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Entitled

Engaging Cognitive Neurosciences in the Classroom

by

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An Abstract of

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Educators’ work in a value-laden profession is interwoven into the seams of our society. Parents, pupils, oversight agencies, and peers make up the fabric of daily classroom practices. A global view of our nation’s classrooms reveals a noticeable absence in education design and implementation - thoughtful and systematic inclusion of scientific knowledge to guide practice. Sylwester (1995) identified that educators do not have the freedom to wait for results of research to guide their classroom practices. Students who fit societal profiles of highly motivated, having strong family support, and belonging to secure homes fare better in our educational system. Educators face the frustrating reality of their students’ widely varying knowledge and support base. A review of where cognitive research has been, how it validates some currently successful educational
practices, and where it is heading can stir debate. This review summarizes historical and current forays into cognitive neuroscientific research and pedagogical practices from books, observations, and current professional journals.
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Introduction

There is no debating the fact that there exists a struggle between applied and basic research in many fields. Education is no exception. Scientists view scientific study in varied and often opposing principles. Often scientists argue that certain research in the name of science is simply an exploitation of the known and not an exploration of the unknown. Others would not consider a changed application of a known theory, or discovery, to differing situations as research. A purist perspective is that new principles and concepts are developed and explored in purely scientific arenas leading to further concepts and ideas. A focus on achieving an overriding commercial goal calls into question the view of basic science as a deity. This embodies the innate understanding that there is a two-way path between science and technological application (Stokes, 1997). In education, the divide between basic and applied research is immensely wide if you consider the sheer number of classrooms that millions of children occupy daily and the actual methods of teaching derived from scientifically based research. Cognitive neuroscience, in its’ relative infancy, can blend diverse fields of study and possibly answer questions that professionals are already pursuing in their discrete fields. It may embody the bridge between the basic and applied field of education.
Within the field of education and teacher education there are distinct and deeply divisive concepts of what constitutes successful education. We know that “teaching does not equal learning” (Jensen, 1998). From a call to “return to the basics,” to the varied curriculum and environments, educators cannot agree on how to harness children’s innate desire to learn and lead them successfully into adulthood. Even a simple question such as the description of a child’s potential lends itself to controversy. Are children tabulae rasae, as John Locke proposed, waiting to receive knowledge or are they magical little adults whose true abilities and potential we cannot fully ascertain and therefore romanticize. An historical and global look at research and debate in the field of educational research proves the distinct need to critically analyze scientific and behavioral data regarding learning and employ the connection between researcher and application in order for the current educational system to become effective for all participants.

Educators face an enormous task with each new group of children. Cognitive neuroscience brings answers to leveling the playing field for all learners. It is not a silver bullet, it is not the curriculum of the month. Cognitive neuroscience simply explains at a cellular and chemical level, the task of learning and memory. It will not answer societal problems, nor will it ensure the teaching profession of an easy answer to complicated problems of funding, familial support, or lesson planning. Our society needs to come to terms with the fact that
we live in an age of advanced scientific research that proves education is a complex, fluid, social system being maneuvered through by constantly changing physiological systems.

One unambiguous goal for cognitive neuroscience would be creating effective teachers. In order to succeed, several steps must be taken. First, taking a realistic and comprehensive review of the physiological mechanisms of learning that are known to date. Physicians, scientists, educators, and teacher educators should then debate the results and discoveries. Next, comparisons to currently effective policies should be made. A complete reinvention of educational practices is not called for, would be impractical and likely impossible to implement. Critical examination can reveal strengths and weaknesses in the current practices and illuminate gaps in research, particularly in research involving typically developing children.

Mark D’Esposito prefaced his edited book Neurological Foundations of Cognitive Neuroscience by stating that changes in neuroscience now make it possible to expand from the study of clinical patients to real-time functioning of an uncharacteristic brain. A summary of these advances in spatial and temporal brain resolution are highlighted in Chapter III, Brain Function and Assessment Methods. In addition, functional views of the physiological components of learning disorders such as dyslexia, aphasia, and apraxia can provide critical
clues and direction for future research using real-time brain functioning. The distinctiveness of each child’s cognitive abilities would cause concern for educators if the only focus in education was a strictly uniform system. Instead, a uniform assessment framework that is sophisticated enough to be blended with unique applications and environments can be formulated using cognitive neuroscientific data.

The basis for a framework can begin formation with some of the fundamental premises of cognitive neuroscience. “Principles of Brain-based Learning”, developed by the Combined Elementary Task Forces of the Metropolitan Omaha Educational Consortium (MOEC), Omaha, NE: University of Nebraska at Omaha (1999) and drawn from work formulated by Regate and Geoffrey Caine; can be summarized into two statements: (a) every brain is uniquely organized and (b) everything that affects our physiological functions affects learning. Implications for educators are that until we can accept these ideas as truths, national educational reform can never truly ascend beyond sound bytes and ineffective practices. Following will be a literature review of the physiological, correlations to current practices, and practical implications of current research in the cognitive neurosciences. It is by far not complete, yet it highlights work and interviews with the most prominent professionals currently working within the blended fields.
Framing the Issue of Cognitive Research Implementation

Cognitive science is a blend of psychology, philosophy, linguistics, computer science, and neuroscience as described by Alison Gopnik (1999). Her speech at the September 2003 21st Century Learner Symposium in Washington, DC revealed her passion for the field of young children and their capacity for knowledge. She stated that nature versus nurture is not the valid dichotomy, but intuition versus science. This is an interesting thought and lends historical perspective to the field of education. Education was the one field missing from her blending of sciences and it belies the fact that often educators are not perceived as the researchers in the field of young children, but the grunt forces in providing the services. Historically, research in the field of education sought behavioral verification for children’s motivation in acting and learning the way that they do. Questions abound whether children are genetically predisposed for particular deficiencies or strengths are commonly debated. If so, how can those unique descriptors be determined and nurtured.

