

# **A Guide to Neuroeducation For Teachers**

- **Teaching the next generation about neuroscience**
  - **Applications of brain research to education**
  - **Resources for learning about the brain**

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## Forward

Welcome to neuroeducation!

While teaching science to high school students in 2001, I noticed that there was little information about brain function in the life science workbook students were using. Catalyzed by my own curiosity to enter into a study of the brain, I discovered many facets of the fields of neuroscience pertaining to health, development, and learning that I thought would be of value to educators. I believe that educators can use available knowledge in neuroscience to *mitigate* brain-related difficulties for students with learning and behavior disabilities by applying advances in research, not simply *manage* them, particularly in special education classrooms.

I became increasingly interested in how information about neuroscience was reaching teachers, school communities, students, and families: and how important it is for the public to be aware of this information. Industry--- from the mall to the military--- already applies neuroscience to our daily lives as consumers. Teachers and students need to be educated so we too can benefit from research and future breakthroughs that affect us as learners.

In 2004 I completed a Certificate program at the University of Washington Extension called “Brain Research in Education.” That was the gateway to further study at Saybrook University. As I delved further into psychophysiology and learned about neurofeedback, it seemed even more important that educators look into emerging strategies for the improvement of brain function itself. This guide contains excerpts from my dissertation, *APPLICATIONS OF NEUROSCIENCE TO EDUCATION AMONG ELEMENTARY AND MIDDLE SCHOOLS TEACHERS: A MIXED-METHOD EXPLORATION*. ---Doris Brevoort

## Table of Contents

1) Neuroeducation—From Research to Practice.....	1
The Timeliness of this Study.....	2
Purpose of this Guide.....	5
2) Sources of Information on Neuroscience for Educators.....	5
Learning about Neuroeducation via Specific Areas of Interest .....	8
Learning about Neuroscience through Structured Opportunities.....	12
3) Applications of Neuroscience to Education.....	13
The Arts and Learning .....	19
Curriculum Choices .....	20
Intervention for Students Who Have Difficulty in Learning or Behavior .....	22
Intervention for Attention Deficit Hyperactivity Disorder (ADHD) .....	25
Neurofeedback for ADHD .....	26
Intervention for Students with Autism Spectrum Disorders .....	34
Curriculum Presentation.....	36
4) The Study in a Nutshell.....	38
Results.....	39
Case Studies of five educators.....	50
Common Themes in Case Studies .....	50
5) Significance of This Study .....	54
Recommendations.....	56
References .....	60
Acknowledgements.....	69

## Tables

Table 1: Brain wave frequencies .....	9
Table 2 Educators' Background in Science or Science Education .....	40
Table 3: Educators' Sources of Information on Neuroscience.....	41
Table 4: Strategies Used in the Classroom or Working with Students .....	43
Table 5: How Often Educators Report Using Music at School .....	43
Table 6: Conditions under which Educators Desire to Change Instruction.....	45
Table 7: Potential Activities to Learn About Current Brain Function and Research .....	47
Table 8: Educators' Level of Familiarity with Neuroscientific Terms.....	48
Table 9: Summary of Characteristics of the Five Case Studies .....	53

# 1) Neuroeducation—From Research to Practice

Educational neuroscience, also called *neuroeducation*, *cognitive neuroscience*, and *mind, brain, and education science*, refers to a mutual collaboration between educators and neuroscience researchers to use elements of each discipline to influence and improve both the education of children and neuroscientific research.

In the May, 2009 edition of the Dana Foundation’s free monthly tabloid, *Brain in the News*, Contributing Editor Guy McKhann (2009) reported on a collaborative meeting of over two hundred neuroscientists and educators at Johns Hopkins University in Baltimore called “Learning, Arts, and the Brain”:

As a neurologist I have watched the expansion of my title’s prefix. First came the surgeons: neurosurgeons. Then we saw an overlap with psychiatry: neuropsychiatry. Then, along came a whole field: neuroscience. Now the flood gates have really opened: neuroethics, neuroeconomics and, most recently, neuroeducation. (p. 3)

McKhann finished his column with a comment by Harvard University psychologist and researcher Elizabeth Spelke that “what’s needed is a new type of transition person who can bridge the education and cognitive neuroscience fields” (p.3).

In 2010, British neuroscientist Usha Goswami, director of the Centre for Neuroscience in Education at the University of Cambridge, and others from a 23- person Task Force on the Future of Educational Neuroscience issued a report, *The Future of Educational Neuroscience*, on integrating neuroscientific research into the “brain and genetic bases of learning and teaching” with educational practice (Fischer, Goswami, & Geake, 2010, p. 68). The task force noted that “educational neuroscience provides an opportunity...to create research grounding for learning and teaching” (Fischer et al., 2010, p. 69).

The Task Force suggested that a next step in developing the field is creation of research schools: public and private schools (for children) affiliated with universities where educators and researchers collaborate in studying educational practice and policy. These can also serve as training opportunities for future teachers and researchers. (Fischer et al., 2010).

Goswami initiated this discussion in her essay, “Neuroscience and education: From research to practice?” (Goswami, 2006). Through collaboration, educators and neuroscientists can identify and dispel what Goswami calls *neuromyths*, i.e., statements about learning or brain function that are too broad or simplistic to be scientifically accurate, but are adopted by the public or partially-informed educators through media and marketing. It is most useful for educators to become sufficiently informed in neuroscience, she says, so they can weigh research results responsibly. They may then appreciate neuroscience for the springboard it contributes to pedagogy, without naively being drawn in by buzz words or appealing but superficial assumptions.

Tenets of the relationship between neuroscience, psychology, and education identified by an international panel of educators and scientists polled in 2008 are outlined by Tracey Tokuhama-Espinosa (2010) in her book, *The New Science of Teaching and Learning: Using the Best of Mind, Brain, and Education Science in the Classroom*. She suggested *Mind, Brain and Education Science* (MBE) as a responsible title for this new field.

### **The Timeliness of this Study**

The emerging field of neuroeducation has an avid following including neuroscientists and educators from around the world. In recent years, whole issues of professional education journals such as *Educational Philosophy and Theory* (from the Philosophy of Education

Society of Australasia) have been devoted to this collaboration (Patten & Campbell, 2011). This growth is largely due to the advancement of functional Magnetic Resonance Imaging (fMRI) and other computer-based technologies. A study from Great Britain found teachers to have a “high level of enthusiasm for attempts to interrelate neuroscience and education” (Pickering & Howard-Jones, 2007, p. 109).

Some educators have little exposure to neuroscience and are not as aware of the breadth of research that has emerged in the past decade. There are books, websites, and training opportunities available for teachers, largely on their own time and at their own expense. Further study of teachers’ training and priorities involving neuroeducation are called for to expand the dialogue among educators as to how this information can be applied to serve children and families. Exchanges of experience between educators and neuroscientists can guide future research in directions that educators deem useful to their day-to-day work teaching children, and vice versa (Hardiman & Deckla, 2009).

Applications of neuroscience have evolved in the past twenty years from exploratory science to a repertoire of strategies that have been picked up by business, marketing, and media— from shopping malls (Ariely & Berns, 2010) to the military (Moreno, 2006). Awareness of this trend may prompt educators to address the role of neuroscience in the lives of their students. Children and families increasingly need exposure to and understanding of their own brain function so they can recognize the effects of such strategies as *neuromarketing* on their choices and spending (Dooley, 2012).

Another application of neuroscience is to behaviors stemming from neurological disorders and mental illness. Treatments are being developed and implemented, both *indirect* using fMRI and brainwave training and *direct* treatments that stimulate the brain itself. These illustrate the potential for future collaboration between medicine, technology, and

neuroscience (Horstman, 2010). A direct treatment called Deep Brain Stimulation (DBS) is used to lessen the effects of Parkinson's disease and epilepsy. An application of DBS, in early stages of implementation, involves the implantation of tiny electrodes into a specific location in the brain; the electrodes deliver electrical signals shown to relieve depression in cases where the depression has not responded to other treatment modalities (Mayberg, 2010).

Implementation of *brain-machine interface* (BMI) technology is progressing from research with rodents and primates to applications for human patients in rehabilitation for such conditions as stroke, spinal cord injury, and Amyotrophic lateral sclerosis (ALS).

*Neuroprosthetics* are physical aids to body function using neuroscientific applications. One example is the use of retinal transplants to aid sight. These work through application of a technology called optogenetics, for example, infusing retinal receptor cells with light-sensitive DNA found in green algae that triggers the cells to respond to visual information when stimulated by light. Another example is the improved design of cochlear implants used to aid persons with hearing impairment, applying scientific advances in understanding how the cochlea and brain interpret sound (Nicolelis, 2010).

As industry and medical applications of neuroscience expand in the future, children and their families will benefit from improved and yet uncharted brain-related interventions. Education is a primary vehicle for today's children to begin preparing to incorporate applications of neuroscience into health, society, and career planning. Children and youth will have increasing motivation to pursue a wide range of careers in neuroscience.

In view of the growing interest in neuroscience, it is good for educators and scientists alike to keep in mind that the brain is still simply one organ of the body, functioning in the context of the whole organism, the whole child. While it has unique faculties in the performance of executive function, memory, and perception—and the connectivity that

integrates and binds these faculties—it is synergistically interdependent with all the other systems, including respiration, circulation, and elimination. No child’s learning or other activity takes place without the body in its surrounding environment, with all the accompanying considerations, e.g., nutrition, rest, stimulation, and love.

### **Purpose of this Guide**

The purpose of this guide is to offer a concise view of neuroeducation to educators. It summarizes a study done in 2010-2011 with a group of elementary and middle school educators, exploring their training regarding brain function and neuroscience. Questions were asked related to the educators’ application of this knowledge in their work with children, and their receptiveness to further training.

Towards the end of this guide you may read the recommendations from the research. A number of them are directed to educators and educational institutions, including the suggestion that a semester of brain science be added to teacher certification programs. That would be a proactive way to inform the next generation of educators so *they themselves* will be able to read and understand neuroscientific literature, discover *additional* benefits of applying neuroscience to education, and *teach the next generation of children about the brain*.

## **2) Sources of Information for Educators**

Educators who want to know more about brain function or related research can pursue neuroscience independently or through a variety of structured programs and opportunities. They may learn independently in many ways including reading books, periodicals, websites, watching TV shows or DVD’s, taking a class or seminar, or attending a national conference geared to the application of neuroscience to education.

Some educators began following the literature regarding the brain 20 years ago. Research about learning was brought to the mainstream in the 1990's when President George H.W. Bush proclaimed 1990-1999 as "The Decade of the Brain" (Bush, 1990). Robert Sylwester, now professor emeritus at the University of Oregon, published *A Celebration of Neurons: An Educator's Guide to the Human Brain* (Sylwester, 1995). This book included a glossary of terms and illustrations accessible to the teacher just beginning to explore the science of the brain. Eric Jensen published *Teaching with the Brain in Mind* in 1998, reaching out to educators to encourage them to explore the relationship between the brain and the classroom. Jensen continues to offer trainings for educators through his website, [www.jensenlearning.com](http://www.jensenlearning.com) (Jensen, 2012).

