pituitary-adrenal axis) to organisms (such as actively learning students) to niches (such as in classrooms under the guidance of an effective teacher). It is these last two levels of organization that we are most interested in, of course, but it is nice to know that the dynamical processes underlying bioecological change are reiterated more broadly (Thelen & Smith, 2006).
7. Structure and function are co-causative at any scale of organization, which is why cognition and other forms of whole organism behavior are best understood as situated and embodied (Gottlieb, 2003; Marshall, 2009).

Admittedly, these concepts are rudimentary, yet for many teachers challenging. Perhaps, in their particulars, they may at first be better employed as theoretical frames for educational scholars engaged in classroom research than for teacher education. Borrowing idioms from the study of system dynamics in neuroscience, biology, and ecology for application to the systems at work in classrooms and schools might well prove a useful corrective to the traditional cognitive-mechanistic and cultural-context theories educational researchers have employed historically. But they may thereby become important idioms for teacher educators and professional development facilitators presenting neuroscience research to teachers and administrators. Developing more compact means of envisioning and communicating these constructs would be useful.

Foundations of Science for Brain-Savvy Teachers

It seems improbable that teachers could come to understand and appreciate the findings of neuroscience – or any kind of science (cognitive, developmental, social, etc.) – without a fundamental grasp of the scientific method, particularly its underlying logic (Willingham, 2012). Although they do not need to master the intricacies of research design, the mathematics of statistical analysis, or the philosophical justifications of Bacon, Popper, or Kuhn, they do need to know how science is rationalized so that they can distinguish scientific claims from the rhetoric of vernacular scientism. By *vernacular scientism*, I mean the sweeping and too quick assertion that a belief, or a truth claim, is scientifically based merely because it makes nodding acquaintance with a field of scientific inquiry – without indication of any scientific research or, more importantly, the qualifications and caveats that should attend the report of scientific findings. Although there are philosophically sophisticated forms of scientism (which argue that science can explain all things), the vernacular forms foster a blind faith in the authority of science and foment what amounts to secular mysticism.

If we expect science literacy from our students, we require it of our teachers. What is good for the goslings, we might say, is good for the geese and ganders. Therefore, before becoming too entranced by the neuro of neuroscience, teachers ought first to be certain they grasp the science of neuroscience – and its limitations.

Websites dedicated to encouraging greater science literacy among students, teachers, and the general public, are very useful in this regard. These include the National Science Teachers Association (http://www.nsta.org), particularly its position statement "The Nature of Science" (NSTA, 2000), and the American Association for the Advancement of Science (AAAS), particularly *Project 2061* (http://www.project2061.org). This site includes access to such resources as the renowned journal *Science* and its special issues (http://www.sciencemag.org) and *Science for All Americans: Online* (AAAS, 1990).

As both the NSTA and the AAAS note, there is a great deal of variation in how science gets done across different fields and disciplines, and it may be the case that a surprising number of scientists, though competent in the methodologies and procedures of their own field, would struggle to correctly describe the scientific method more generally (Gauch, 2003). Still, there are insights to be drawn from hypothetico-deductive methodology that would clarify the logic of neuroscience research, and teachers would profit from a familiarity with these. The scientific rationale for testing assumptions or hypotheses through falsification rather than through validation (Popper, 1935/1959) would be a good place to start, and help teachers critically evaluate the too-glib assertions of brain-based education.

Discussion: Developmental Neurology for Educated Teachers

Those attracted to the supposed certainty of scientific evidence may be troubled with the suggestion that something as notoriously poetic as metaphor should be a feature in educational neuroscience. Yes, figures of speech can illustrate analogies that may be helpful for comprehension, such as those above, but beyond that, metaphors seem just a lyrical flourish and could prove potentially distractive or confusing to teachers, as the foregoing example of the achievement "gap" illustrates. What value could metaphors actually have for teaching science concepts?

As it turns out, metaphor is more than just a common rhetorical trope. It often works to concretize particular aspects of experience so that the analogy can be extended in conceptually fruitful ways (Lakoff & Johnson, 1999). As philosophers of science have noted, metaphors are often used as general frames or "World Hypotheses" (Pepper, 1942) for coordinating the construction of more pragmatic and applied levels of theory in scientific inquiry. Metaphors are used to organize findings, guide theoretical modeling, and justify dominant methodologies. Newton likened the universe to a pocket watch. Lorenz likened animal drives to pneumatic pressure. Cognitive psychologists liken the mind to complex computer programs. Such analogs allow us to encapsulate a raft of complex structures, relationships, and functions in a memorable and easily readapted or extended form. Moreover, it arguably can direct researchers' assumptions, questions, methods, and interpretations (Hruby & Matthews, 2007; Pepper, 1942).