Marcia D’Arcangelo (1998) interviewed five prominent authors in the field and their highlighted beliefs regarding the influence of cognitive neuroscience in the classroom can be summarized as follows:
Marian Diamond, a leading neuroscientist, stresses that learning involves changes to neurons in cerebral cortices. The ability to change in response to environmental interactions is the plasticity that allows us to learn. This has to be balanced with the notion of optimal timing for cortical input that is believed necessary for such tasks as vision, hearing, and beginning language.

Pat Wolfe, an educational consultant, stresses the importance of the connections between neurons that create pathways through use of neurotransmission; the electrical processes that provide the basis of our behavior. She proposes that the fundamental challenge for education is to provide enriched classrooms. Meaningful learning environments stimulate neuronal firing. The more times that two neurons fire together, the more efficiently they can develop memory.

Robert Sylwester, a professor emeritus of education, expands on the notion of optimal periods for introduction of new skills and the importance of presenting them to children before the brain systems governing those skills are used for something else. He also stresses the fact that behavioral problems are often created out of environment and scheduling as “it is biologically impossible to learn and remember anything that we don’t pay attention to” (D’Arcangelo,
It is crucial to plan for students’ emotional well-being as emotion drives attention which in turn drives memory.

Educator, Geoffrey Caine, views education over the past century as developing from a teacher controlled stand and deliver instructional approach to a rapidly changing and more open period of technological advances and incursions of societal influences. Brain research, in its’ infancy, has already led educators to create rich, complex, engaging environments. His work has led him to believe that cognitive neuroscience will challenge our paradigm further into a classroom environment where teachers and learners are partners, and educators draw out learning based on children’s interests. Educators must challenge their models of learning and education, and find a connectedness throughout and between subject matters.

Educator Eric Jensen’s work with challenged learners has influenced his view of the classroom implications of brain research. Teaching is viable when the educator understands the learners’ biological changes and motivating stimuli. He recognizes that educators feel a constant need to maintain their students attention. As cognitive neuroscience has expanded our knowledge of brain chemistry, it is obvious that alert times of the brain are cyclical, physiologically motivated, and at odds with current educational scheduling and practices. A great teacher may only need 20 to 30 percent of a classes’ attention, while the
students spend the remainder on processing, writing, peer teaching, and projects. Emotion drives attention and Jensen promotes the idea of engaging children in productive, non-excessive emotions while learning.

In order to represent a complete view of the discussion, it is necessary to present some of the cautions to brain research’s forays into application. Jensen addresses some educator’s concerns over the applied research of brain-based education. In response to the complaint that there is nothing new in this approach and that some findings are misrepresented, he cautions two things: first know the study. Second, do not change classroom strategy based on one study or finding. Most of what we know of good teaching is a “collection of basic psychology and common sense refined by trial and error” (Jensen, 2000, p. 76).

As stated earlier, teachers are using brain-compatible strategies without consciously understanding the physiology behind their success. For example, brain research is providing promising results in several areas, such as the growth of new cells in damaged regions through two mechanisms: educational challenges and running. How this research is applicable to daily classroom planning has amazing potentials, but it is only one piece of the puzzle in figuring out the brain. Randomly assigning “running homework” will not translate directly into higher grades, but can adjust classroom environments and scheduling to take advantage of this research in creating more optimal learning
environments. “The brain is what we have; the mind is how we use it” (Jensen, 2000, p. 77).

Critics also state that the field of cognitive neuroscience changes too rapidly for any effective dissemination of information. Educators must be discriminating and teacher educators must dialogue and impart some cohesiveness in presenting this information; which is likely our best chance to dismantle hit or miss education. Despite the confusion surrounding some research, and the seemingly overwhelming number of consultants and media outlets attempting to capitalize on a “new concept”; educators, advocates, and policy makers must make every effort to dissect and understand this unique field.

Children come into the world with an innate set of virtues and sense of socialization and self-preservation. They are not predisposed to hate and suspicion, which supports the brain based learning theory that the brain is a social learner. Nature has designed adults to support children’s protracted immaturity and in essence become the educator whether in a formal or informal capacity. This behaviorally based fact supports the social/physiological causation for cortical changes in human beings. I believe that two niches within education can provide a unique perspective for framing the dialogue surrounding cognitive neuroscience. My previous research into the pedagogical
foundations of early childhood education and a subsequent comparison to the implementation of unique physical education programs validates the social/physiological basis for learning and brain changes. This will be discussed further in Chapter IV, Links to Current Educational Practices.
Brain Function and Assessment Methods

Educator’s can appreciate psychologist’s belief that “a neural approach to mental processes seemed too reductionist to do justice to the complexity of cognition” (Kendal & Squire, 2000, p. 1113). Although this is true, it does not diminish the importance of understanding cellular and molecular processes of cognition. Neuroscience is seeking to define and understand two dichotomous concepts – that the brain has a capacity for “hard-wiring” as well as an environmentally distinct plasticity Richard Restak (1995) points to two fundamental principles that highlight the environmental nature of brain function. “1) the brain exists in order to provide an internal representation of “reality” with the knowledge that every person’s reality differs; 2) certain recurring themes have dominated the theories of those who have studied the brain and its importance of achieving self-understanding” (p. 3).