Other authors publishing for an education audience in the 1990's included Howard Gardner of Harvard University School of Education, who wrote *Multiple Intelligences: Theory into Practice* (1993) and a number of other books on the learning process. Geoffrey Caine, Renate Caine, and Sam Crowell, wrote *Mind Shifts: A Brain-compatible Process for Professional Development and the Renewal of Education* (1993), encouraging school administrators to bring practices informed by contemporary neuroscience into their schools and classrooms.

Research and discovery regarding the brain's capacities generated literature including the anthology edited by Geraldine Dawson and Kurt Fischer, *Human Behavior and the Developing Brain* (1994). Kurt Fischer went on to spearhead a concentration in neuroscience at Harvard School of Education, now called Mind, Brain, and Education. He was instrumental in founding the International Mind, Brain, and Education Society in 2004 ([www.imbes.org](http://www.imbes.org)). This society began publishing the journal *Mind, Brain and Education* with seminal articles relating neuroscience to education, in 2007.

In 2008, Fischer and colleagues published an anthology of commentaries called *The Educated Brain: Essays in Neuroeducation*, which synthesized thinking on mind, brain and education into a field of pursuit (Battro, Fischer, & Lena, 2008). This valuable collection of commentaries by academic leaders is an expanded version of papers presented at a convocation of the Pontifical Academy of Sciences in Rome, Italy, in November, 2003. It includes such topics as applications of brain plasticity in education (Singer, 2008), biological clock and circadian rhythms (Cardinali, 2007), cycles of cognitive and brain development (Fischer, 2008), and neurodevelopment related to humans' ability to read and do arithmetic (Dehaene, 2008).

Kurt Fischer co-edited a second volume extending the scope of *The Educated Brain* entitled *Mind, Brain and Education in Reading Disorders* (a volume in the series *Cambridge Studies in Cognitive and Perceptual Development* (Fischer, Bernstein, & Immordino-Yang, 2007). It is an indication of advances in the field of neuroscience applied to education that books from the 1990's have been re-issued with updates in new editions. For example, the first edition of *Human Behavior and the Developing Brain* (Dawson & Fischer, 1994) has been revised into a second version in two volumes: *Human Behavior, Learning, and the Developing Brain: Typical Development* (Coch, Fischer, & Dawson, 2007), and *Human Behavior, Learning, and the Developing Brain: Atypical Development* (Coch et al., 2007), which delves into some prospective origins of autism and dyslexia.

Anticipating a need for textbooks as college and graduate programs offer neuroscience applied to education, *The Jossey Bass Reader on the Brain and Learning* (Jossey Bass, 2008) incorporates selections from numerous educators and researchers into an overview of the budding field of neuroeducation.

## Learning about Neuroeducation via Specific Areas of Interest

There are multiple avenues by which interested teachers may find connections in approaching neuroscience:

The first avenue is the anatomy, physiology, and function of the brain itself. Coloring books such as *The Human Brain Coloring Book* (Diamond, Scheibel, & Elson, 1985) and *A Colorful Introduction to the Brain* (Pinel & Edwards, 2007) can be used to learn about the brain using a visual and kinetic approach: the reader (now artist!) colors coded pictures of the brain and nervous system while studying accompanying details. This mode of learning is appealing to youth and can be used to teach middle or high school students about neuroanatomy. Rita Carter's book *Mapping the Mind* (Carter, 2010) describes the brain using color illustrations and clear, detailed explanation. Her book, *The Human Brain Book* (Carter, 2009), is another colorful explication of brain structure and function; it comes with a DVD, adding another dimension of visual learning to the text.

For people who learn best with a concrete anchor to their subject, **studying the brain itself first through pictures—or touching models of the brain or neurons**—may help to make this seemingly mysterious organ hidden beneath the skull more tangible and accessible. There is a brain model tutorial showing photographs and diagrams of brain anatomy online at <http://pegasus.cc.ucf.edu/~Brainmdl/brain.html>. This site was created as a teaching aid by a professor at the University of Central Florida (Darty, 1996).

Educators and their students will find interactive, illustrated approaches to brain structure and function online. One is the website *Neuroscience for Kids*, created by Dr. Eric Chudler of the University of Washington <http://faculty.washington.edu/chudler>. *Neuroscience for Kids* offers games, quizzes, downloadable pictures of the brain for coloring, calendars, jigsaw puzzles to assemble online. It provides activities teachers can

adapt for classroom warm-ups or sequentially to introduce students to brain structure and function. There are fun suggestions for making brain and neuron models, of paper or clay, at the “Modeling the Brain” section of the website.

Other websites include *NERVE (Neuroscience education resources virtual encycloportal)* at <http://www.ndgo.net/sfn/nerve/>, The Dana Foundation ([www.dana.org](http://www.dana.org)), and the Society for Neuroscience ([www.Sfn.org](http://www.Sfn.org)). The Society for Neuroscience offers a downloadable primer on brain function, *Brain Facts*, and has collaborated with private foundations to launch **www.brainfacts.org** as a public information source on advances in brain research that includes teaching tools for educators (Future Science, 2012).

**The history of investigation into brain function** is another fascinating avenue into the study of neuroscience. This will reach people who appreciate the historic contexts that have set the stage for discoveries of the nervous system: the speed that a frog leg nerve responds with a twitch to electric stimulation (1850), a neuron cell better seen with a stain applied (1873), or monkeys’ brains stimulated by their mirror neurons’ response to a researcher eating an ice cream cone after lunch (1990’s). Detailed accounts of the history of neuroscience and its place in medicine include *Soul Made Flesh: The Discovery of the Brain and How it Changed the World* (Zimmer, 2005), *Origins of Neuroscience: A History of Explorations into Brain Function* (Finger, 1994/2001), *Minds behind the Brain: A History of the Pioneers and Their Discoveries* (Finger, 2004).

Any teacher who fears that neuroscience is too dry to keep students’ attention must try one of these books about the curiosity and dedication of early investigators of human anatomy, some of whom were bold enough to exhume bodies from cemeteries in order to retrieve them for study (Finger, 1994/ 2001)! And if the reader has not yet been satisfied, there is Brian Burrell’s *Postcards from the Brain Museum: The Improbable Search for*

*Meaning in the Matter of Famous Minds* (2005) about the study and collection of prominent peoples' brains in the 19<sup>th</sup> Century. The history of neuroscience brings home the excitement people felt through the ages as they discovered, little by little, the very processes by which humans can feel and understand themselves.

Another entry point to study of the brain is through the **stages of brain development from conception through childhood** as depicted by Lise Eliot in *What's Going On in There? How the Brain and Mind Develop in the First Five Years of Life* (1999). Eliot is a neuroscientist who uses the birth and growth of her daughter as a springboard for her book on brain growth *in utero*, from differentiation of sensory systems, pruning and neuroplasticity in the newborn brain, through language acquisition and mobility of the toddler. The warm, humanistic presentation of this book will engage teachers and parents who can relate to Dr. Eliot's story as a mother as well as scientist.

Yet another book in this vein is *Bright from the Start: The Simple, Science-Backed Way to Nurture Your Child's Developing Mind from Birth to Age 3* (2007) by Jill Stamm, a professor of education at Arizona State University and co-founder of the New Directions Institute for Infant Brain Development. This explanation of child development uses examples gleaned from Stamm's experience observing and caring for her own daughter who was born prematurely. It is built on the framework of three needs: attention, bonding, and communication, as the basis for health and function in children. Marian Diamond, one of the authors of *The Human Brain Coloring Book*, wrote *Magic Trees of the Mind: How to Nurture Your Child's Intelligence, Creativity, and Healthy Emotions from Birth through Adolescence* with Janet Hopson (1998). For parents, and those who love children and the miracle of growth, this path reviews a very personal journey that each human embarks upon—from embryo, to child, to a thinking, communicating adult.

Patricia Kuhl, co-director with her husband Andrew Metkoff of the University of Washington's Institute for Learning and Brain Sciences gives a chronology of research on child **language acquisition** on the Institute's website <http://ilabs.uw.edu> in a format that is a hybrid of bibliography and explication (Kuhl, n.d.).

Moving beyond childhood, contemporary authors are looking at neural function as the basis for **adult awareness of body movement and presence in our own space**. *The Body Has a Mind of Its Own: How Body Maps in Your Brain Help You Do (Almost) Everything Better* (Blakeslee & Blakeslee, 2007) uses a variety of body "maps" and patterns to introduce neural functioning in an accessible narrative. Another book that invites the reader to learn more about brain function is *Mirroring People: The New Science of How We Connect with Others* (Iacoboni, 2008). Iacoboni elaborates on the discovery of the brain's *mirror neuron* system at a laboratory in Italy, when primates were observed imitating researchers eating ice cream cones as they returned to their lab after going out to lunch. Beginning in infancy, humans physically imitate (mirror) things they see other people doing. On a subtle micro-muscular level, humans perform movements they see others enacting, particularly when they can relate to the performer's intention in the movement. It may be of particular interest to educators to learn about the nature of children's mirroring of adults and peers, and how mirroring is involved with children's learning. Iacoboni discussed some current observations regarding mirror neurons and children with autism, noting emerging theories on how autism may be related to a deficit in mirror neuron function.

## **Learning about Neuroeducation through Structured Opportunities**

In addition to learning about brain function independently, there are many structured opportunities to study this field: Conferences are offered for educators and researchers several times a year on the east and west coasts called “Learning and the Brain.”

**Annual meetings** of professional groups such as the Society for Neuroscience, the International Neuroethics Society, the Association for Applied Psychophysiology and Biofeedback (AAPB), and the International Society for Neurofeedback Research (ISNR) provide opportunities for neuroscientists, educators, and related professionals to meet in major cities. The Society for Neuroscience, with over 42,000 members, is the largest organization for neuroscience professionals in the United States. Its 2010 Annual Meeting in San Diego hosted some 30,000 participants with a wide range of presenters including researchers such as Stanislas Dehaene, author of *Reading in the Brain* (2009) and *The Number Sense* (1997), and Helen Mayberg, keynote speaker on her work with deep brain stimulation (Mayberg, 2010).

**Independent trainers** offer seminars, typically advertised on the trainers’ own websites (Jenson, 2012; Willis, 2010). Degree programs and seminars with emphasis on neuroscience and education are offered at such schools as Columbia University, Harvard University, Johns Hopkins University, and University of Pennsylvania. George Washington University offers a degree in neuroscience applied to special education. Some institutions may offer certificates such as the University of Washington Extension’s “Brain Research in Education” (offered from 2002-2005). Professional development for teachers in the Seattle area is available through Puget Sound Educational Service District # 121 in the form of a series of on-line classes including “The Brain: Memory and Learning Strategies,” “Developing Lifelong Learning Habits,” and “Understanding the Physical Brain” (*One to One*, 2011).