The same would be true in using a metaphor for grasping the nature of the brain (in a nutshell, one might say metaphorically). Indeed, metaphors of the brain are already fairly widespread. The media prefer likening the brain to a computer, and some cognitive neuroscientists would agree. So, in fact, metaphors are already at work in guiding our understanding (or misunderstanding) of the brain.

However, some neuroscientists have expressed misgivings about computational metaphors of the brain (Churchland, 2002; Gernsbacher & Kaschak, 2003), and most seem to assume something different: that the brain is a complex suite of biological systems. This is not really a metaphor, however; it is a scientific statement of what neuroscientists believe the brain is (a good reason for attending to it). But from that core assertion, several ancillary metaphors can be generated for extension to learning and teaching. If the brain is a biological system and learning is what biological organisms do, then learning can be parsed as *growth on behalf of adaptive response to ecological conditions*, for that is the core assumption about what sets biological entities apart from inert matter (Thompson, 2007). From this, we could derive that teaching is cultivating such growth.

This bioecological metaphor contrasts with the popular metaphor of the brain as a computer, where the mind is software, and thus learning is data processing, and teaching is programming and data entry (cf. Fodor, 2000; Pinker, 1997). This dichotomy echoes a similar dichotomy in genetics and molecular biology, as well as in evolutionary and developmental psychology, that between *instructionist* or encoded, symbolic, or computationalist frameworks and *probabilistic* or dynamical, bioecological frameworks for making sense of developmental process (Lickliter & Honeycutt, 2003).

Notably, the mechanism implicit in the brain-as-wet-computer metaphor matches the implicit mechanism of factory metaphors of schooling (schools, by extension, being the factories for manufacturing human learning machines). Arguably, this line of metaphorical reasoning has failed to make good sense of the ubiquity and persistence of human variation, as demonstrated by the current emphasis on standardized student performance assessments. The lower end of the distribution is usually labeled dysfunctional, abnormal, unacceptable failure – factory seconds, if you will – and treated as evidence of an industrial production flaw. Policy then tries to address this with quality control measures drawn from industry: more detailed accountancy and further standardization. Every student rolling off the educational assembly line, say proponents of this kind of reform, needs to be above average; striving for anything less is said to hamper our international competiveness and market share.

By contrast, if brains are biological systems and learning is growth and teaching is cultivation, then schools are gardens, not factories, and school systems are agricultural systems, not industrial systems. Indeed, this is precisely what learning and schooling were once likened to. Variation is to be expected, in this view, because variation is the fulcrum around which the dynamics of biological change proceeds, making learning, development, and even evolution possible. Indeed, Dennett (1996) has referred to nature's tendency toward *replication with variation allowing for adaptive response to environmental conditions* as the universal algorithm. This algorithm is not only the apparent backbone to Darwin's theory of natural selection; research suggests that it is the functional basis for the autoimmune system, neurotransmitter regulation, neural blast migration, neural and dendritic pruning, synaptogenesis, genome self-regulation, and more. Thus, in the nutshell of a simple algorithm drawn from the dynamics of biological process, a motif emerges that teachers can come to grasp and apply in their thinking about developmental processes in classrooms, even as the particulars of the biological processes that realize the algorithm at any particular scale of analysis remain to them obscure.

Be this as it may, the recent history of civilization has rendered agricultural and gardening motifs unpersuasive; they strike people as quaint, pastoral, and weak. The once dominant organic metaphor of learning as growth (as employed, say, by Froebel in his coinage *Kindergarten* = garden of children) was displaced a century ago by industrial metaphors, which at the time seemed very progressive and powerful (since productivity was then tied to industry as it once had been to agriculture). The last hoorah for biological metaphors in education might well have been Dewey's functional psychology (Dewey, 1896; Green, 2009), although it has continued to echo as a minor motif ever since.