Modern neuroscience is founded on purposes that propose to achieve understanding of those two principles:

1. Neuronal doctrine describing the brain as an organ composed of discrete signaling units called neurons. Neuronal connections are
invariant, highly specific, and allow information to flow in only one direction.

2. Ionic hypothesis that offers a mechanistic view of the nervous system and precludes the varied study of electrical and chemical synaptic actions.

The speed and range of neuronal messengers can provide essential and applicable information to educators who can capitalize on facts surrounding physiological changes in the brain such as the mechanics of long-term memory. It is known that some memory is derived through synaptic actions that can last for days. On a physiological level, this consists of protein kinases translocating to the nucleus of cells where they phosphonylate transcription factors that alter gene expression, initiate growth of neuronal processes, and increase synaptic strength (Kandel & Squire, 2000). Neural activity is crucial to brain development as it refines connections and forges adult connectivity patterns. Although it is known that some neural activity is spontaneous in early development, sensory input is essential as children grow.

Behaviorists argue that psychologists should focus their study on observable stimuli and responses rather than unseen interactions at a physiological level. Unfortunately, lack of physiological knowledge has often caused educators to let challenged children slip through the cracks and makes planning a purposeful curriculum a gamble. In its infancy, cellular studies in the
1950’s proved the symbiotic nature of neuroscience and psychology. In this cooperative atmosphere the basis for localization of functions occurred and behavioral studies edged towards a mechanistic explanation of internal representations of human experiences as the brain filters and processes sensory information.

Memory, though, is distinct from perceptual and cognitive skills as shown by Brenda Milner’s studies of a patient known only as HM. HM suffered amnesia a bilateral medial temporal lobe resection to relieve epileptic symptoms. Memory is not a solitary operation of the brain but the cooperative work of multiple systems with differing anatomies and end functions. Declarative recall of facts is unique and diverse from skills, habits, and conditioning. Declarative memory is supported in the medial temporal lobe while “the hippocampus and other medial temporal lobe structures permit the transition to long-term memory” (Kandel & Squire, 2000, p. 1118; Sylwester, 1995).

Nondeclarative memory is a collection of brain substrates. For example, many kinds of motor learning depend on cooperative effort with the cerebellum. Emotional learning and memory modulation through emotional ties, are a function of the amygdala while the basal ganglia controls habit learning. Unconscious, routine performance of memory driven action is an evolutionary phenomenon. One cannot watch professional sports without acknowledging
with absolute certainty, some individual’s adept performance of nondeclarative memory task as phenomenal.

When dealing with children’s brains, we know that preschoolers’ brains are quite simply more active than an adult brain. The number of synapses in a child’s brain peaks at age two to three with approximately 15,000 neurons. Research shows energy consumption in the brain is double that of an adult until nine or ten years and declines only to adult levels at about 18 years. This allows the adult brain to be more specialized and compartmentalized by pruning weak connections and allowing useful connections to become stronger (Gopnik, 1999; Zull, 2003; Wolfe & Brandt, 1998; Fischer & Rose, 1998; Bruer, 1998). Usefulness of a connection is the key factor in its’ survival, for it is not simply the amount of stimulation that is critical during sensitive periods, but the balance and relative timing of stimulation. Simple increase in activity in the brain is not a direct correlation to intelligence. Increased stimulation at inoptimal times may result in no long-term recall abilities.

Research published in the 1970’s led by David Hubel and Torsten Wiesel concerning critical periods in the visual system is one of our clearest examples of this concept. Exciting as this research is, it may say little about formal education’s impact on critical periods as they seem to apply to the development of basic sensory abilities such as vision, hearing, and language (Bruer, 1998). Further
studies of these systems can underline the dilemma. It is also important to caution educators and parents that although children need complex environments to stimulate these sensory systems. Complex must not be confused with enriched. Enriched is a value-laden term and culturally exclusive.

Researchers believe that critical periods develop in three stages of varying length and times: first, a rapid phase where the function matures. Second, a period of sensitivity to deprivation occurs. There is some plasticity if the stimuli occurs before the window of opportunity closes. Third, scientists believe that the evolutionary process has allowed for a type of “experience-expectant” plasticity where evolution expects a stimuli to be readily available in the environment (Greenough, 1992). Cases of severe abuse have shown how expectant these systems are.

Fischer and Rose (1998) support another concept relating to critical periods and plasticity with stronger ties to education. The brain appears to develop less in the manner of a series of consecutive steps than recurring growth cycles, or developmental levels, that repeat several times between birth and age thirty. Spurts in development along the parallel strands of skills or knowledge, involve two cycles. The shorter cycle involves successive levels of skills from a single behavior or action through mapping and into a complete system. These cycles then ‘nest’ within a longer cycle that has four tiers of reflexive, action,
concrete representation, and abstraction applications. Educational theorists and early childhood educators have strong support for the concept of children moving through these stages. When educators focus on and challenge the zone of emergence for each optimal level, you can see learners’ actions as they advance through each strand.