### 3) Applications of Neuroscience to Education

One focus of this research study has been how educators apply their knowledge of brain function in their classroom teaching or related work with students. In order to *apply* current knowledge, in regard to this question, educators must be *informed* about the development of a range of applications being researched and implemented in the field: Computer-related technologies have been springboards to the development of applications of neuroscience to education in the last two decades, particularly functional magnetic resonance imaging, called fMRI (Haier, 2009; Jung & Haier, 2007; Varma, McCandliss, & Schwartz, 2008). It is useful to subdivide the field into several general strands:

**The first strand is research on how particular strategies in teaching and educational psychology (e.g. music, the arts, a phonological approach to reading instruction) affect such processes as learning, attention, and memory for typically-abled children** (Posner & Patoine, 2009).

The act of **reading**, fluently and with comprehension, is one of the most essential elements of children's education, both because it is the gateway to literature and because achievement in other academic areas is dependent upon it. In the past two decades research has explored how children commonly learn to hear the sounds of language, relate them to symbols of the alphabet, read words, and comprehend ideas in writing. Learning abilities and disabilities in reading, writing, and mathematics are interrelated, as reading is intertwined with all these skills.

One example of how neuroscience relates to the learning experience of children is the basic developmental process of **myelination of axons**. In myelination, the axons of brain cells in the cortex or thinking brain are gradually covered by a sheath of lipid called myelin, from

glial cells that wrap around the axon, providing insulation for electronic pulses called *action potentials* that travel along the axons. Myelination is programmed by a child's genes, happening in the temporal and parietal lobes of the brain earlier in development than in frontal lobes (Berninger & Richards, 2002).

At puberty there is a growth spurt of neurons in the brain, followed by a time of "pruning" where some cells flourish and some die off. During this time, myelination increases in the frontal lobes; this process continues through the adolescent years and into the early 20's (Brain Briefings, 2007). The young adult brain continues maturing up to the age of 25 years old. Myelination provides a 100-fold increase in transmission of action potentials along axons and between neurons; the **executive function of the frontal lobe increases as myelination proceeds through the teen years** (Koizumi, 2007). Realizing that there is a physiological maturation (myelination) of the brain during the teen and young adult years helps to explain the immaturity of executive decision-making during puberty and gives a context to the maturity of executive function as a youth grows into adulthood (Nagy, Westerberg, & Klingberg 2004).

Educators do not expect middle school children to have the executive decision-making skills of an adult—their brains have not fully grown (myelinated) into this ability. University of Oregon Professor Emeritus (and neuroeducator) Robert Sylwester has written a book for families and educators entitled *The Adolescent Brain: Reaching for Autonomy* (2007) that discusses the brain and emotional maturation of adolescents in some detail. Sylwester discusses the need for adolescents to stretch not only their wings but their developing brain function as well. Taking risks is a predictable pattern for adolescents, Sylwester explains, as their executive functions are still maturing but their limbic system-based emotions are fully functioning. The **amygdala** in the brain "adds positive and negative emotional content to the

memory of an experience for use in subsequent similar situation, thus playing an important role in the consolidation of long-term memories” (Sylwester, 2007, p.90). There are two amygdalae, one in each hemisphere of the brain, but they are commonly referred to as “the amygdala,” named after the Greek word for “almond,” the general shape of the structures.

Sylwester continues to describe that the cingulate, an area with connections to the prefrontal cortex (and other brain systems), matures during adolescent years. This is important to maturation of a youth’s decision-making because the cingulate

determines the emotional importance (from mere awareness to intense pain) of sensory information sent from the amygdala...coordinates the retrieval and analysis of memories of similar challenges or the development of creative alternative responses and transmits this information to the prefrontal cortex for conscious decision and action. (Sylwester, 2007 p. 90)

As the cingulate and other executive functions mature (including axon myelination) a youth is more able to weigh feelings and memories; he or she acts not as much to exercise autonomy but with increased ability to make plans and decisions based on experience and memory.

**A second strand of neuroscientific research is on specific developmental conditions related to brain function in children such as dyslexia and autism** which hinder educational progress for affected children (Mehta, 2009). Neuroscientists seek genetic or biochemical markers that will lead to early detection and treatment for these conditions. Developmental issues including genetics, missteps in prenatal brain construction, and cortical connectivity are addressed in a collection of essays entitled *Mind, Brain, and Education in Reading Disorders* (Fischer et al., 2007).

**A third strand of research is the design of interventions** engineered using computer technology, by implanting small computerized chips or similar devices into the brain itself, or by brain-machine interfaces (BMI). A book by Miguel Nicolelis (2011) of Duke University came out in 2011 explaining BMI: *Beyond Boundaries: The new neuroscience of connecting*

*brains with machines---and how it will change our lives.* BMI are devices that convert thought processes of the brain to motor or sensory input that drives a response (e.g., hearing, seeing, movement) in lieu of the natural system of neurons that would typically govern that motion or sense. Examples of BMI include neuroprosthetics, in other words, replacements for injured or compromised motor or sensory systems governed by the brain that help people *hear* through cochlear implants, and *see* using retinal implants. Neuroprosthetics are also being designed, for example, to *generate movement* in limbs that have lost function due to stroke and to *regulate* brains prone to epileptic seizures.

One ambitious goal of researchers including Nicolelis is the *Walk Again Project*, based at Duke University in Durham, North Carolina. Researchers are working on tools to **restore mobility to people with paralysis**, for example, due to spinal cord injury, using a full-body prosthesis: electrodes implanted in the brain transmit the brain's directions to a computer that follow these directions, bypassing the injured spinal cord to guide the prosthetic body suit in driving movement (Nicolelis, 2011). Restoring function for children with hearing or visual impairments, physical injuries or developmental disabilities through use of BMI will greatly affect their educational, vocational, and social opportunities.

**A fourth strand is the application of research to the planning and design of educational programs.** One example is the *school district-wide scheduling of schools' start and ending hours*. While scheduling decisions are often made to fit transportation budgets or other logistical demands, there is wisdom in taking into consideration the **Circadian rhythms** of teenage brains---typically more attuned to going to bed later, and sleeping later in the morning, than the early start time some high schools require (Cardinali, 2007; Owens, Belon, & Moss, 2010).

Scheduling hours for classes may seem simple—shouldn't every high school student be up at dawn every morning, hale and cheery and ready to come to school? Not necessarily in the case of adolescents, whose circadian rhythm tells a different story:

The human body has a biological pattern over 24 hours called *circadian rhythm* that determines its preferred sleep and wake cycle. The suprachiasmatic nuclei of the hypothalamus, in the midbrain, acts as a timer to adjust hormones such as melatonin associated with body temperature and the sleep/wake cycle. In adolescents, the timing of sleeping and waking shifts “toward a more owl-like tendency for later bedtimes and wake-up times” (Cardinali, 2007, p.121). Combined with factors that lead to later bed times such as socializing, evening employment, homework, television or computer use at night, many youth stay up past 11 PM. After puberty the body physiologically feels more awake until late hours of the night, but still needs approximately 9.25 hours of sleep. The effect of early start time (before 8 AM) for high school is that students average about 7 hours of sleep on school nights, resulting in drowsiness and reduced attention. Youth are suffering from what may essentially be sleep deprivation.

While parents in individual households might urge their children to go to bed earlier so they ostensibly will be ready to get up in the morning, this does not match the circadian rhythm of the youth's body. A recent study of 201 high school students (grades 9-12) in Rhode Island indicated that **a delay of a half-hour in the opening of school**, from 8:00 to 8:30 AM, resulted in improved alertness, mood, and health on the part of students (Owens et al., 2010). The National Sleep Foundation has detailed, reader-friendly information on youth sleep patterns related to school start times on its website, including results of research on school start times in Massachusetts and Minnesota and a study in Kentucky on driving safety. The Kentucky study found that when school start time was

moved from 7:30 to 8:30 AM in 1988, auto collision rates for teens were reduced in the surrounding county for youths 16-18.

Obviously, moving bell times is one major step in a larger picture of ensuring that adolescents get the sleep they need....it is important for teens to know about their sleep needs and have the skills to make a conscious effort to get a good night's sleep. (National Sleep Foundation, n.d. Collaborating in the Best Interests of Students section, para. 3)

Besides alertness and improved mood, **memory consolidation** is another critical benefit of sleep. Though the mechanisms that cause the brain to process information during sleep are not completely understood, research shows that the brain is actively engaged during the sleep cycle in "sleep-dependent memory processing" (Walker & Stickgold, 2004, p. 121).

Other school program design that would be influenced by applying knowledge of brain function in decision-making includes assuring that children get **enough exercise** during the school day to promote physical and neural health: The brain comprises about 3% of the body's mass, but uses 20% of the body's oxygen supply, increasing when the brain is engaged in more active processing. The brain needs sufficient oxygen to function well. Research has shown that more oxygen supplied to the brain results in improved cognitive performance: A Korean study using fMRI demonstrated improved performance on a visual-spatial task when increased oxygen supply was administered to the brain (30%, compared to the 21% found in regular air) (Chong, Iwaki, Tack, Yi, & Lee, 2004).

Children of all ages, including secondary school, benefit from regular opportunities for exercise (Sousa, 2006). Elementary school children benefit from recess as a time to move; older children who no longer have recess time at school must get exercise from physical education class (if it is in their schedule), moving between classes (often in a rush, which does not comprise refreshing physical exercise for body and brain), or a half-hour lunch period

which allows only enough time for a brief walk or shooting some baskets in the gym before the bell rings for the next class—if students are motivated to use the time for exercise.

With greater awareness on the part of teachers and administration about brain health, elements of school design such as scheduling and opportunities for active movement may be discussed more widely in future planning. School design affects both teachers and students, as brain health pertains to people of all ages.

### **The Arts and Learning**

**A fifth strand of neuroeducation may inform decisions on prioritizing funding for programs such as arts and music in schools.** The Dana Foundation, a philanthropic consortium of neuroscientists, sponsored a three-year study culminating in the publication of *Learning, Arts, and the Brain: The Dana Consortium Report on Arts and Cognition* (Gazzaniga, 2008). This report contains articles on the relationship between arts training and cognition, including benefits of the inclusion of music, dance, and arts in education.

The August 14, 2010 issue of *Science News* has a feature section on music and the brain called “A Mind for Music.” Included are articles on mothers’ relationships with their babies through musical vocalizations that babies follow called “communicative musicality” (Bower, 2010, p. 18) and the role of music in evoking emotions such as pleasure and reward, working to abate fear and reduce stress (Gaidos, 2010, p. 24). The series features an article dedicated to the benefits of music instruction for children: “*Music of the Hemispheres: Playing Instruments Gives Brains a Boost*” (Ehrenberg, 2010, p. 30). According to Laurel Trainor, Director of the Auditory Development Lab and McMaster Institute for Music and the Mind at McMaster University in Ontario, Canada, there is no one area of the brain that processes music—music engages the brain rather as a whole.

