Master of Education Program Theses

12-2009

Improving Education Through Brain Research

Lisa J. Ihnen

lmproving Education Through Brain Research

Abstract
Educational practices are improved because of brain research. Cognitive and behavior sciences have provided important concepts for educational practice. Within recent decades, neuroscience has also contributed to the field of brain research, thus enhancing our understanding oflearning. Three main concepts from neuroscience are explored: synaptogenesis, critical periods, and enriched environments. When the entire body of knowledge from all disciplines of brain research is viewed together, then fmdings can be applied to educational practices.

Document Type
Thesis

Degree Name
Master of Education (MEd)

Department
Graduate Education

First Advisor
Pat Kornelis

Keywords
Master of Education, thesis, brain research, cognitive science, behavior science, neuroscience, learning, synaptogenesis, critical periods, enriched envirnoment

Subject Categories
Behavioral Neurobiology | Cognitive Neuroscience | Education | Educational Methods

Comments
Action Research Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Education

Improving Education Through Brain Research

by

Lisa J. Ihnen

B.A. Faith Baptist Bible College, 1988

Thesis
Submitted in Partial Fulfillment
of the Requirements for the
Degree of Master of Education

Department of Education
Dordt College
Sioux Center, Iowa
December 2009

Improving Education Through Brain Research

by

Lisa J. Ihnen

Approved:

Director of Graduate Education

1-22-10

Date

Table of Contents

Abstract

Educational practices are improved because of brain research. Cognitive and behavior sciences have provided important concepts for educational practice. Within recent decades, neuroscience has also contributed to the field of brain research, thus enhancing our understanding of learning. Three main concepts from neuroscience are explored: synaptogenesis, critical periods, and enriched environments. When the entire body of knowledge from all disciplines of brain research is viewed together, then findings can be applied to educational practices.

Introduction

What an amazing creation God made when he created the human brain. With its vast ability to grow, change, and process information, the brain has captured the attention of neuroscientists. This organ is different than previously thought. In the past the commonly held theory by researchers was that the brain at birth was a "self-enclosed, hard-wired organ with a preset, unchangeable set of rules" (Kotulak, 1997, p. xv). With the theory of the brain as an organ with a preset design that goes through similar steps in maturation at the forefront, it was a reasonable assumption that education could be efficiently accomplished with the factory model of education. However, recent findings have challenged this concept of the brain and learning. The brain's plasticity is now known. That is, the brain is changeable; new neural pathways are formed and unused areas are pruned, changing in response to its environment. Diamond and Hopson (1998) state, "Where society once viewed the child's brain as static and unchangeable, experts today see it as a highly dynamic organ that feeds on stimulation and experience and responds with the flourishing of branching, intertwined neural forests" (p. 1). When the brain is changing, it is learning. Goswami (2004) offers a precise definition of learning, "Learning essentially comprises changes in connectivity: the release of neurotransmitters at the synapse can be altered, or connections between neurons can be strengthened or pruned. Successful teaching directly affects brain function by changing connectivity" (p. 175). Therefore, a new paradigm in teaching is emerging. Students are no longer expected to follow a prescribed pattern in their education, but rather teachers seek to differentiate instruction and teach children to learn based on the student's strengths and weaknesses using strategies especially designed with the brain in mind.

The development of neuroscience has excited educators about the possibility of understanding the workings of the brain and applying this knowledge to teaching and learning. Understanding the functioning of the human brain implies a more efficient pedagogy. Teachers are encouraged to teach using brain-based educational strategies. While neuroscience is making strides in discovering the activities occurring within the brain during various tasks, educators need to understand the new information and how these discoveries are useful in the classroom. In his article, Bruer (1997) contends that educators already have a useful tool in behavioral sciences with which they are able to continue developing effective pedagogy. He urges educators to use caution when applying new discoveries to the classroom. While many strides in educational research have indeed been made, neuroscience has the potential to take educators beyond their current understanding of teaching and learning. The new information gained through neuroscience could help develop improved teaching strategies.