There are also four complimentary levels of function in the human cortex during assimilation of stimuli, according to Richard Restak (1995). Each has a function that is dependant upon the other and mirrors the four basic functions of the human brain as described by biologist James Zull: gather, analyze, create, and act. First, the primary cortex deals with vision, hearing, and touch processing of sensory stimulation. For example, someone would be able to identify the color red in a picture. Second, the unimodal cortex elaborates and seeks detail of the primary cortex’s stimulation. The red becomes a dress. At this point, the sensations are still kept distinctly separate. Third, the heteromodal association cortex is a matrix of nerve fibers that unite the part into a unified perception. This is when the red dress is evident as being worn to a party. The heteromodal association cortex still lacks meaning in what you perceive and your attitude or response in light of the knowledge. Finally, the supramodal layer is where behavioral control is exerted over the lower level functions of the brain. You feel happiness and decide to dance at the party. With so many systems and organs in the brain responsible for retrieving, integrating,
acting upon environmental stimuli it is almost overwhelming for educators to concentrate on simply one child and their optimal pattern for storage and retrieval of information. If any challenges, such as chemical imbalances or processing disorders, create unique and characteristic differences then individualization challenges increase tenfold.

Although child-specific education seems a daunting task in light of current educational settings, a holistic model of single-sell structure, functional behavior, and chemical breakdown of naturally occurring behavior will become an impetus for research in the coming decades. A basic understanding of first, the advances in neuroimaging and second, molecular events during cognition is the information that Nelson and Bloom (1997) convey in their work.

Neuroimaging now permits: (a) inferences about brain-based behavior; (b) direct visualization of the brain with excellent resolution in the spatial domain; (c) direct visualization of the brain and comparable resolution in the temporal domain. In the study of cognitive neuroscience, we only need to focus on tools that investigate human development through non-invasive and non-clinical means. Subjects must also be able to tolerate the study. Researchers utilize differing methods based upon those criteria, therefore this review is simply descriptive and only includes methods that meet those basic factors.
Neuropsychological Tools – predating neuroimaging is the use of inferential hypothesization. Scientists can develop “behavioral litmus tests”, often using groups of tasks with both normative and clinical populations, to identify areas of the brain which are responsible for particular behavior.

Metabolic Procedures – function through correlation of a metabolic action with ongoing cognitive activity. Scientists caution that they are only useful in describing where, not when, thinking occurs.

Positron Emission Tomography (PET). PET typically involves injecting radioactive energy sources (oxygen or glucose) and then detecting where positrons are emitted as the radioactive substance decays. Localization of the areas utilizing more fuel are then identified. This technique was used extensively with infants and children to identify synaptic formation.

Functional Magnetic Resonance Imaging (fMRI). fMRI operates on the principle that deoxygenated hemoglobin is paramagnetic. An MRI tracks subtle increases and decreases in oxygen as tasks are performed by particular brain regions. Patterns are compared under task and non-task conditions. fMRI has been used extensively to identify sensation, perception, and cognition. It is also the technology responsible for mapping the entire human visual system.

Electrophysiological Procedures – this research tracks the electrical activity produced during synaptic action.
Electroencephalograms (EEG). EEG are taken by placing electrodes on the scalp to record the background electrical activity of neural communication. These studies are particularly effective for behaviors such as experience or expression of emotion, but not to the study of cognitive processes. Valuable uses in an educational setting may be to predict which individuals are predisposed to internalization disorders such as depression. Educators can prepare special environments and support certain interactions to assist the student in becoming successful.

Event Related Potential (ERP). ERP also test involving electrode placement on the scalp, but it is timelocked to a discrete event and does not require the participant to respond verbally or motorically. ERP is extremely useful when examining cognition in infants.

Magnetic Procedures - track brain activity using the principles derived from the small magnetic fields created with every neuronal bioelectrical signal. Assessing these signals is extremely difficult and environment sensitive.

Magnetic Source Imaging (MSI). MSI localizes dipoles near the surface of the brain and in combination with an MRI, provides a look at both brain structure and function simultaneously. MSI is not useful in imaging deeper structures involving emotion and some cognition as it relies on the small magnetic fields that are created at right angles to the bioelectrical flow of neuronal signaling.
Implications for advanced understanding of neuronal function lies in improved imaging that may rise beyond identifying the biological basis of behavior and cognition, and make it possible to diagnose, determine efficacy of treatment methods, and validate various educational theories by identifying underlying brain mechanisms involved. These measures would add a new degree of validation and respect to the teaching profession.
Links to Current Educational Practices

While researching the links between early childhood education, physical education, and brain-based learning, distinguished and unique factors are similar among successful programs. One unique aspect, as identified by Caine and Caine, is that learning engages the entire physiology. This precept is easily identified in both physical education and early childhood education programs that are based upon constructivist, engaged, child-directed learning environments. These learning environments were designed in response to behavior based theory that supports learning as physiological and social. Cognitive neuroscience validates those practices.