**Studying and playing an instrument generates improvement in *control processes*** such as memory, fine motor skill, and attention. Neuroscientists from Harvard University have researched the areas of the brain that process music and language. These overlap, suggesting that musical training could help children who have difficulty with language processing ( Schlaug et al., 2005). Learning to play an instrument has benefit beyond simply listening to music. A study of six-year olds given weekly lessons on keyboard for fifteen months found that these children had improved movement control over children who were in a weekly music class without learning to play an instrument (Schlaug, Norton, Overy, & Winner, 2005).

For teachers who are musically inclined, it may seem apparent that singing, playing music, or dancing in the classroom adds a dimension of fun, emotion, and engagement to the lesson. Using fMRI, neuroscientists are beginning to piece together reasons behind human perception of this dimension (Howard-Jones, 2005).

### **Curriculum Choices**

Educators involved with curriculum choices such as teaching methods apply **a sixth strand of research regarding the way the brain processes learning of subjects such as reading and mathematics** (Dehaene, 1997, 2009; Wolf, 2007). Three neuroscience educators assessed scientific and pragmatic concerns in the field of educational neuroscience, articulating opportunities for collaboration in their article, “*Scientific and Pragmatic Challenges for Bridging Education and Neuroscience*” (Varma et al., 2008). They discussed the role of neuroimaging with fMRI to gather data about brain function and gave examples of how research illuminates the process of learning.

One study they report on is of children ages 8 to 19 **solving simple arithmetic** problems. Speed in solving problems increases with the age of the child. They found that this

increase in speed was not due to increased efficiency of the same brain areas engaged in the function over time, but that **neural functioning shifted with age from the prefrontal cortex**, in other words, using general memory and reasoning, **to visual and verbal areas** in the left parietal and temporal cortex: a shift from *domain-general to domain specific processing*. While the authors did not identify an immediate application to the classroom, “This study raises the possibility of designing activities that help children to shift from domain-general to domain-specific modes of thought,” (Varma et al., 2008, p. 144) that would require less dependence on memory and the brain’s attention resources (Rivera, Reiss, Echkert, & Menon, 2005).

Another study examined how the brain computes mathematics by observing (via fMRI) the difference in processing for the adult subjects studied while solving single-digit multiplication and subtraction facts. **To multiply, the brain involves networks common to verbal processing**, including the angular gyrus in the left parietal lobe. This is “consistent with retrieval of verbally coded multiplication facts—a fast strategy” (Varma et al., 2008, p. 145). **To subtract, the brain uses a different network in bilateral parietal lobes associated with visual and spatial processing—an internally visualized number line of sorts—that takes more time** (Dehaene, Piazza, Pinel, & Cohen, 2003).

While this research is more exploratory than definitive, it opens an opportunity for neuroscientists and educators to collaborate to “investigate whether this strategic difference is a consequence of the different ways that the operations are taught and practiced” (Varma et al., 2008, p.145). The brain function appears to reflect the method adults likely used when they learned to perform these arithmetic functions as children— **by memorizing multiplication tables verbally, and by linear drawing and counting numbers in sequence to subtract**. This knowledge may inform future mathematics teaching practice as we understand

more about how the brain trains itself according to patterns of function practiced when learning basic skills.

### **Intervention for Students Who have Difficulty in Learning or Behavior**

**A seventh strand of research investigates the needs of students who have disabilities in learning and performing tasks in reading, writing, or mathematics.**

Disability in reading is called *dyslexia* (Berninger & Wolf, 2009; Wolf, 2007; Wolf et al., 2002). Disability in writing is called *dysgraphia* and disability in learning mathematics, *discalculia* (Dehaene, 1997; Berninger & Richards, 2002). The research contributed to development of interventions to address these difficulties.

**Developmental issues including genetics, missteps in prenatal brain construction, and cortical connectivity** are addressed in a collection of essays entitled *Mind, Brain, and Education in Reading Disorders* (Fischer et al., 2007).

Research identifies core skills of reading that underlie more complex reading tasks. These skills have been outlined sequentially in detail by Virginia Berninger of the University of Washington (Berninger & Wolf, 2009). First is *aural recognition of phonemes* (basic building blocks of sound, such as the letter names) from speech and connecting them to visual letter symbols. Phonemes, their sounds and symbols, must be mastered before other steps on the ladder of reading skill can be successful. *Phonemic symbols combine into words*, which the brain begins *recognizing together as sentences*. The brain then learns to *construe these sentences as meaning* and builds the ability to comprehend sentences together and retain information. French researcher Stanislas Dehaene (2009) conducted fMRI studies that show that a brain network located in the left lateral occipito-temporal sulcus area (which Dehaene

calls *the brain's letterbox*) recognizes written words and processes their meaning or sends on the recognized word to further networks for comprehension.

[In this discussion the author uses phrases such as *the brain begins recognizing* or *the brain then learns* to indicate a process of connection or change taking place in the brain.

While scientists and educators may use this convenient phrasing, it is pertinent to note that the brain is *not* an actor itself, as if isolated or anthropomorphized. The brain acts interdependently with all the body's systems; it is the *person* who learns, not the brain.]

Maryanne Wolf is a reading professor at Tufts University who has studied reading and dyslexia and written prolifically for over 20 years. Wolf wrote *Proust and the Squid: The Story and Science of the Reading Brain* (Wolf, 2007), which is anchored in science while highly readable for educators. The squid is introduced because its very long, large central neuron has been studied by neuroscientists to discover how neurons work; Proust because of his eloquent descriptions of his love for reading. Wolf suggested that reading did not develop as naturally as speech did for early humans. She explained that reading is a skill that humans invented a couple thousand years ago; it uses very complex brain processes that must all fit together smoothly for words on a page to become ideas in a mind's eye.

Wolf's research into the causes of dyslexia is outlined in her paper regarding what she calls the *second deficit*, naming speed: "The second deficit: An investigation of phonological and naming-speed deficits in developmental dyslexia" (Wolf et al., 2002). In this study, 144 low-achieving readers in 2<sup>nd</sup> and 3<sup>rd</sup> grades were given a battery of reading, intelligence, and achievement tests including the Rapid Automatized Naming (RAN) Test for Letters and the Comprehensive Test of Phonological Processing. The results showed that **there is a relationship between the ability to identify words and the speed with which a child can name the words and comprehend a reading passage.** To support struggling readers, the

research team developed a program called RAVE-O (Retrieval, Automaticity, Vocabulary Elaboration-Orthography). It concentrates on strengthening comprehension through improving automaticity in basic phonological, writing, and semantic skills needed for reading fluency (Wolf et al., 2002). RAVE-O is one example of an intervention program that is based on the progression of steps in reading confirmed by brain research. This is a work of neuroeducation. A neuroeducator who has helped develop curricula, in this instance for children with writing disability, is education psychology professor Virginia Berninger of the University of Washington in Seattle. She articulated an important distinction about writing, that the *pace* of writing is a critical factor in writing fluency:

**Handwriting automaticity**, which is assessed by the number of letters written correctly within a brief time limit, is a strong predictor of the quality of composition in normally developing and disabled writers. If letter production is automatic, memory space is freed up for higher level composing processes, such as deciding what to write about, what to say and how to say it. (Berninger, 1999, Handwriting Automaticity section, para. 1)

Berninger and colleagues developed an assessment tool, the Process Assessment for the Learner (PAL), and an accompanying curriculum, *PAL Guides for Intervention* to teach writing using lower and higher level cognitive and linguistic skills simultaneously in the same lesson. In this model, children engage in composing writing at the same time as they are taught handwriting or spelling (Berninger, 1998). The accompanying curriculum, or Intervention Kit, provides composition starters and a teacher's guide. The concept of this program is based on the brain-function observation that automaticity is a crucial skill if children are to have the *memory space* to compose what they want to write. Berninger and colleague Todd Richards, a radiologist at the University of Washington, wrote a seminal book, *Brain Literacy for Educators and Psychologists* (2002), which introduces educators to the world of the brain accessed by functional magnetic resonating imagery (fMRI) and

explains what fMRI reveals about the areas of the brain associated with basic skills in reading, writing, and math.

### **Intervention for Attention Deficit Hyperactivity Disorder (ADHD)**

Teachers, psychologists, health practitioners, and neuroeducators all seek ways to mitigate the learning and behavioral difficulties that affect students with Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD).<sup>1</sup> Children with ADD have an inconsistent attention span and are easily distracted from academic tasks. They are sometimes quiet in class at school; since they don't generate behavior problems, they may get along suitably in a general education classroom, though their achievement suffers when they do not fully understand or complete academic work. Symptoms of behavioral difficulties such as ADHD include poor impulse control, frequent movement out of a child's seat or work station, talking out in class, and lack of follow-through in task completion.

Focused, personalized attention from parents, classroom teachers, special education teachers and classroom instructional assistants often helps children with ADD and ADHD to stay on track and master enough academic and self-management skills to attend to their assignments so they can, with monitoring, progress sufficiently to stay at grade level in school (Monastra, 2005).

Symptoms of ADD, ADHD, autism spectrum, and other learning and behavioral difficulties are commonly addressed in public schools with special education services.

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<sup>1</sup> The current diagnostic nomenclature of the American Psychiatric Association collapses the two – ADD and ADHD – into one diagnosis, called ADHD, with inattentive, hyperactive, and combined subtypes (American Psychiatric Association, 2000).

Children must qualify for services, a process that may require a diagnosis by a physician (if ADD or ADHD), evaluation by a school psychologist, and consensus of a school's *multidisciplinary team* in communication with parents or guardians. Each student who qualifies for special education services has an Individual Education Plan (IEP), written by a teacher with certification to teach special education. The IEP defines the services that child is to receive at school. (In the questionnaire used in this study, special education teachers are referred to as IEP teachers, as they write these IEP's for each student and act as that student's case manager in the school setting.)

An article written for Project Forum, a division of the United States Office of Special Education Programs, gives "An Overview of Critical Issues" (Muller, 2011, p. 1) bridging neuroscience and special education. The article contains descriptions of three programs where "neuroscience informs programs serving students with disabilities" (Muller, 2011, p. 5). The examples are 1) a comprehensive program for students in grades 2-10 with Asperger's Syndrome, 2) a recovery program for young adults with traumatic brain injury, and 3) a pilot program for students 6-9 years old with a range of disabilities. This program uses software called *BrainWare Safari* (2012) that employs positive feedback to train the brain to improve executive function through games and exercises.

### **Neurofeedback for ADHD**

**Biofeedback** is a treatment modality in which the subject uses an electronic instrument (such as a skin **temperature** thermometer or a gauge of heart rate) to note his or her present physical state. The availability of *feedback enhances awareness of the physiological process, which then facilitates voluntary control*. The subject is given an opportunity to change that physiology intentionally by altering the pace or intensity of some

behavior (such as breathing, relaxing the mind or muscles). When he or she sees a physical change noted on an indicator, this change, or feedback, reinforces success (e.g., warming up the skin temperature or lowering the heart rate by relaxation).