Therefore, the purpose of this literature review is to explore how teaching can be improved for the benefit of students by applying findings and discoveries from recent brain research. To address this research objective, the following research questions will be addressed.

Research Questions:

1. What does neuroscience teach concerning the workings of the human brain?
2. Do findings from brain research enhance pedagogy?
3. How will teaching change when teachers use strategies developed from brain research?

Definition of Terms

Several terms will be used throughout this paper and are defined as follows:

Behavioral sciences: a scientific discipline, such as sociology, anthropology, or psychology, in which the actions and reactions of humans and animals are studied through observational and experimental methods. (*The American Heritage Dictionary of the English Language*, 2009).

Brain-based education: pedagogical methods that take into consideration the functioning of the brain (Bruer 1999).

Brain plasticity or neuroplasticity: the ability of the brain to forge new pathways or reorganize itself by forming new neural connections throughout life (D'Arcangelo, 1998).

CAT scan or CT scan: Computed axial tomography (CAT) scan, an imaging method that uses x-rays to create cross-sectional pictures of the body (Sousa, 1995).

Cognitive science: a science of the mind (Bruer, 1997).

Cognitive neuroscience: the investigation of cognitive processes in real time. (Mackey, 2006).

Critical periods: times of increased synaptic growth (Bruer, 1997).

Electroencephalograph (EEG): an instrument that charts fluctuations in the brain's electrical activity via electrodes attached to the scalp (Sousa, 1995).

Event-related potentials (ERP): brain recording technique measuring the electrical or magnetic fields neural activity generates at the scalp surface (Bruer, 1997).

Functional magnetic resonance imaging (fMRI): a lower budget variation yet much faster variation of an MRI (Jensen, 1998).

Magnetoencephalography (MEG): uses sensors to locate faint magnetic fields generated by the brain's neural networks (Jensen, 1998).

Magnetic resonance imaging (MRI): non-invasive procedure that uses powerful magnets and radio waves to construct pictures of the body (Sousa, 1995).

Neurons: cells in the nervous system that process and transmit information (D'Arcangelo, 1998).

Neuroscience: the scientific study of the nervous system (Bruer, 1997).

Positron emission tomography (PET): detects radioactively-tagged sugar tracking blood flow in the brain (Sousa, 1995).

Pruning: dying off of unused or unconnected dendrites (D'Arcangelo, 1998).

Synapses: a neural junction used for communication between neurons (D'Arcangelo, 1998).

Synaptogenesis: a time of rapid synaptic growth (Bruer, 1997).

A Brief Review of the Relevant Literature

Neuroscience is a relatively new field of scientific research. According to Katzir & Paré-Blagoev (2006) it has been a specialized field of study for less than 40 years, and it continues to expand. Neuroscience investigates how the brain learns at the molecular and cellular levels, as well as, the structure and function of the brain.

Watching the brain work is not as simple as watching other parts of the body work. Scientists can see the heart pump and can follow the path the blood takes through the body. Not so with the brain. To 'see' the functioning brain, scientists use imaging techniques. It is presupposed that when the brain is active, there is an increase of oxygen and blood in that part of the brain.

> Neuroimaging is based on the assumption that any cognitive task makes specific demands on the brain. These demands are met by changes in neural activity. The brain pumps more blood to meet demand. Cognitive neuroimaging methods either measure local changes in blood flow directly (PET) or indirectly (fMRI) or measure the extremely low-voltage electrical impulses associated with brain activity (EEG & ERP). (Goswami, 2004,

p. 177)

These changes in blood flow and oxygen levels are the basis for interpreting the images from positron emission tomography (PET), magnetic resonance imaging (MRI), computed axial tomography (CT), and functional magnetic resonance imaging (fMRI) scans which are only some of the tools used by neuroscientist studying the brain.

Several methods are used by neuroscientists to understand how the brain functions: assessing reaction time, gross electrical recording, studying brain damaged patients, imaging techniques and animal studies (Byrnes & Fox, 1998). The first method, reaction time, is used to determine the speed at which the subject can make simple and complex responses. It is thought that reaction time correlates to intelligence and neural speed (Byrnes & Fox, 1998). While this method is easy, inexpensive and noninvasive, Byrnes and Fox maintain that this method is not very helpful in understanding brain functioning.