Educators in the field of physical education have been utilizing some of the basic concepts of cognitive neuroscience and integration of environment for some time without specifically stating foundations in cognitive neuroscience. Some of these researchers such as Karl Newell, George Graham, and Mary Ann Roberton have been emphasizing the strong links between environment, task, and learner for decades.
Karl Newell proposes analyzing tasks through manipulation of the environment, learner, and task itself. This constraint theory of education works cooperatively with cognitive neuroscience’s support for the uniqueness of learners brain function, the importance of environment, and the perception of the knowledge by the learner. Working within each of the constraints, educators can plan progressively more challenging environments and tasks, and have a framework for cataloging children’s experiences.

George Graham (1998) is also an advocate who promotes the belief that physical educators are responsible for designing environments in which children can navigate tasks competently within a skill theme approach. Physical educators modify fundamental movement concepts into increasingly more complex situations. This approach not only describes what is taught, but how it is taught within groupings he defines as: precontrol, control, utilization, and proficiency. He visualizes this learning as occurring in an upward moving spiral where children’s proficiencies in distinct areas of movement increase and decrease as they move through the spiral to the next level. His curriculum focus promotes that children learn by first building a motor foundation in Pre-K through grade 5. They then explore a variety of movements up to grade 9 when they have the opportunity to develop expertise in life-time skills and healthy living activities.
Mary Ann Roberton provides students training in the field of physical education the opportunity to understand and work with developmental sequencing, drawn from the concepts of developmental task analysis. She teaches that developmental task analysis is the seminal aspect of motor development instruction. Individualized, uniform, and increasing in complexity; developmental sequencing seeks ethological ties to not only physical behavior in a classroom environment, but also its’ link to natural occurrences in daily activities. As educators manipulate tasks and goals, observation must occur and then influence future tasks. As the complexity of a task is manipulated by altering one factor such as ball size, speed, target, etc.; children respond variably, sometimes regressing in one component of the movement that they had previously mastered. Physical knowledge’s occurrence within a three dimensional context challenges commonly espoused theories of cognition, but it is still necessary to understand these types of skills and their connection to automatic brain patterns.

These cyclical properties evident in the three pedagogies highlighted above, tie strongly to Fischer and Rose’s work mentioned earlier. New developmental levels are reflected in reorganization of skills. Each new developmental level that is achieved, reflects an optimal challenge to the learner’s functioning. Because exposure to a variety of experiences, sub-optimal or optimal, is essential in daily life; educators should use these findings as a
guide to understanding physiology of learning and not simply as a substitute for understanding learning itself. All learners need to progress through cyclical growth spurts at a wide range of normal levels to shape and widen their ‘neuronal web’ for resilience and plasticity.

Interestingly, these correlations between cognitive neuroscience and current applications in classrooms, particularly movement based and child-directed programs, brings about a question. When an entire school is founded upon principles that combine the best of research in science and behavior, what unique and amazing results are in the future. There are many more school now that are responding proactively to the research in this field. As this literature review is meant to challenge educators in their own beliefs through direct research, I am simply providing a reference for three such schools that have been mentioned.

Dry Creek Elementary is a Chapter I school located in Rio Linda, California whose founding impetus was the work and direct input of Renate and Geoffrey Caine. Improvements in academic performance have occurred as the Caine’s have created what they call an apprentice community where students can experience the many relationships and information that they will face in the real world, in a safe, nurturing, and challenging environment. Dry Creek Elementary contests the traditional teacher directed model of education with inflexible
scheduling and non-creative use of technology and presents a new, dynamic
learning environment. A key concept is that the brain is a complex parallel
processor and must learn in realistic environments. They seek to challenge, not
limit, children’s own natural desire to learn. This is not an instant, easily
reproducible fix to what is wrong in education. Instead it is a challenging, messy
process that requires educators to work through their pre-conceived ideas and
emerge into a professional community that is dynamic. Although the pathways
to creating these types of environments are ambiguous, they are worth following.

Elsie Whitlow Stokes is a charter school in Washington DC that was founded in
1995 out of frustration with schools that were not keeping up with curriculum
nor meeting the needs of children in either the present or future. It promotes four
underlying premises that serve the holistic needs of children: (a) it is
intentionally diverse, nationally and globally; (b) it creates a peaceful
environment and students are guided to understand the essential value of peace;
(c) it requires high academics founded upon communication and language
immersion; (d) it emphasizes responsible citizenship and community service. A
unique component of this learning environment is how it incorporates its
movement programs. Due to being landlocked, it uses community resources for
dance instruction, tennis lessons, golf, and other diverse physical activities. Its’
founder and director, Linda Moore, spoke about the conscious use of brain-based
theories and pedagogies of Gardner and Piaget at the outset of the project.
New City School in St. Louis was founded upon the theory of Multiple Intelligences first identified in Howard Gardner’s 1983 book *Frames of Mind*. What makes multiple intelligence theory different from other attempts to transform education was that it looked at the traditional problems from the aspect of the learner and his or her potential. No learner was completely exempt from having worth, simply stronger abilities within differing means of interacting with the physical world. Gardner’s work was in the field of psychology and with brain damaged patients. Within his work, he began to consider that brains possess distinct potentials and sought to create a list of criteria that would identify an intelligence. Interestingly, when Gardner sought to identify whether a skill was simply an ability or truly an intelligence, his first criteria was its’ potential for isolation by brain damage. Multiple Intelligences is not a curriculum, and is very site and context specific. Implementation is dependent on the educators, learners, and community.