**Neurofeedback** is a term used for **biofeedback applied to brain function**. A treatment strategy for children with ADHD is electroencephalogram (EEG) neurofeedback. This is a neuroscientific research-based intervention that gives the child an opportunity to train his/her brain waves to become regulated more like those of typically-performing children's brains by responding to a computer program that displays information about his/her brain wave patterns. Over time, typically after 20 sessions of neurofeedback (lasting a half hour to 45 minutes, weekly or twice a week) change is found to affect behavior and help a child to be more focused in thinking, with greater capacity for self-discipline and insight into his behavior (Monastra, 2008).

ADHD has potential genetic etiology that has to do with dopamine supply to neurons. Dopamine neurotransmitters facilitate a comfort and reward response in the brain. In some cases of ADHD, the brain is not receiving enough dopamine message because its genes script cells for too little dopamine reception and too much *re-uptake* of dopamine at the synapses, resulting in an improper balance for transmission of adequate dopamine signal. The child's brain responds through hyperactive behavior to compensate for its deficit in dopamine's comfort and reward.

The billions of neurons in the brain communicate with each other through electrical *action potentials* that stimulate a receiving synapse and travel down the axon, stimulating release of neurotransmitters at the next synapse to transfer their message from one neuron to the next. This is happening in the cortex all over the brain—electrical signals communicating in local networks and from one area of the brain to another (an aspect of brain function called

*connectivity*). The thalamus and cortex areas are constantly both generating and processing these electrical potentials. There are rhythms in detectable frequency ranges, or *bands* “related to specific thalamocortical generator mechanisms...that emerge over specific topographic regions of the brain” (Monastra et al., 2005, p.98). The brain is always generating an electrical field that rises and recedes producing a range of waves that can be specifically measured in frequency and amplitude by sensors placed on the surface of the scalp. Wave frequency is measured in Hertz (Hz), which is the title for *cycles per second*. Brain wave frequencies are referred to as described in Table 1.

When an EEG machine is used, sensors are placed on the scalp in specific positions, most often at the midline of the brain above the sensorimotor cortex, to pick up or “read” the brain wave pattern being generated by the brain from moment to moment. This pattern is converted by a computer program to a visual display of brain wave frequency and amplitude for student (and practitioners) to see.

There is another kind of reading of brain waves called quantitative EEG, or “QEEG,” a diagnostic reading using multiple sensors distributed over the cortex. The QEEG reading is compared to normative data from healthy brains. Kirtley Thornton has written a comprehensive book on the application of EEG and QEEG in treatment for children with learning and attention disabilities in which he proposes more detailed *subtype analysis* of QEEG’s to make them more applicable to the diagnosis of particular learning and behavioral patterns. He is an avid advocate for the use of neuroscientific data and strategies for children to increase success through improved brain function (Thornton, 2006).

Table 1: Brain Wave Frequencies

Brain wave/ characterization:	Frequency:	Referred to as:
<b>Delta</b> (sleep waves)	.5 to 3 Hz	
<b>Theta</b> $\theta$ (drowsy)	4 to 8 Hz	Slow waves
<b>Alpha</b> (resting, daydreaming meditation, hypnosis)	8 to 13 Hz	“
<b>Mu rhythm</b> (3-14% of people)	~ 10 Hz	Mu rhythm
<b>SMR</b> (sensorimotor, focused relaxation)	12 to 15 Hz	Fast waves
<b>Beta</b> (focused, thinking active dreaming)	13 to 30 Hz	“
<b>Gamma</b> (synchronized, binding, cognitive/behavioral)	30 to 100 Hz	High fast waves

(Neumann et al., 2003)

Vincent Monastra (2005) is a psychologist whose book *Parenting Children with ADHD*, describing neurofeedback as a therapeutic approach, was published in 2005. The same year, researchers including Monastra published a white paper, “EEG Biofeedback in the Treatment of Attention-Deficit/Hyperactivity Disorder” (Monastra et al., 2005), endorsed by the two leading professional societies in the field of biofeedback, the Association for Applied Psychophysiology and Biofeedback and the International Society for Research and Neurofeedback. In this article the authors cited literature to discuss the risks of youth with ADHD and genetics as a contributing factor to the availability of dopamine to synaptic receptors. They report aspects of *cortical hypo-arousal* in 85-90% of ADHD patients, that is,

their QEEG profiles indicate heightened theta in relation to alpha and beta brain waves over frontal and central midline of the cortex. A pattern of *hyper-arousal* is also evident with heightened beta and less relative alpha wave power, and lower ratios of theta to beta across the cortex.

Monastra elaborated on themes expressed in layman terms in *Parenting Children with ADHD* (2005) in a more recent book, *Unlocking the Potential of Patients with ADHD: A Model for Clinical Practice* (2008). Monastra outlined in detail the neuroeducational treatment program he and colleagues teach at their Attention Disorders Clinic in Endicott, NY. He described the ten-week parenting program taught for parents and families (in enough detail that practitioners using this guide could conduct the class themselves or purchase Monastra's video set to present to a group.) He encouraged the use of several checklists that he has developed, included in the book, for assessing behaviors in different contexts. He provided detailed information on rating tools such as the computer-administered *Test of Variables of Attention* (About the TOVA, 2010) and the use of a QEEG diagnostic profile of a child's ADHD in determining a treatment plan.

Treatment may include medication (often a form of methylphenidate, sold under the brand names Ritalin, Concerta, Metadate, and Methylin) to maintain a child's behavior so s/he can focus productively on school participation and home cooperation. Children can participate in EEG training while taking this medication. EEG training may take from 20 to 50 sessions, over weeks and months, before benefit is evident. Monastra (2008) emphasized that each child is different in how ADHD symptoms present and how the brain responds to training. Some children improve enough through their EEG training to cut down the dosage of their medication while maintaining gains in behavioral improvement.

It is noted in Monastra's book (2008) that EEG training does not replace medication per se. Children on the correct medication and dosage to manage their hyperactive or inattentive behaviors often behave suitably while their medication is in effect. However, *when the medication wears off (after whatever number of hours it is expected to be in effect), untreated behaviors return. The difference with EEG training is that after a course of training, behavioral improvement is retained. Once trained, the brain does not revert to former patterns.*

Systems for administering EEG may differ in some details, but a sample application would be for a child to sit comfortably at a computer so s/he can see a game or screen that displays the brain waves being trained in whatever protocol is being used (theta, SMG, or beta). One or more sensors are affixed to the child's scalp, using a bit of conductive paste or gel to increase the sensor's ability to pick up brain electrical patterns. Sensors are placed in positions according to the chosen protocol (often along the midline where each hemisphere's sensorimotor area intersects the midline) with reference and ground sensors often clipped on the ears. The child then watches the screen where there are graphic displays of his/her brain waves displayed as moving color areas. The child's task is to keep the displayed colors within a given box, band, or similar parameter indicator on the screen or try to enlarge the area of a color to exceed a given box. The child's brain must intuitively (nonverbally) devise its method of maintaining or changing the color displays within the given parameter. Reward is built in by way of some video activity, motion, sound or point count that reinforces the incremental success of the child's effort every few seconds. Session length may vary from 5 to 30 minutes, depending on the child.

In current educational practice in the United States there is emphasis on using learning modalities that have been shown to be effective by credible research. The Association for

Applied Psychophysiology and Biofeedback (AAPB) is the professional organization that promotes competent, responsible application of biofeedback methods and provides professional development and networking among researchers, academics, and practitioners through its website, ([www.aapb.org](http://www.aapb.org)) trainings, and an annual conference.

A prevalent form of treatment that has had numerous studies and review articles published about it is *EEG biofeedback* using protocols for retraining the brain's theta/beta ratio (decrease theta, increase beta), increasing sensory-motor rhythm (SMR), and/or regulating *slow cortical potentials* (SCPs). The results using this form of neurofeedback have been shown to be statistically significant as compared to control groups.

One of the challenges of research to demonstrate the efficacy of neurofeedback for ADHD is creating methodology with control groups that meet double-blind and control group research standards. There is also a need for longitudinal studies of the effects of neurofeedback for ADHD to learn more about the long-term effects and benefits of treatment protocols. Joel Lubar, researcher at the Southeastern Biofeedback Institute, has provided limited evidence, based on controlled outcome studies using pre- and post-treatment measures, that the effects of EEG biofeedback training continue to be evident for months or years after a course of treatment is over (Lubar, 2003).

The field of neurofeedback applied in education has significant potential according to researcher and clinician Kirtley Thornton, who offers cost analysis and discussion of cost benefit in the use of biofeedback modalities in comparison to current cost of treatment through special education (Thornton, 2006).

An additional model of neurofeedback training, called *NeuroOptimal* is used by some neurofeedback practitioners and naturopaths who offer training for children and adults. More information and related research regarding this model is available at [www.zengar.com](http://www.zengar.com) .

A caveat in treating the brain for ADHD or other conditions is that educators and families not begin to think of the brain as the “problem area” that needs to be fixed, setting aside a child’s environmental circumstances, need for good nutrition, exercise, structured activities, physical and emotional safety. Neuroeducators may treat a child with an individual intervention, but it would be wise to keep in mind the range of factors possibly affecting the child’s level of stress or distraction: family and societal conditions, electronic devices, pollutants in the air and water, chemicals in food, and so forth. Effective intervention requires that interveners monitor the web of complexity surrounding children in this fast-paced 21<sup>st</sup> Century, taking this into account while exploring and developing new methods of prevention and intervention.

### **Intervention for Students with Autism Spectrum Disorders**

According to statistics from 2008 gathered by the Autism and Developmental Disabilities Monitoring (ADDM) Network of the United States Centers for Disease Control and Prevention, an estimated 1 in 88 children eight years of age have a diagnosis of autism; approximately 1 in 54 are boys, 1 in 252 are girls (Centers for Disease Control, 2012). Educators, including both classroom and special education teachers, seek information on the etiology of autism (including Asperger’s Syndrome) and successful ways to work with students and their families.

David Sousa’s (2007) book *How the Special Needs Brain Learns* includes an outline of **symptoms common to children with autism**. Strategies **to address their learning needs** include: the use of visual aids to help students organize their work and day; consistency and predictability in classroom structure; and using speech and visual cues simultaneously in teaching about social interaction. Sousa includes references to research regarding possible causes for autism and Asperger’s syndrome such as variations in brain structure,

neurotransmitters, genetics, and a possible deficit in the mirror neuron system affecting the child's Theory of Mind—the “everyday ability to infer what others are thinking or believing in order to explain and predict their behavior” (p. 185). He discusses both behavioral and instructional approaches to intervention.

Research is being done into the causes of autism in toddlers and preschool-aged children. The rate of serotonin production in children with autism is being studied using PET (positron emission tomography) scans (Chugani & Sukel, 2007). As previously discussed, **the role of mirror neurons** in autism is also a current topic of investigation (Iacobani, 2008; Ramachandran, 2011).