But in the twenty-first century, industrial metaphors have become outdated in turn, and the factory model of schooling, when it is still invoked, is generally a term of derision. Today the prevailing cultural idiom is informational; we are said to live in a postindustrial information economy powered by digital technologies that are all about collecting, processing, and disseminating information. Information is what now makes us productive. This is one reason why the cognitive metaphor of the mind as a computer software program continues to resonate even as the design of computers and their operating systems become increasingly opaque and obscure for the average person. Interestingly, even the computer metaphor is beginning to sound quaint and is giving way in the media to metaphors that describe the brain as an Internet, with numerous connections whose function and growth are continuously shifting, or like iPads or smartphones, loaded with apps to work the social Internet. (As the Internet is increasingly navigated for social connection, likening society to the Internet has become increasingly intuitive.) It isn't just about the machines anymore; it's about the information flow.

It is self-evident to see how education would be parsed through information metaphors (information = knowledge; although this can be argued as a false equivalence, reducing knowledge to mere data points). As digital technology becomes increasingly integrated with formal instruction in and out of school, this analogy will become increasingly intuitive to educators. To stay in step with the Zeitgeist, it will become necessary to emphasize that "brains process information" – which, in a metaphorical sense, they do. Unfortunately, information flow metaphors could encourage a revival of the didactic transmission metaphor of teaching and pose serious challenges to biologically supported constructivist theories of learning.

Biological systems are also being likened to information processing systems, just as, during the heyday of industrialism, biological entities were likened to machines, factories, and so on. Genes are said to carry genetic information "instructing" cells in what to do and how to do it. They are even often described as "blueprints," although this is quite inaccurate, as blueprints do not revise their expression in response to environmental conditions the way genomes do (Tung et al., 2012). Although brains are said to process information, neurons do not in fact send signals representing information the way circuits in computers do. An action potential is not a signal in the sense of being a symbolic representation of something else, say, an encoded quantity representing yet another symbolic representation, as in a computer. Symbol use certainly occurs at higher levels of neural organization, but not at the level of the biochemical cascade that results from the depolarization of a neuron's cell membrane. The analogy is way off and more about the logic of figures of speech than an accurate description of the natural world.

Confusions like this are often called (metaphorically, of course) "mistaking the map for the territory." Just because we use symbolic representations to make sense of the brain, and it is our brain that allows us to do so, it does not follow that brain itself is essentially symbolic at all levels. At which level of biological organization the capacity to engage in symbolic thought emerges is hard to say (cf. Bennet, Dennett, Hacker, & Searle, 2007). But it is doubtful that sea slugs, salamanders, or iguanas engage in something like symbolic thought, even though they possess nervous systems and brains.

The mistake at work is a new variant of anthropomorphism: trying to explain the natural world by way of a human technology, instead of understanding information processes as emergent and reflective of natural systems dynamics in the biology of human nature. In this way, theories of causation in development gravitate toward intelligent design models (as at least implied in computational metaphors), eliminating the possibility of emergent processes in the natural world. In the end, the dynamics of biological process in the natural (larger-than-human) world may do a better job of explaining the potential of information systems than the other way around. (Indeed, some robotics and artificial intelligence researchers have already reached this conclusion, but the debate continues; cf. Brooks, 2012; Clancey, 1997; Cooper, 2012; Dyson, 2012.)

Caveat: The Legacy of Educational Theory, Practice, and Research

Although the neurosciences, the developmental, and life sciences reveal much that should be of interest to educators and educational researchers, the educational community should not be distracted from what they already know with a fair degree of confidence about effective education. Educational research (and the historical record of its application) tells us a good deal already about effective practice. And, after all, research on effective practice would be the sort of research that would most likely tell us something research-based about effective practice. Research on other phenomena, such as how the brain works, or on models of cognitive process tells us about those things directly, but not about effective practice except by way of interpretative extension (Hruby & Goswami, 2011).

Moreover, the research on effective instructional practices provides evidence of regularities in complex group behaviors that require more explanation, as might be provided by neuroscience. But when interpretations from such work by well meaning non-educators contradict what educational research consistently demonstrates about effective instruction, we might assume that it may be the neuroscience theory that deserves critical review, not our knowledge of classroom tendencies. Thus, educators and educational scholars should have a collaborative role to play in the emerging enterprise that is educational neuroscience (Hruby, 2012).