Each of these examples, and dozens of others, will have a unique connection with each educator that seeks further, in depth, information on curriculum and implementation. I challenge, once again, educators to become researchers.
Environment Implications

John Bruer (1998) summarizes that there are three valuable ideas for educators to recognize from early brain research: (a) synapses form rapidly in young children; (b) critical/optimal periods for sensory stimulation occur in every child’s development; (c) enriched environments are critical to enhancing brain development. All research reviewed in this work can be analyzed and separated into these areas. Hopefully, future research will also lead us to answers relating to efficacy of treatments and benefits of unique instruction.

According to Sally Shaywitz, pediatrician and coordinator of the Yale Center for the Study of Learning and Attention, in an interview with Marcia D’Arcangelo, brain research is critical in how we create children’s learning environments. Although the brain is always taking in information and creating optimal connections, young children accomplish this task with less effort. When speaking of environments, we should also include lessons.

Dr. Shaywitz’s research has focused on reading, and consequently she predicts through her work, that 30 to 40 percent of school children have difficulties reading. What does this mean for educators in light of cognitive
neuroscience? In essence, we use three brain systems to read. In the front, there is the inferior frontal gyrus, responsible for articulation (Broca’s area). In the left back are the parieto-temporal region (responsible for analyzing and sounding out) and the occipito-temporal region (visual word formation). Through brain imaging, scientists have found that there is significant under activation of areas in the back regions, evident from childhood. Children do not outgrow this under activation. Researchers believe that children compensate by utilizing front regions and rear right regions of the brain, which makes reading slow, not automatic. Teachers need to help students create experiences and neural connections that make reading automatic on a neurobiological level. Creating lessons that enhance fluency and phonemic awareness; and doing it at an early age, are critical operations for educators. Dr. Shaywitz emphasizes “Do it early and do it right!” (D’Arcangelo, 2003, p. 9).

Another critical environmental application of brain research relates to the understanding of optimal amounts of stimulation. Educators need to understand that the brain works in ways of self-preservation in order to prevent becoming overwhelmed with stimuli. It sets limits using absolute refractory periods as well as critical mass in neuronal stimulation, to allow a sufficient period to elapse between activation of neurons. Gating mechanisms, through use of inhibitory neurons, assist in regulating the flow of information into the brain. Richard Restak (1995) encourages educators to be cognizant that competing for the same
neuronal pathways by presenting information that requires identical processing will prevent the gathering of that sensory input. Humans can move rapidly through emotions, or from receiving auditory to visual stimulation, but we cannot feel opposite emotions or attend to more than one visual stimulation simultaneously. It may benefit administrators to assess educator’s skill in presenting information when determining their effectiveness, as opposed to simply looking at their students’ standardized test scores.

When considering the environmental matter of scheduling and timing of information presented to age groups, schools should consider that development can be described as progressive inhibition. In Barbara Strauch’s 2003 book The Primal Teen, she describes the process that as children mature their prefrontal cortex gains the ability to inhibit the inappropriate and improves impulse control, allowing children to control the flow of information into their brain. In the cases of infants, toddlers, and teenagers, adults often have to act as their prefrontal cortex. Addressing biological concerns when creating schedules and classroom environments, allows educators to plan for and prevent situations that necessitate children utilizing skills and abilities that they are not physiologically capable. If we set them up for success, not failure, we enhance the entire system.

A biological concern in the critical period argument is the fact that scientist now know that myelination of cortical regions is completed in varying
time frames, and enhances learners abilities in those areas. For example, myelination of the motor cortex may be completed by five or six years of age, then allowing children to move more effectively. Myelination in cingulated and hippocampus areas that connect quick reactions to historical and contextual thought may still be occurring into the teenage years. Not only does this create unique challenges in providing optimal nutrition and rest environments for teenagers, but may prove that they are not entirely in control of their actions. Language areas may not fully develop myelination until the teenage years, particularly connections between Wernicke’s and Broca’s areas. This explains why education should focus on making children successful in areas that they are ready to develop at younger ages, such as gross motor and fine motor skills, while leaving some of the more advanced language skill development until later years.

Action for Healthy Kids Report, which grew out of a 2002 Healthy Schools Summit held in Washington D.C., was issued in September of 2004 and outlines the link between academics, and nutrition and physical education programs. This national advocacy group is lead by 51 state teams and a national coordinating and resource group, guided by 40 national organizations and government agencies. Several key points are made by the report, which supports that good nutrition is necessary to provide nutritional building blocks for cells. One example is the link between iron deficiency and shortened attention spans,
irritability, fatigue, and lower concentration. Another key concept is that children whose basic hunger needs are not being met, cannot attend to classroom activities, are more fatigued, and are less likely to resist infection. A link between physical activity and test scores shows a positive correlation, even when the physical activity takes away from classroom instruction. The National Association for Sports and Physical Education (NASPE) recommends that children “engage in at least 60 minutes – and as much as several hours – of age appropriate physical activity all or most days of the week.” More than a third of high school students do not participate in any activity on a regular basis. Fewer than 25% of American children get a minimal 30 minutes of activity per day. More than 75% get no more than 20 minutes of vigorous activity weekly. (Action for Healthy Kids, 2004). Current review of studies outlining movement programs in schools provides as dismal a picture. Through longitudinal studies concerning BMI and childhood obesity, we find that schools are offering fewer hours of active time in their schedules. Datar and Sturm (2004) concluded that increasing physical education by one hour per week in girls who were overweight, or at risk, helped combat obesity. Physicians, parents, and educators all know the risks associated with poor health and measures of cognitive skills, but most devastating from this study was the finding that only 16% of kindergarteners received PE instruction daily and about 13% received PE instruction less than once a week, or never. In general, only a small minority of children in any age group participate in daily classes and active class time is far below the
recommended 50%. When combined with cognitive neuroscientific findings relating movement to enhanced mental capacities in young children, and the obvious importance of successful movement environments in learning for young children’s brains, we see a piece of the puzzle to why schools are failing.