The second method of gross electrical recording is a recording of electrical impulses on the scalp surface. An electroencephalography (EEG) is the recording of "spontaneous natural rhythms of the brain" (Goswami, 2004, p. 177). Goswami (2004) describes this method in his article. He describes an event related potential or ERP.

> When particular events are designed by the experimenter to affect spontaneous rhythms, systematic deflections in electrical activity are evoked (hence the event related potential). ERP rhythms are time-locked to specific events designed to study cognitive function. (p. 177).

These electrical potentials help experimenters locate regions of the brain that are active during cognitive tasks. However, they are not able to pinpoint the exact location of brain activity during the cognitive task (Byrnes and Fox, 1998).

Another method used to collect information about location of brain functioning is the study of brain damaged individuals. Seeing what functions have been lost due to illness or damage to the brain has taught scientists much about the function of the brain. Sousa (1995) points out the usefulness of case studies. "Beside the information collected by these techniques, the growing body of case studies of individuals recovering from various types of brain damage is giving us new evidence about and insights into how the brain develops, changes, learns and remembers" (p. xiv). These studies have shown some of the amazing attributes of our brains. In cases where damage to an area of the brain identified with certain skills is sustained, it follows that loss of skills would occur, but researchers have found that damage to an area of the brain does not eliminate the skill (Byrnes and Fox, 1998). The functioning is significantly reduced, but the brain compensates in other areas to perform those skills. Researchers have also studied cases of patients with lesions in various regions of the brain. People with lesions in the third frontal convolution of the left hemisphere lost the ability to say words, but understand what is said. Interestingly, people with lesions in the Wernicke area near the temporal-parietal junction in the left hemisphere speak fluently but don't understand what is said (Byrnes and Fox, 1998). Subtle differences are also seen in some patients suffering damage to different regions of the brain. In some individuals with frontal lobe damage the ability to name objects is reduced, yet in others this same difficulty is found with temporal lobe damage (Byrnes and Fox, 1998). Also, researchers gain further information about areas of the brain responsible for tasks by studying patients as they are slowly anesthetized prior to surgery or by studying patients whose corpus callosum is severed in cases of severe epilepsy (Byrnes and Fox, 1998).

Another imaging technique, CT scans gives a detailed cross-section view of the brain. The CT scans are used to detect strokes, cancer, malformation, but are not able to detect the location of specific functions of the brain (Sousa, 1995).

A PET scan uses radioactive isotopes injected into the blood stream, and then records the position of the isotope as a cognitive task is performed (Byrnes and Fox, 1998). This shows a moment-by-moment picture of radioactive substance in the blood stream thus tracking brain activity (Sousa, 1995). Due to the expense of this method and the use of the radioactive substances, the sample size is less than ten per study group. Inferences made on a small sample need to be used cautiously.

An MRI works using the magnetic properties of atomic particles. The huge magnet causes particles to align themselves. A pulse of harmless radiation disturbs the particles and causes them to switch polarity giving off a small amount of energy. This energy is used to create a two-dimensional image of the area. The fMRI is used to create images of active areas of the brain. This shows changes that are fifty milliseconds apart (Sousa, 1995). This technique is more desirable than the PET scan because it gives good spatial and temporal resolution, does not use radioactive substances, and studies of the same person can be repeated (Byrnes and Fox, 1998). A three-dimensional image is built with repeated imaging. Furthermore, with longitudinal studies, a four-dimensional image is possible giving a picture of how the brain changes over time (Katzir & Paré-Blagoev, 2006).

Animal studies have yielded much information for researchers. Diamond and Hopson (1998) point out the value of animal studies.