Knowledge of effective practice as indicated by expertise, research, and history is important because it stands as the most powerful corrective to the too common use of vernacular scientism to dismiss the value of that expertise and evidence in favor of imaginative interpretations supposedly proven by brain research. Typically, such feints are meant to evade the evidence that would contradict an ill-conceived or ineffective, but financially lucrative, intervention. On occasion, neuroscience studies are selectively arranged to appear to substantiate the use of a failed policy or practice. Boondoggle and mischief are more likely the intent than improved student achievement. A nostrum may be said to cohere with how the brain is said to work, but if it fails to cohere with how students in classrooms work, it is of little value for education.

Of course, we are a long way from having a comprehensive or definitive understanding of effective classroom instruction. The research base and the historical record on effective practices are variable from content area to content area, grade level to grade level, or subpopulation to subpopulation. Nonetheless, there are some general teacher-friendly reviews (Marzano, Pickering, & Pollock, 2004) and resources (e.g., What Works Clearinghouse, http://ies.ed.gov/ncee/wwc) that should be helpful and by which neuroscience findings can be interpreted and thereby incorporated with what we know as professionals about effective practice.

Practical Implications

Early childhood care providers, teachers, and their professional development faculty could realize the recommendations of this chapter in a number of direct ways. First, they should rely on organic metaphors to explain learning and skill development and advance a more bioecological idiom in their professional discourse, instead of relying on mechanistic metaphors (e.g., the computational brain) or contextualist metaphors (e.g., sociocultural construction). “Nourishing ability,” “enriched environment,” “cultivating appropriate responses,” “rooting ideas,” and “grafting contributions” are all examples of organic metaphor, as are already familiar terms such as “growth,” “training,” or “support.” Secondly, variance, as already noted, needs to be accepted as not only unavoidable but desirable and integral to the bioecological dynamics of brain development. Difference is not necessarily disability. And, thirdly, popular brain-based claims and materials should be approached the way scientists approach hypotheses: through *falsification* (challenging claims by seeking contradicting evidence) rather than *validation* (arguing something is true with a good sounding story), and for the exact same reasons: to avoid false positives and confirmation bias.

A truly "brain-based" education would be one in which we use our brains, one where we forgo rainbow-colored phrenology charts and simplistic assertions about "hardwired" and "genetically blueprinted" intellectual ability, and where we evade the confusions borne of disconnected, often erroneous, factoids about the brain that most teachers currently lack the background in science, let alone in biology, to understand or interpret.

A little learning can be a dangerous thing: it gives us false confidence and hampers the humility and acuity necessary for carefully focused formative assessment, differentiated instruction, or self-directed professional development. Overconfidence in our knowledge and abilities as teachers can undermine our trust in the resilience and capacity of our students, particularly those too readily labeled as "at risk" in our ham-fisted efforts at societal tracking. Overconfidence in our knowledge about the brain might similarly undermine our trust in educational research, historical example, and teachers' expertise. As educators develop the foundations necessary to make sense of brain science, they must guard against such hubris.

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Closing Thoughts: Remaining Optimistic, Cautious, and Active

Debby Zambo and Leslie Haley Wasserman

As part of Springer's *Educating the Young Child* series, this volume brings together a group of distinguished educators and researchers who have a common vision and goal: the appropriate, ethical, and useful application of neuroscience to education. This is an important focus because now, more than any other time in history, we have the tools to peer into the brain and understand how it functions and why certain behaviors are seen. New technologies are helping neuroscientists understand the biological and environmental forces that affect the brain, and as teachers, we are becoming aware of this information, and interested in it, because it is part of our world. With the rise of information technologies, new ideas from neuroscience are being spread at an incredibly rapid rate to places never dreamed possible (Stamm, 2007; Stein, della Chiesa, Hinton, & Fischer, 2010). As Jarvis (1999) notes, everything seems to be changing and the expression "I don't know what the world is coming to" has never appeared to be more true or real. Change is here, and it can be exhilarating and intimidating at the same time. As things change, we as educators roll with it and accept, and confront the challenges change brings. Change is not always bad because it forces us to become more reflective about our practice and consider how research and technological advances can make us better at our jobs. As workers in an information society, our jobs have become transparent and we are being held accountable. Our jobs demand continual assessment and upgrade, and the application of findings from neuroscience can be just the thing we need. Some neuroscientists are collaborating with educators and working to convert their specialized field and technical jargon into useable strategies and ideas. We as teachers have become fascinated, dazzled, excited,