Education is not simply a matter of putting the right information in front of the learner, but also presenting it at the optimal time and in a successful format. Educators who look for the biological basis of behaviors in children are much less frustrated and quite simply more successful.

In the case of teenagers, neurobiological concerns are more complex and important as we understand that hormones operate in complex feedback loops, and teenagers are often unaware of why they are feeling and acting the way that they are. For example, teenagers who get fewer than nine hours of sleep a night show signs of severe sleep deprivation. Adults understand how poorly we function under those conditions, but we also have more self-inhibition to control our reactions. Scientists also know that teens will fall into REM sleep mid-morning when given the chance. Teens need to sleep later into the morning. Why do high schools set schedules in direct conflict with those biological functions? Implications for not enacting environmental changes in schools based on currently validated information are debatable, yet would simply be speculation of status quo. With this knowledge, researchers need to find out to find out if
public schools can achieve positive changes based on these findings. The implications for doing nothing are as serious as those for enacting change.
Teacher Education Implications

Applying cognitive neuroscience to the field of teacher education presents unique challenges when the field already consists of a multitude of varying philosophies regarding the definition of a teacher. Are they professional artists, advocates, or technicians? Grineski and Bynum (1990) speak to the three differing views of educators. I would challenge adding another descriptor to the list: scientists. We often see characteristics defining each of these views in many of our peers. Often, the educators whom we consider “the best” have a mix of these characteristics and the skill to know where each has a place in the profession. Essentially educators are in the business of relaying and presenting information, and then requiring students to demonstrate recall of the information. Good educators will require then further manipulation and exploration of the knowledge. Inherently, this is memory.

James Zull, biology professor and Director of the University Center for Innovation in Teaching and Education at Case Western Reserve University, describes four basic functions of the brain; consequently four “pillars of human learning”. Essentially humans gather, analyze, create, and act upon information. Educators must produce a physiological change in the brain, yet the processes of
doing so, in his belief; is an art and a leap of faith in the learner themselves. Learners essentially control their intake of knowledge, but as we educate educators it is important to advance their understanding of optimal learning situations. Those situations consist of environments that both evoke emotion and build upon practice without triggering habituation. When the stimulus becomes unimportant to the learner, neurons stop firing. As adults, we experience the behavioral validation of that fact daily as we commute and no longer “see” the corner store or stop sign with cognitive recognition.

When Pat Wolfe (1998) supports the belief that cognitive neuroscience validates effective teaching methods of the likes of Madeline Hunter, Dewey, and Piaget, she is expressing the fact that the brain stores different types of memories in different ways. Declarative (explicit) and procedural (implicit) memories are stored, and retrieved, by the brain in differing patterns. Wolfe states that research supports declarative memories are stored in the cortex and require retrieval to be brought into consciousness. Procedural memories, conversely, form when neurons fire together. The more frequently that firing takes places, and the chemical situations created in the brain when the firing occurs, create a “hard-wiring” of that information. Here cognitive neuroscience validates Hunter’s belief that “practice doesn’t make perfect, it makes permanent.” All of these early educators understood intuitively that learning required interest from the learner.
and unique settings to assist in both storing and recalling lessons and to apply the information learned to new challenges.

In order to create uniformity in the information being presented, and consequently retained and utilized by students as cultural capital, there has to be a manner of allowing children to demonstrate their recall and application in a known setting to preserve their self-esteem and strengthen their self-concept while measuring and probing their knowledge and higher level cognitive skills. Caine and Caine (1991) identified three environmental guidelines for educators to gauge level of performance and understanding: (a) evaluate a child’s performance in multiple contexts; (b) know how to question to find the answers; (c) provide the settings, and expect performance in unexpected situations that are spontaneous and conversational.

Caine and Caine’s guidelines are expanded upon by Marilee Sprenger, another educator interested in understanding memory in children. She writes that not only is memory a two-way street of imparting and then assessing, but recall also consists of five pathways. Memory includes: semantic, episodic, procedural, automatic, and emotional. Emotional is the most powerful, and is governed by the amygdala. Because semantic memory deals with words, it is critical to education and although the hippocampus does not store the actual memories, it does catalogue them along with episodic memory. Episodic
memory is location driven. Procedural takes affect when performing physical
tasks such as throwing a ball. Automatic, or stimulus-response, describes
knowledge like the alphabet and song lyrics. She advocates that educators can do
a better job helping students learn and retain information if they are more critical
in applying teaching and assessment methods that are in unison with each other.
Use the learning environment to enhance emotional memories and visualization.
Do not change assessment practices from the setting and manner in which you
relayed the information. There is always a need for students to apply learned
information, but the setting should be low-stress and supportive.