Another facet of the brain under study is the **pattern of spacing of minicolumns of neuron axon bundles** in the human cortex. The density of this spacing is consistent within individual brains. Density is “distributed in the general population in a bell-shaped fashion, in which people on one end of the bell curve showed very closely packed minicolumns while those on the other had very broadly spaced minicolumns” (Eide & Eide, 2011, p.38). Research spearheaded by Manuel Casanova of the University of Kentucky suggests that **people with autism have *more densely spaced* minicolumns, resulting in “local hyperconnectivity and long-range hypoconnectivity”** (Williams & Casanova, 2010, p. 59) that contribute to a strong focus on immediate objects of attention with less overall perspective in thinking.

On the other side of the bell curve, **people with dyslexia have a pattern of *less densely packed* minicolumns resulting in “hypoconnectivity and long-range hyperconnectivity”** (Williams & Casanova, 2010, p.59). In the case of dyslexia, the cortex has less connection to use for specific details and more for the broader meaning or gist of a topic; the **axons must extend out farther from their minicolumns to connect with adjacent neurons, which increases connectivity.** Further understanding of this physiological

indicator of minicolumn spacing may prove useful in future evaluation of students with learning difficulties.

### **Neurofeedback and autism**

Neurofeedback is being used and researched as an intervention for autism (as discussed regarding neurofeedback for ADHD in the previous section). Robert Coben and colleagues have conducted a literature review (Coben, Linden, & Myers, 2010) and studies regarding the application of neurofeedback to children on the autistic spectrum. One study using 20 sessions of neurofeedback to increase longer range connectivity (connectivity among non-adjacent brain regions) in the brain function of 37 children documented a 40% improvement in children's symptoms (Coben & Padolsky, 2007).

As neuroeducation becomes more commonly known in schools, and as vocabulary integrating brain function and neuroscience becomes more familiar to teachers, administrators, and families, modalities such as neurofeedback may be more commonly used. Other new avenues of intervention may emerge, applying research and technologies to help children learn more effectively in schools and have safer, more productive lives at home and in their communities.

### **Curriculum Presentation**

The choice of overall curriculum in public schools is often made by committees that choose a publisher's curriculum series spanning multiple grades. Though teachers may sit on selection committees, the choice is not directly in teachers' control. School district committees may look, now and in the future, for publishing companies' documentation regarding how their curricula incorporate neuroscience and brain function.

Perhaps closer to home for teachers are the day-to-day strategies used to engage student interest in a lesson as it is taught. Opening the lesson with the success story of a child who has overcome odds to succeed, the startled expression on a face in a news photograph, or

the devastation of a family's home after an earthquake all involve students' emotions in learning. Research shows a web of connections between emotion and memory (Kensinger & Schacter, 2011). Classroom climate contributes to learning outcomes: with a positive experience, including laughter, endorphins are released in student brains which stimulate the frontal lobes and facilitate learning. When the experience is stressful, the hormone cortisol is released in the brain and body which detracts from learning as the student's attention is diverted towards the cause of stress. When learning is concurrent with an emotionally charged experience, the amygdala is stimulated and the body's release of adrenalin heightens the memory of the learning experience (Sousa, 2006).

Cognitive psychologist Stanislas Dehaene has researched and written books exploring learning of both mathematics (*The Number Sense: How the Mind Creates Mathematics*, 1997) and reading (*Reading in the Brain: The Science and Evolution of a Human Invention*, 2009) that elucidate in detail how the brain processes these subjects.

In the classroom, teachers have choices about the activities and materials they use to present and supplement their curriculum to meet the needs of their students. Sousa, in *How the Brain Learns*, gave strategies for teaching that will help students who have different learning strengths benefit from their lessons: Introduce concepts both verbally and visually to give ample auditory and visual clues to facilitate retention and later retrieval of the information. Discuss concepts from both logical and intuitive perspectives, so that factual information is further processed through thought-provoking questions or applications that encourage the students to find meaning in the information. These strategies use processing in both brain hemispheres to integrate learning (Sousa, 2006).

The notion of *left-brained* (e.g. linear, sequential, verbal) and *right-brained* (e.g. concrete, visual, big-picture meaning) learning is not espoused by neuroeducators. Though it may be useful in characterizing how some people receive information, it oversimplifies brain processing. Researcher Richard Haier instead approaches learning from the point of view of intelligence. He posits that that “not all brains work the same way” (Haier, 2009); his team has identified numerous areas of the brain that work together in *networks* (Jung & Haier, 2007).

These topics point towards an increasing repertoire of opportunities educators have to use neuroscience research in schools. Neuroeducators will surely continue to explore and discover more benefits of neuroscience as research advances, and educators become more widely aware of the applications of neuroscience to education. This awareness, on the part of educators in four Seattle public schools, is the subject of the dissertation. What follows is a brief report of the study and results.

## 4) The Study, in a Nutshell

*APPLICATIONS OF NEUROSCIENCE TO EDUCATION AMONG ELEMENTARY AND MIDDLE SCHOOL TEACHERS: A MIXED-METHOD EXPLORATION* addresses four questions: 1) What do certificated K-8 educators know about brain function and its significance for education? 2) How and in what settings have the educators gathered this current knowledge? 3) How do educators apply their current knowledge of brain function in the course of their classroom teaching and related work with students? and 4) What level of interest do educators express towards further education about brain function, neuroscience, and educational applications?

The study employed an online questionnaire designed on “SurveyGizmo” asking educators about their background and training in science and neuroscience, whether this training was through teacher/educator preparation programs, subsequent self-initiated learning opportunities, or professional development. It asked whether and how educators have applied this information in classroom practice or related work with students, and explored educators’ receptiveness to further training in neuroeducation. Case studies of five respondents to the questionnaire were developed from follow-up interviews expanding upon their answers.

The goal of this research was to explore educators' self-described training in the topic of neuroscience, their background in science, how they use this training and knowledge in their work with children, under what conditions they would like to increase their use of neuroscience in their work, and their level of interest in additional training to advance their own knowledge of the field.

The study enlisted participants representing a full range of roles of certificated

educators in schools, both classroom teaching and in supportive capacities. Subject specialists included librarian, music and art teachers, language teachers, technology and computer teachers, and assistant administrators. Educators with ESA (Educational Service Associate) certifications included school psychologists, counselors, nurses, speech and language pathologists, occupational and physical therapists.

Interviews conducted with five respondents to the questionnaire illuminate in more detail how these educators have learned about neuroeducation, how their practice has evolved to apply neuroscience in their classroom or work with children, how it has affected their teaching, and how it may influence their plans for future training.

### ***Results: Questionnaire Responses***

The *Teacher/Educator Questionnaire on Neuroscience and its Applications to Education* was designed to progress from educators' demographic information concerning their teaching careers through their training in science and neuroscience; whether they had self-educated or taken additional training regarding the brain or neuroscience; how they used this information in their work in the classroom or with children; whether they have taught this subject to students or discussed it with colleagues; if they were interested in additional training and under which of several given conditions they would take more training. In the last section, educators were asked to rate their level of familiarity with twelve common neuroscientific terms. In conclusion, there was an opportunity to give feedback about the questionnaire and about the study in general.

Ninety-three certificated educators of a possible 162 in four schools, or **57.4%**, responded to the questionnaire within the time frame of the study.

## ***Background in Neuroscience and Brain Studies***

Participants were asked whether the teacher/educator certification programs which they had taken included a class offered with emphasis on brain structure and function, cognitive science, and/or research on these topics. While less than one third of the educators had taken a course related to neuroscience in their certification programs, **about half of the educators had some exposure to brain function in their initial certification program.**

**Table 2: Educators' Background in Science or Science Education**

Extensive (e.g. a science major or Teaching Certificate endorsement in science)	18	19.4%
Moderate (e.g. actively self-educated with reading, classes, workshops, or professional development)	33	35.5%
Some (e.g. read or listen to news about science on TV or in the media)	23	24.7%
Basic (e.g. the minimum required for my certification program and/or science unit teaching)	19	20.4%

Four questions in the questionnaire asked about the frequency an educator reports engaging in an activity. In each question regarding frequency, the scale used is the same. This scale was devised by the researcher. The criteria are as follows:

*Frequently* means having engaged in an activity 12 or more times—a minimum average of three times during each school year for four years, or once each season (fall, winter, spring) (or, in the case of elementary school, once each trimester.) *Sometimes* means having engaged 5-11 times, an average of more than once a year for four years. *Rarely* means having engaged 1-4 times, an average of one time per year for four years. *Never* is self-evident.

Educators were asked how often they have read books or articles on brain function or neuroscience topics. Fourteen (15.1%) of educators reported reading such material frequently, 32 (43.3%) sometimes, 41 (44.1%) rarely, and 6 (6.5%) never. Combining frequently and sometimes, 46 or **almost half (49.5%) of the educators have read a book or article about neuroscience at least an average of once a year over the past four years.**

A follow-up question asked, “What did you read that was of most interest to you?” Seventy-three (73) comments were received, including: four comments about teenage brain development, three about autism, five about movement, ten about learning or applications to teaching, six referencing specific books such as *Brain Rules* (Medina, 2008), and four about childhood abuse or trauma.

**Table 3: Educators’ Sources of Information about Neuroscience**

	<u>Count</u>	<u>Percent %</u>
a) Read independently (books, magazines, newspaper)	70	75.3%
c) Visit a website or search the internet	43	46.2%
e) Watch TV program(s) or DVD's	43	46.2%
f) Take a class at a college or online	16	17.2%
g) Attend an event such as a conference or seminar	16	17.2%
h) Professional development through school district or ESD (Educational Service District)	13	14%
i) Participate in a Brain Awareness Week	1	1.1%
j) None of the above	11	11.8%
Total Responses	93	

\* Based upon reported use within the past four years

One educator reported participating in **Brain Awareness Week**, which is an event presented around the country during one week each March to give opportunities for children to learn about the brain, promoted by the Society for Neuroscience. In Seattle, Brain Awareness Week has taken place at the University of Washington under the direction of Eric Chudler, author of the website *Neuroscience for Kids* (Chudler, 2010) for a number of years. Chudler gives an entertaining presentation for students, then students participate in hands-on

exhibits and demonstrations about the brain and neuroscientific research, many which are staffed by students from University of Washington and other local colleges.

Educators reported how often they had taught lessons about brain function or brain research in their classrooms or introduced this topic to students. Six educators (6.5%) reported teaching lessons frequently, 16 (17.4%) sometimes, 26 (28.3%) rarely, and 44 (47.8%) never.

A question asked the level of interest in learning about the brain that educators *attribute to students*. Thirteen (14.6%) answered very engaged; 44 (49.4%) somewhat curious; 22 (24.7%) mildly interested; and 10 (11.2%) no interest shown by students. 57 people (64% —**nearly two thirds of respondents**) **gauged student interest in learning about the brain as either curious or engaged.**

The follow-up question, “What interests students most about the brain?” drew comments including:

How it works, how people’s brains are different; What parts of the brain control what in our bodies.; How the brain changes during adolescence; That their brain is developing and the more they try to learn subjects that are hard for them the more neuron connections the brain makes; How habits are acquired and how our actions and thoughts become stored in our memory and affect who we become.