Like so many other significant discoveries in medicine and life science, the history of

> enrichment research starts with the laboratory rat. The rodent's brain is smoother, simpler and of course, far smaller than a person's. However, the nerve cells, the living units that comprise most of the rat brain, are virtually identical to human brain cells and work in exactly the same major ways. This is true of the cat, dog, guinea pig, and monkey, as well. Because of the close similarities human neural research can rest comfortably on a furry foundation of mammalian anatomy, physiology, and behavior. (p. 6)

Byrnes and Fox (1998) write that animal studies are useful when it is unethical to do experiments on humans. Animal studies include procedures such as, making incisions in or removing portions of the brain, transplanting brain tissues, inserting hormones, neurotransmitter-blockers, lowering the temperature of a portion the brain, inserting microelectrodes, and performing environmental enrichment studies (Byrnes and Fox, 1998).

Through these methods, much has been learned about the functioning of the brain. Although generalities can be made, the brain is unique and individual. Goswami (2004) states, "There is a striking variation in the size of different brain structures and in the number of neurons that different brains use to carry out identical functions, even between genetically identical twins" (p. 176).

Scientists have been able to map several areas of the brain. This is useful when studying the functioning of the brain during the performance of different tasks. The occipital lobe receives sensory input from the eyes and interprets images. The parietal lobe processes the sense of touch, spatial processing and perception. The temporal lobes are important for memory, audition, language, and object recognition. The frontal lobes are active during planning, reasoning, control of speech, and emotional reactions (Goswami, 2004). Interestingly, recent discoveries in neural science have shown how the brain performs subtasks in different parts to accomplish at task. Goswami (2004) takes a closer look at reading. Several neural regions are necessary for reading. Alphabetic and orthographic processing use the occipital, temporal and parietal areas. Letter shapes are processed in the occipital-temporal region while phonological awareness happens in the parietal-temporal junction. He also reports that the occipital-temporal area distinguishes between linguistically structured words and non-words.

There are many facts learned from the research. Yet throughout the literature, three concepts in neuroscience research that should guide educators in understanding the research and its implications for the classroom emerge: synaptogenesis, critical periods, and enriched environments.

Synaptogenesis

One concept that should guide educators is synaptogenesis. The brain for all its complexities is made of few structures. Neuron cells and chemical neurotransmitters do the work of cognition. The connections between neural cells are not all formed at birth. Soon thereafter and continuing throughout infancy and early childhood is an explosive growth of synaptic connections called synaptogenesis. The infant brain makes trillions of synaptic connections in the first year of life. Researchers have found that within the brain of an infant synapses were generated at the rate of three billion per second (Kotulak, 1997). It is thought that at this age is the most explosive time of learning before a process of pruning, the dying off of unused neurons, takes place. It is not, however, the only time of growth. Blakemore (2007) discusses another time of synaptogenesis occurring in adolescence. The brain has a high level of plasticity and continues making connection throughout life. It may not be able to ever again reshape itself at the rate it does in infancy, but it continues, nonetheless, to reshape itself (Kotulak, 1997). The growing brain quadruples in volume between birth and adulthood. The brain consists of one hundred billion neurons with massive connection to other neurons (Goswami, 2004). In her article, Yero (2001-2) tries to articulate the complexity of the brain and the role of the environment. She states,

> The human brain is composed of about *ten billion* neurons, each of which has perhaps *ten thousand* connections to other neurons. This results in approximately *one hundred trillion* connections in the brain…, each of these connections, from the moment of formation, is subject to change by interactions with the environment – through experience. In other words, the brain is constantly changing in response to experience. (p. 2)

A region of the brain that experiences early synaptogenesis is the visual and auditory cortex. The density of connections peaks at around 150% of adult levels between one and twelve months of age. Pruning takes place and the density is reduced to adult levels between two and four years of age (Goswami, 2004). The density of connections in the prefrontal cortex, which is involved in planning and reasoning, peaks after the first year. It takes ten to twenty years to return to adult levels (Goswami, 2004). Goswami (2004) summarizes the process: "The general pattern is clear. Brain development consists of bursts of synaptogenesis, peaks of density, and then synapse rearrangement and stabilization. This occurs at different times and different rates for different brain regions" (p. 176).