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and bewildered by neuroscience, even if we are not quite sure what those fMRI images mean or what they can really bring to us. As teachers of young children, we want information from neuroscience to help us teach better so that each and every one of our students learns. We want to be good teachers, and because of this, we are attending workshops on the application of neuroscience to our classrooms and reading about neuroscience in educational journals, the popular press, and on the Internet. We want the newest, evidence-based approaches because we care about young children and have been entrusted with educating them. Yet, not all the information we receive is accurate, valid, and reliable, and turning ideas from neuroscience into practical strategies has created both frustration and debate in the field of learning and teacher preparation. The authors in this volume recognize these debates and have worked to take a cautious but optimistic stance and bring the best, most applicable, and dependable scientific information to you. In this volume, you have learned about the smallest brain parts and largest brain structures, brain development, the importance of nature and nurture, and how important early intervention and lifelong learning are to healthy brains. Contributors to this volume have provided practical ideas like Universal Design concepts, Mind Brain Education, and ways to teach all children including those who struggle with print, have autism, and are twice exceptional. Each chapter is unique, and collectively they point us in the right direction. As the editors of this volume, we would like to close with the following summation of ideas.

It Is Time to Be Optimistic

The authors of this volume have continually called for transdisciplinary conversations or consilience. Several authors have noted the positive changes that are happening because neuroscientists, educators, psychologists, sociologists, and others are working together to develop a common language and scientific understanding of the brain, how it functions, the environment it needs, and how to teach in ways so children learn. In this volume, a few well-researched principles underlying learning and behavior have been provided, and this information adds a layer of understanding to your practical knowledge. We believe teachers know a lot because they work with children every day, and neuroscience can add a fresh breath of air to this work. Learning the neurocognitive basis of learning has the potential to help early childhood teachers teach all children and appreciate individual talents and needs. A few key ideas presented in include:

- Good teachers are effective because they teach the way the brain learns.
- Experiences shape brain development.
- Young children need mediated learning (floortime).
- Humans are hardwired to imitate.
- Relevance, patterns, and emotions matter.
- Repetition leads to automaticity.

- Providing multiple representations, allowing children to express what they know in multiple ways, and providing multiple ways to become engaged are good strategies because of the way the brain processes information.
- Attachment and synchrony build trust and learning.

These ideas stem from neuroscience, cognitive science, developmental perspectives, and more. The authors of this volume have provided a multi-voiced perspective and strategies that are practical and useful in classrooms.

It Is Time to Be Cautious

Even though neuroscience brings much promise, teachers still must proceed with caution and care because it is alluring, evolving quickly, and, in many instances, spreading false ideas. Teachers of young children are reading about the brain in teacher journals, hearing about it on television, and watching videos of it on the Internet. In today's information-rich society, teachers know more about the brain than ever before, and because of this, it is important to remain open to new information but skeptical at the same time. Information about the brain is helping confirm many of the things we already known about children and teaching, but it has also found its way into the hands of unscrupulous manufacturers. The authors in this volume remind you that:

- There are curricula, books, and products that purport to utilize findings from neuroscience to promote improved learning without any scientific backing.
- Evidence-based teaching methods need to be supported with research on neural mechanisms and the neurobiological basis of learning.
- Emotional catch phrases are being used to pose quick and easy answers to complex learning and behavioral challenges.
- Testimonials are not the same as empirical facts gathered by researchers with reliable and valid tools.
- To make sense of the brain, learning, and environmental effects on the brain, a comprehensive and compelling metaphor needs to be developed.

Given these facts along with the promises, we as educators of young children must remain optimistic but with a critical eye. Our minds like all others want answers, but they can also easily be fooled. Neuroscience can be alluring, and neuromyths are easily built because they fit intuitive notions of how the brain works. As teachers we want answers, and this may lead us to quick adoptions of materials and claims. We, as easily as anyone else, can build false hopes and misread, misquote, and overextend ideas to confirm the beliefs and biases we already possess. Instead of proceeding cautiously, we can jump in, believe wholeheartedly, and lose sight of what learning and teaching are about. Confirmation bias can narrow our views and leave us vulnerable to false claims that cause us to waste valuable instructional time, treat children unfairly, set low expectations, and spend hard earned money on worthless products and programs that do little good. When it comes to neuroscience, we must proceed cautiously.