I believe it is important and look forward to learning more myself; I’m very interested in teaching students more about neuroscience; Integrate the visual and performing arts when teaching about the brain; Understand the difference between brain and mind.

I often talk about the brain and our learning with my students. I emphasize letting each student think of the answer themselves, rather than whispering answers to them. EACH person needs to think so that their brains grow stronger!

Educators reported on which of a selection of teaching strategies they use in the classroom or in working with students. [Note that each strategy offered in the following table includes a citation documenting its relationship with brain function.]

**Table 4: Strategies used in the classroom or working with students**

	Chosen by:	
a) Use more than one medium (e.g., visual, auditory, movement) to present a new concept (Sousa, 2006)	85	<b>92.4%</b>
b) After presenting a new concept, follow with a related activity using art, music, drama, or other form of creative expression (Gazzaniga, 2008, regarding the value of arts education)	57	62%
c) Teach a concept on one school day, and revisit the concept on the following school day (Walker & Stickgold, 2004, regarding sleep and memory consolidation)	78	<b>84.8%</b>
d) Ask students to stand up and move or stretch after a lesson is presented for 10-20 minutes (Chung, Tack, Lee, et al., 2004; Sousa, 2006, regarding oxygen and brain function)	57	62%
e) Practice handwriting with students until they can form letters automatically (Berninger & Wolf, 2009, regarding automaticity in writing)	21	22.8%
f) Practice reading words out loud, increasing speed as the student is ready to do so (Wolf, O'Rourke, Gidney, Lovett, et al., 2002, regarding reading pace).	38	41.3%
g) When teaching a new concept, include an anecdote or experience engaging students' emotions (Kensinger & Schacter, 2012, regarding emotion's effect on memory)	71	<b>77.2%</b>
h) When finishing a unit, ask students to create something using what they have learned (Gazzaniga, 2008)	55	59.8%
i) None of the above	4	4.3%

**Table 5: How Often Educators Report Using Music at School**

	Count	Percent %
Daily.....	21	22.6%
Weekly.....	12	12.9%
Occasionally.....	36	38.7%
Never.....	15	16.1%
Not applicable in my role with students	9	9.7%

According to the table above, **over a third of respondents (33 or 35.5%) use music either daily or weekly in their work with children.** Respondents also had the opportunity to comment upon their observations of how the use of music affects children's learning.

There were 54 responses, including:

Relaxes them to sing—they love it; Helps them remember details; It unites the kids, somehow. They're much more collaborative and tend to function more as a team;

For English Language Learners, it has provided them an opportunity to participate in a low anxiety atmosphere

Educators were also asked **how often they used new instruction or different classroom practices in the past four years because of their knowledge of brain function:**

Of 92 respondents, 23 (25%) reported using new instruction or practice frequently, 30 (32.5%) sometimes, 19 (20.7%) rarely, and 20 (21.7%) never. The question asks teachers about their application of information about neuroscience to their classroom teaching or work with children.

Combining those who reported frequently or sometimes, **well over half (53 or 57.6%) reported having changed their instruction because of their knowledge of brain function in the past four years.**

A follow-up question asked educators to tell of new instructional practices they have used. Answers included: Adjusted my language and delivery; I differentiated instruction based on the child's learning style; Crossing of arms & legs to stimulate brain cells; Movement, patterns, repetition front loading; Used web based programs that illustrate the dynamics of brain/neurologic functions; Stretch breaks, food, outside, dance, movement in

room, speed walking around track, writing stuff for some kids; Drawing pictures of what we think, eating, water.

Participants were questioned about their desire or motivation to apply their knowledge of brain function to introduce new practices or change some aspect of their work with studen

**Table 6: Conditions Under Which Educators Desire to Introduce or Change Instruction**

	<u>Count</u>	<u>Percent %</u>
Yes, if I had time to prepare lessons	45	49.5%
Yes, if I had the flexibility in my role with students	26	28.6%
Yes, if I could collaborate with other educators	41	45.1%
Yes, if I had funds to cover materials	21	23.1%
No, not at this time	21	23.1%

Asked if there were something they would like to introduce or change in their work with students, given their knowledge of brain function, educators were able to choose as many of the responses as they wished. **Nearly half of the educators reported some addition or change they would make in their practice:** Comments that add depth to educators' choices include

What I am doing (teaching music) reinforces brain development;

Workload, job structure, money for resources, and too little time to collaborate adequately with colleagues are huge barriers;

The questionnaire included a question on how often educators have discussed brain function or its relationship to education with colleagues in the past four years:

**20 educators (21.5%) reported discussing brain function frequently** with peers, 27 (29%) sometimes (5-11 times in four years); 32 (34.4%) rarely, and 14 (15.1%) never.

***Receptiveness to Further Training.***

Some responses to the questionnaire indicate that educators *would like to include more applications of neuroscience in their work*. Many recognize that this would require more training. Asked how interested they were in learning more about brain function and current research:

**18 (19.4%) indicated that further training would be a high priority;**

**55 (59.1%) a medium priority;**

**20 (21.5%) a low priority.**

The following table gives some indication of the types of activities educators would participate in, and conditions that would encourage them to do so:

**Table 7: Potential Activities to Learn About Brain Function and Research**

	Count	Percent
a) I would take more professional development on this topic	65	<b>69.9%</b>
b) I would attend training on brain function if I were paid for my time	64	68.8
c) I would take an online class or workshop outside of school	22	23.7
d) I would participate in a peer study group or book group on this topic	38	40.9
e) I would teach about the brain to my students, if I had training to do so	44	47.3
f) I would provide training for parents/guardians or other educators, if I had training to do so	23	24.7
g) I would read updates on brain research and its applications to education if made readily available	59	63.4
h) I would participate in an annual conference for educators in my region	21	22.6
i) None of the above	1	1.1

**Familiarity with brain anatomy and function..** Twelve terms were chosen as representative of three categories of knowledge about the brain that would likely be common to a college student who had taken a class about neuroscience in recent years: 1) *anatomy* of the brain, 2) words describing systems or attributes of brain *function*, and 3) *technology* used in conjunction with brain research.

Respondents were asked to rate their level of familiarity with each word as a way of gauging the educator's familiarity with vocabulary regarding the brain or beginning neuroscience.

The key is: F= Familiar: I could explain this term.

H= Heard: I have heard of this term, but could not explain it.

N= Not familiar.

**Table 8: Educators' Level of Familiarity with Neuroscientific Terms**

	Familiar	Heard of	Not familiar	Total
Cerebellum	<b>57.0%</b>	38.7%	4.3%	100%
	53	36	4	93
Neuroplasticity	37.0%	34.8%	28.3%*	100%
	34	32	26	92
Mirror neuron	17.6%	28.6%	<b>53.8%</b>	100%
	16	26	49	91
Neurotransmitter	48.9%	46.7%	4.3%	100%
	45	43	4	92
Amygdala	23.4%	38.3%	38.3%*	100%
	22	36	36	94
Neurofeedback	35.2%	<b>53.8%</b>	11.0%	100%
	32	49	10	91
fMRI	22.0%	20.9%	<b>57.1%</b>	100%
	20	19	52	91
Circadian rhythm	37.4%	28.6%	34.1%*	100%
	34	26	31	91
Synapse	<b>65.2%</b>	31.5%	3.3%	100%
	60	29	3	92
Hippocampus	37.1%	48.3%	14.6%	100%
	33	43	13	89
Myelination	29.7%	19.8%	<b>50.5%</b>	100%
	27	18	46	91

	Familiar	Heard of	Not familiar	Total
	32.6%	<b>51.1%</b>	16.3%	100%
Connectivity	30	47	15	92

[Note: In the above table, each word's row displays the % of total responses to that item on the top line, followed by the number of responses. The number of responses for that word are totaled in the right hand column. Not all participants answered each item.]

**Cerebellum** and **synapse** were the only two terms that over 50% of respondents reported being “familiar” with. (**Neurotransmitter** was not far behind with 48.9% familiar). Over 50% had “heard” of neurofeedback and connectivity, but could not explain them.

Fewer than 50% were familiar with mirror neurons, fMRI, or myelination. In addition, 28.3% were not familiar with the term neuroplasticity, 38.3% not familiar with the amygdala, and 34.1% not familiar with circadian rhythm.

Participants offered nine additional notations responding to an open-ended invitation to comment upon any topics addressed in this questionnaire, or about the questionnaire itself:

Thank you for stimulating my synapses;

Employing current brain research in education is vastly lacking and that which is doesn't seem to be explained well to educators. I wish there was more of this covered in teaching programs, especially that having to do with sensory processing issues and how to apply helpful strategies to improve learning and maintain optimal states [of attention] for various situations.;

While I am fascinated by all the science of the brain, for me the physical regions and parts of the brain (reflected in question 14) are NOT what is important for educators to understand...it is the process of memory creation, the implications of brain conditions leading to Spectrum diagnosis—autism, dyslexia, paranoia... it is the strategies that educators can use to help children read, remember, see patterns, acquire new knowledge.

The latter two comments represent views that were noted by several people: a desire for more neuroscience applications to education, and a preference for practical applications that educators might use (over more technical knowledge of neuroscience as a subject.)

## **Case Studies of Five Educators**

In addition to a questionnaire completed by 93 certificated educators, the study includes case studies gleaned from individual interviews with five educators, following up their responses to the questionnaire. The interviewees were selected based upon their expressed openness to learning more about the field of neuroeducation. The researcher reviewed the questionnaire responses of each interviewee and chose questions that prompted the interviewee to elaborate on views indicated in the questionnaire. These include the interviewee's background in science, his or her experience learning about neuroscience in a teacher certification program, what steps participants may have taken to educate themselves about the brain *since* the certification program, how this information is applied in their classroom or work with children, and if they would like to continue with additional professional development in this area, what plans they might have to do so.

## **Common Themes in Case Studies**

The case studies uncovered some interesting similarities in both personal and professional stories: Three educators reported that they have been told in professional development that particular educational practices are based on brain research, but noted that they had not been given the actual research to read or study. This suggests a topic for further investigation: is there an assumption in professional development, or teacher education in general, that teachers are not interested in research, do not have the skill, or cannot take the time to delve into the details of research studies?

Teachers expressed interest in learning more about neuroscience and neuroeducation *along with other educators*. They would like to collaborate, and be paid for their time. This is understandable—neuroscience is a new field for many teachers, and they would like to work with others who are also be learning, exploring applications, and developing curriculum.

Three classroom teachers of primary grades said that they would like to teach their students about the brain but would need curriculum provided for them that is easy to use, and has visual appeal. While some books are available about the brain for children (Frith & King, 2007), a curriculum does not appear to be available to these teachers.