Another body of writing that is also influential in framing the study of
brain-based learning for classroom instruction and assessment is the work of Dr.
Mel Levine. He speaks about the triad of content, process, and skills intertwining
to create outcomes. His flow along this process begins with the learners prior
knowledge and abilities. He defines eight neurodevelopmental constructs:

1. Attention – three interactive control systems that regulate mental
   energy control, or the follow of cognitive energy. Processing control, or
   the intake of information, Production control, which equates to output.
2. Temporal Sequential Ordering – a system that provides infrastructure
   for interpreting, remembering, and creating sequential information
   relating to time.
3. Spatial Ordering – a system that provides infrastructure to interpret, remember, and create information that comes in or goes out as a simultaneously presented set of stimuli relating to space.

4. Memory – the mind’s storage system includes short term (knowledge), active-working (skills) and long-term (experiences) memory.

5. Language – critical system that facilitates the receipt, understanding, and expression of ideas, feelings, and information.

6. Neuromotor Functions – connections and interactions between the brain and various groups of muscles that move. These include gross motor, fine motor, and graphomotor.

7. Social Cognition – functions necessary for verbal pragmatic abilities (using and understanding language in social contexts) and social behaviors (acting in a way that creates optimal relationships with other.)


In Dr. Levine’s book, *A Mind at a Time* (2002), he documents and discusses examples of children who are normal or superior in their overall abilities, but are challenged by differences in the actual functioning of their brains. These neurodevelopmental variances are often misunderstood by adults and are not tolerated well in restrictive classroom environments. Learning differences
compile a large portion of the student population with manifestations from
difficulty expressing ideas and thoughts through deficiencies in basic language
and computational skills. His eight neurodevelopmental constructs could
provide a framework for evaluating children’s abilities and areas of need without
the subjective and often belittling social labeling that occurs with children whose
learning is challenged. Levine’s constructs provide an environmental “map” for
classroom planning.

Mariale Hardiman isolates five dimensions of “higher order thinking
skills” and combines clarification of these skills with best practices to meet the
needs of all learners; particularly those with special needs who are mainstreamed
into general education classrooms. Hardiman emphasizes the key principles of
emotional learning and utilizing the learners’ previous knowledge.

Dimension One: Positive Attitude – the limbic system responds to emotional ties.
There are optimal levels of chemicals to both stimulate but not cause undue
anxiety that would inhibit formation of neuronal connections.

Dimension Two: Acquiring and Integrating Knowledge – failure to coordinate
flow of information from right to left hemispheres of the brain is thought to
cause poor acquisition in reading skills. We need to further study how to
integrate information within the systems of the brain for diagnoses and
treatment methods.
Dimension Three: Extending and Refining Knowledge – learners coordinate retrieval and integration of classifying known concepts to generate unique performances.

Dimension Four: Using Knowledge Meaningfully – ability to investigate knowledge in experiential learning. This is not simply creating hands-on situations, but requiring problem solving.

Dimension Five: Habits of Mind – involves metacognitive thinking, or the monitoring of one’s own thinking processes. Students with spatial-visual brain orientations can visualize three-dimensional problems. Children whose brains do not function in this manner can use learning strategies to improve their performance in situations requiring spatial-visual thinking.

These six educator’s beliefs and practices run the spectrum of cognitive neuroscience application and thought. In reviewing their practices, we open dialogue for informing our own classroom beliefs and practices. In this manner, education will continue to evolve through the spectrum of science, art, and technical skill.
Conclusion

When Carolyn Pool interviewed Ron Brandt (editor of Educational Leadership) in 1997 regarding innovations in learning and the effective schools movement, he reflected on the developments that educators world-wide use to engage their students. In regards to brain-based learning specifically, he believed that he was ahead of the times with the 1981 series on brain learning written by the Caines, Sylwester, and John Abbott. He feels that the time has come for educators to be able to digest the information coming out of the new field of cognitive neuroscience. Seven years ago, the information was amazing. Now it has become a vast force to consider. Just a simple review of the theories and activities of researchers who have devoted their entire careers to improving the education of all children is astonishing. It is also very obviously looking for common language and purpose. In reviewing the research presented in educational journals over the past fifteen years, we can see how much work lies ahead. It is the necessary and impending evolution of education. Essentially, the strongest and most critical information will come from rich dialogue with other professions. Educators are responsible for developing children’s brains. Unless we begin to advocate and become the leaders in this research, we will not be able to create transformation in our field.
“Children may be poets of the five senses, but their research is silent and invisible. They don’t articulate their experience in a language easily accessible to grown-ups.” (Goodenough, 2003, p. B13) Regardless of whether these sentences resonate with the educator’s spirit inside of you, or you disbelieve that there is any mystery or art involved in the pursuit of knowledge, it is essential to consider the holistic impact that formal education has on children. When did the mystique of our own educational experiences begin to leave us as we grew into adulthood and traded those secret spaces of learning and exploration for paychecks and consumerism. Our entire society is vested in formal education. Even those who shun it are driven by it. In its’ simplest form, learning is a reflection of the magic of the human brain’s perception of the world, and of itself. As we stand on the threshold of cognitive sciences’ arrival into the foray, maybe we can begin to learn how children do indeed conduct their “research”. Maybe we can make the pursuit of knowledge accessible to all children. Then perhaps adults can once again recognize the wonder of the world around us using the most powerful instrument on earth – the human mind.
References


New City School @http://www.newcityschool.org.