It Is Time to Become Informed

Thanks to neuroscientists, teachers, psychologists, and others, explanatory theories are being developed, but it is up to each one of us to decide if they are applicable to our context and the children in our care. To understand what neuroscience is, how it can be used, and why we should use it, teachers need to be trained. Teacher preparation needs to include more courses on the dynamics of biological development, learning, and what this means to the classroom. How and why teachers use neuroscience in their classrooms should not come from emotional testimonials or simple efforts to link strategies with fMRIs. It is time to look at neuroscience with a critical eye and remember:

- The best information from neuroscience is gathered with reliable and valid tools, replicated, and combined with personal insights.
- The tools neuroscientists use are new, popular, rapidly changing, and persuasive. We need to understand these tools, the level of analysis they are able to perform, the reliability/validity of results, and what this all means to us in understandable and useable terms. In short, we need a better understanding of the science involved and the scientific method.
- Teachers and neuroscientists need a common understanding and common vocabulary.

Becoming critical consumers of information is important and will likely lead us to understand that the years of research and knowledge that has laid the path for neuroscience must not be forgotten. Neuroscience cannot tell us what or how to teach, but it can be used to confirm, enrich, and refine the theories and models of learning and behavior we already have and use. Educational psychology, cognitive psychology, and educational research explain why some teaching practices work whereas others do not. It is our responsibility to become informed and seek credible sources and credible individuals who perform this work.

It Is Time to Take Action

While advances in neuroscience are clearly exciting, exhilarating, and impressive, evidence of significant improvements in educational practices based on it is not yet evident day to day. The big picture is being revealed, and brain structures, functioning, and dysfunction are coming from well-designed research, sound methodology, and data (quantitative or qualitative) that capture academic, behavioral, and social gains. Laboratories, clinics, hospitals, and other places are doing big picture research, but no matter how good it is, teachers still need their own independent demonstrations of effectiveness in their classrooms. Findings from neuroscience reveal what is in the mind, but without behavioral data, these findings are limited to particular children, processing information in a machine, at fixed moment in time. As educators, we need to understand these limitations.

Big picture research is necessary but so is our own action research, or the study of our own practice. A typical action research cycle starts by locating a problem and then proceeds to researching a solution, trying the solution, gathering and analyzing the data we have gathered, reflecting on the findings, and determining the next steps. We can take ideas from neuroscience and put them through these steps. For example, if the children in our classroom are struggling to learn a concept, we can investigate what neuroscience says, blend this with ideas from cognitive science and development, and alter what we do. We can then design data collection tools like pretests, posttests, surveys, and observations and collect and analyze this data to see if the ideas we tried makes a difference. If teachers did this work and published it in teacher journals, a mass of ideas would be built and neuromyths could be put to rest. We are capable professionals who can perform practical research.

It Is Time to Become Advocates

The field of neuroscience is growing and has many positive implications. But it can also be used to apply labels, verify stereotypes, and narrow learning, behavior, and emotions to biological processes alone. Neuroethics sits at the intersection of neuroscience and the ethical, legal, and social implications; it brings matters because teaching is a moral profession. As teachers, we are caught in the whirlwind of changes going on around us, and we need to consider the possibilities and challenges neuroscience can bring. Every day across the world, parents entrust us with their most valued possession, their children. As teachers of young children, we know this and work diligently to find the best ways to teach. We are turning to findings from neuroscience to help us, but we must also remember that we need to use it fairly, ethically, and responsibly. Neuroscience is bringing us hope and at the same time it is bringing challenges. As scientific advances are made, we will need to consider how we will keep information confidential and ensure each child's safety. Teaching is a moral profession, and we must not forget the unintended consequences some treatments bring. Invasive interventions can make active, boisterous, inquisitive children passive so they fit in our classrooms, but they can also alter brain chemistry and rob children of their identities and true selves. Children need the correct, least invasive, and most ethical interventions possible, and neuroscientists can provide these, but as teachers we need to be at their sides explaining the consequences and advocating for children. When it comes to applying neuroscience to our classrooms, we must constantly consider what is right, wrong, good, just, and unfair.

It is an exciting time to be an educator because of the scientific breakthroughs being made, but we need to proceed with open eyes. If we are optimistic and cautious, informed, active, and advocate for reasoned policies, the children in our care will benefit, flourish, and grow into healthy, happy, human beings.

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