The way the interviewees came upon their introductions to neuroscience have some similarities. Carla and Rosa were exposed to brain function through other educators who were involved with teaching the topic. They also talked of family experiences which brought brain health to their attention: Carla through her own healing journey and Rosa through observing the growth and development of her child. Amy was introduced in a national curriculum organization's training. Frank began absorbing the subject in undergraduate psychology and in his occupational therapy training, and continues to read related literature. Jane G. grasped the importance of the topic and educated herself while finding others of like mind to work with. [Note: Names used for these interviewees are not the actual names of participants.]

All three of the classroom teachers, and the occupational therapist, use music frequently in their work. One, Carla, uses instrumental and vocal music to accompany classroom work time. Amy and Rosa use singing and chanting, as does Frank on occasion, to help students learn and remember what they are learning. Jane G. uses music weekly for its calming effect in her classroom. This suggests that many teachers are naturally using music with children, though they may not be acquainted with the documented benefits of the arts in education (Gazzaniga, 2008). As these teachers become further versed in neuroscience they may find funding or opportunities to engage in research of their own, connecting music and the arts to brain development.

There are several suggestions given for integrating more neuroscience into professional development: Jane G. offers a substantial suggestion: train reading and

mathematics coaches, who already provide professional development for teachers, in neuroscience so they can add brain function to the repertoire that they pass on to the teachers in the schools where they are coaches. Frank mentioned two other existing contexts where brain research could be added: one is to **inform the Response to Intervention model** used in the elementary schools to provide remediation for students who are not progressing at desired standards. The other is to **make neuroscience a focus for inter-school professional learning communities** where interested educators would meet on a regular basis to share information and glean new ideas to use in their schools and classrooms. Both contexts offer rich opportunities to add depth to educators' practice.

These five educators have varying degrees of training in brain function or neuroscience. Their teacher certification training came from different decades. Four of the five described their science background as “basic”—only one had a scientific oriented college degree. They had various experiences, through family, colleague mentors, or self-initiated reading that provided initial insight into brain studies. Table 19 summarizes thirteen key aspects of educators' experience, gleaned from their responses to the questionnaire and interview.

Regardless of background, all five educators responded positively to completing the questionnaire for this study, and expressed concern and readiness to be engaged in more training.

**Table 9: Summary of Characteristics of the Five Case Studies**

Characteristic	I. Carla	II. Rosa	III. Amy	IV. Frank	V. Jane G.
Role at school:	K teacher	K teacher, dual language	1 <sup>st</sup> grade teacher, dual language	OT/PT	Resource room IEP teacher
Decade of teacher certification training	Mid-2000	1990's	1990's	Early 1990's	1980's
Class on brain function in training?	Part of an Overview	No	No	No	No
Educational degree	BA	M.Ed	M.Ed	M.Ed	M.Ed
Science background	Basic	Basic	Basic	Extensive	Basic
Initial experience in learning about brain?	Through health condition and a mentor	Through school colleagues' writing and mentorship, and her child's development	Through NUA Training	Through study of psychology as undergraduate	Through work with colleagues, self-education
Use brain-related strategies in own class? (Question 8)	Yes, all 8	Yes, 7 of 8	Yes, 7 of 7	Yes, 6 of 8	Yes, all 8
Use music in the classroom?	Daily	Daily	Weekly	Occasionally (does not work in classroom)	Weekly
What priority is learning more about the brain?	Low	High	High	High	High
With training: would teach students about the brain	Yes	Yes	Yes	Yes	-----
Would teach parents and educators about the brain	-----	Yes	-----	-----	Yes
Expressed need for curriculum to use in teaching students	Yes	-----	Yes	-----	-----
Interested in taking further training	Yes, but time constraints of children/family	Yes, and already seeks self-education	Would be interested to do so with colleagues	Already self-educates through PT profession	Has completed 3-classes online about the brain through ESD

## 5) Significance of this Study

The field of neuroeducation has the potential to inform educators regarding strategies that can make their teaching more efficient and effective through classroom practices, curricula, and interventions. Knowledge of brain function is necessary for educators to use these strategies with intention. Educators who understand the scientific purpose behind strategies will be better equipped to evaluate the benefits of strategies for their students and communicate this to parents and families. Educators who understand the tenets of neuroscience will be more prepared to read and understand the results of research and new applications as they are developed. They will then be more able to contribute to dialogue with neuroscientists about what educators consider relevant topics for neuroscience research to address.

Documentation of the level of participants' expressed interest in further training may inform professional development providers, including individual school districts, Washington State educational service districts, and independent presenters, of the potential demand for offerings in neuroeducation. If state and school districts were to offer more opportunities for educators to take introductory training in neuroscience, the author believes that they would find educators ready and willing to study. In approaching educators in the four schools involved with this research, the author came upon several educators at each school who expressed interest in learning much more about brain function and applying it in their work with children. As the case studies illustrate, some teachers have already taken steps to self-educate, and they express avid interest. Online classes offered by Puget Sound ESD # 121 are one place to start.

Another venue for training educators is through teacher certification programs. While courses on neuroscience are offered at colleges and universities in Washington State and nationally, they are frequently offered through psychology, biology, or other departments that are not necessarily articulated with teacher certification programs. It may be possible for individually motivated students to take neuroscience classes while in teacher certification programs, if their schedule allows. *Only if neuroscience and its applications to education become a part of the core curriculum* (credits required by the state for certification) *will all newly trained educators be uniformly motivated to gain exposure to the field of neuroeducation.*

The field of neuroscience is being applied in various domains of personal and public culture—for example, neuroscience is being applied to marketing and finance as *neuroeconomics*, the study of how people make choices to spend or invest their resources (Politzer, 2008). There is now a Center for the Study of Neuroeconomics at George Mason University in Fairfax, Virginia, and a Center for Neuroeconomics at New York University. Behavioral neuroscience is being applied to business advertising and political campaigning. Concerns of law enforcement such as the reliability of lie detector tests are under scrutiny as a result of advancements in fMRI technology (Mehta, 2008). The discipline called *neuroethics* that has emerged in the past decade examines the impact of neuroscientific research on public services such as health care and personal concerns such as cognitive performance enhancement (Illes, 2006).

Today's elementary school students are the next generation of world citizens: scientists, educators, artists, professionals, politicians. Starting at a young age, children are growing up electronically savvy “digital natives” (VanSlyke, 2003). They are also living in a time of accelerating biomedical research where scientists and health providers seek deeper

understanding of factors underlying illness, wellness, and longevity. All of these are interconnected with brain function. Contemporary research is moving into pursuits where technology and sciences, including neuroscience, converge such as neurofeedback, deep brain stimulation and brain-machine interface (Nicholelis, 2011). Educators may well call upon their understanding of brain function to help children prepare for future careers and lives shaped by such convergences. The significance of this research is that it explores educators' preparation to take on this challenge.

According to the data gathered for this study, both from the questionnaire and case study interviews, there is substantial interest on the part of educators in more professional development opportunities regarding brain function and neuroscience. 19.4% of respondents said further education is a high priority, 59.1% more a medium priority. Together, this is over three-quarters (78.5%) of participating educators. Almost half of respondents (47.3%) said that they would teach students about the brain *if they had the training to do so*. Almost a quarter of respondents (24.7%) said they would train parents/guardians or other educators *if they had the training to do so*. To address such demand, the researcher recommends program development in curriculum, teacher preparation, methods to teach neuroscience, career preparation, professional development, and further collaboration between scientists and educators:

## RECOMMENDATIONS

### Curriculum:

1. Develop (and make available) age-appropriate, interactive curricula on brain function for students in grades K-12, for adult (parent) education, and professional development. (There are free, high quality resources online now including the Dana Foundation and Society for Neuroscience websites.)

### Teacher preparation:

2. **Teacher training programs prepare the next generation of educators** to read and understand reports on neuroscience research, glean information that they can use in their classroom practice, and collaborate with colleagues to apply this information. Adding a semester of brain structure and function to the core teacher preparation curriculum would promote uniform exposure to this information for future teachers, which is critical for the next generation of students to receive consistent instruction in this area.
3. **Teacher preparation programs include methods for educators to teach** brain science to their students in the context of each educator's grade level, subject specialty, or ESA role. The next generation of educators may then empower students to interact productively with neuroscience-based technologies, which already affect the lives of these students through psychology, economics, marketing, health care, and human relations.

### Career training:

4. **Offer students Brain Awareness Week, job shadow, and other exposure** to neuroscience in the community. This may inspire students to excel in high school health science courses that prepare them to pursue such fields as psychology, radiology, bioengineering, robotics and brain/machine interface. These can open the door to careers

in prevention, treatment, and medical intervention for brain-related diseases, spinal cord and brain injuries, and brain-related learning disabilities.

Professional development:

5. School districts and educational service districts **provide annual professional development** to teachers, ESA's, and administrators so that existing educators are trained with up-to-date knowledge of brain function and applications of neuroscience in industry, marketing, and medicine.
6. **Provide professional development in neuroscience and its applications for educators who work with students with disabilities**, including information specific to the populations they work with. As special educators increase their knowledge of brain function and human development, it would be wise for school districts/administrators to support them in applying relevant strategies and interventions in their classrooms and in student case management. In this way the paradigm of special education may begin to shift from *management* of brain function-related disabilities to *mitigation* of disabilities through improvement of brain performance that underlies learning and behavior.
7. Institutions such as school districts, educators' unions, medical centers, complementary medicine providers, and centers for higher education **support professional learning communities and other collegial opportunities for educators**. Through these networks, educators can share knowledge, strategies, and insights from their work with children with neuroscientists to advance the collaborations inherent in neuroeducation.
8. These same institutions **collaborate in providing opportunities for neuroscientists** to visit schools, talk with teachers about students and learning, and share their scientific expertise in science classrooms. This is a way for scientists to reach across the bridge of neuroeducation for insight to guide their research.

9. School districts, special educators, neurofeedback practitioners and neuroscientists with expertise in psychophysiology **collaborate in further research on the outcomes and efficacy of neurofeedback** training for students with ADHD, autism, and other brain-related conditions. [If neurofeedback training is shown to be effective, this research could open doors to school district facilitation, grant or other funding, or health insurance coverage for further treatments for students with brain-related disabilities.]
10. **Provide professional development for school district administrators, educators' union leadership, and State legislators who determine school funding and guide curriculum**, in order to build capacity in their understanding of brain research and the benefits of its applications to education.

***A Note to Teachers :***

Thank you so much for exploring neuroeducation by reading this guide! I hope you will continue to discover and enjoy the world of brain science, and that you find these ideas useful in your work with children. A primer on brain function, *Brain Facts*, can be downloaded free from the website [www.brainfacts.org](http://www.brainfacts.org)

The dissertation summarized in this guide is available on *Proquest*, a national database of dissertations, or by contacting the author at [fieldofswans@comcast.net](mailto:fieldofswans@comcast.net). Your feedback is welcome!

## REFERENCES

*Note: the entire reference list from the dissertation has been provided as a resource for readers. Not all these books are cited in this brief Guide, but the references themselves hold a world of information about neuroeducation!*

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