After times of synaptogenesis are times of pruning as the synaptic connection become permanent. Sousa (1995) points out the following:

> Connections the brain finds useful become permanent; those not useful are eliminated—the brain is selectively strengthening and pruning connections based on experience. This process continues throughout our lives, but it appears to be at its greatest between the ages of 2 and 11. (p. 5)

As connections are strengthened by repetition, a myelin sheath is built around the connection, making the synaptic connection more efficient (Jensen, 1998). This sheath speeds up neural transmissions and makes it possible for many networks of connections to fire at the same time (Goswami, 2004).

Critical Periods

The second concept that is significant for educators to consider is the idea that critical periods exist during which knowledge is more quickly and easily learned. Critical periods are times throughout early life characterized by synaptic growth and are rife with many pathways that haven't yet been pruned by the brain. Goswami (2004) ties the times of synaptogenesis with critical periods, although he would refer to them as sensitive periods rather than critical periods because the window of opportunity for learning doesn't close. Different functions performed by the brain have different critical periods. Bruer (1997) states, "how long critical periods and their phases last depends on the specific function and on the maturational timetable for the brain areas that support the function" (p. 8).

A study done on cats acquiring visual acuity shows the importance of sensory input during the critical periods. In Bruer's (1997) article, he discusses a study conducted by researchers Hubel and Wiesel (1965), who experimented with cats and found infant cats, after having their eye sewn shut, became blind in that eye. However, researchers Chow and Stewart (1972) showed that given therapy the kittens were able to recover or develop the sight in the deprived eye. This led researchers to acknowledge a brain plasticity that lasts throughout our lifetime. We continue to learn. Adult cats with their eyes sewn shut for a period of time did not lose their sight. The idea of recognizing critical periods is to target those times with specific instruction. It is thought that students would be more successful. Rather than promoting earlier education as some do, Bruer (1997) uses this knowledge of critical periods to suggest that we should be careful to diagnose sensory problems early since the study was dealing with sensory deprivation and provide the appropriate interventions.

An interesting study undertaken by Kwon and Lawson (2000) may support a critical period that happens during adolescence. They investigated a time of little brain growth, or plateau, followed by a growth spurt as measured by prefrontal lobe activity. The purpose of Kwon and Lawson's (2000) study

> was to test the theory that the acquisition of theoretical concepts (e.g., air pressure) as a consequence of science instruction depends also on the development of hypothetico-deductive reasoning ability. Furthermore, the development of hypothetico-deductive reasoning depends in part on maturation of the brain's prefrontal lobes. (p 44-45)

In their study, Kwon and Lawson (2000) tested adolescents ages 13-17. The students were in eight groups. Each group was administered tests of four prefrontal lobe activities, a test of scientific reasoning ability and a test of air pressure concepts derived from kinetic-molecular theory (Kwon and Lawson, 2000). They were then subject to 14 lessons about air pressure followed by readministration of tests. Students ages 13 and 14 showed a dip in performance while older students performed better. Kwon and Lawson (2000) concluded, the "present results provide support for the hypothesis that an early adolescent brain growth plateau and spurt exists" (p. 58).

Bruer (1997) maintains that the claim from educators that neuroscience proves a critical period exists is reading too much into what we know from research. Early in the development of infants there is a time of great synaptic increase followed by a pruning of these synapses. We only know the numbers change. Bruer (1997) further states, "our current understanding of synaptogenesis can tell educators little, if anything, about what kinds of early childhood, preschool, or learning experiences might enhance children's cognitive capacities or their educational outcomes" (p. 7).

Enriched Environments

The third concept for educators to consider is enriched environments which refers to offering stimulating circumstances and surroundings for the brain to use or learn from, in developing pathways of learning. Interactions with people and the environment shape the brain.

> According to Robert Thatcher, a noted brain researcher, studies have shown that 40 percent of short-term and 70 percent of long-term connection in the brain are influenced by heredity. This suggests the 30 to 60 percent of the brain's connections come from environmental influences or an interaction of heredity and environmental influences. (Flohr, Miller, & Debeus, 2000. p. 4)

The brain takes in sensations from the environment and seeks to build meaning. The toddler experiencing the soft, pleasant feel of velvet wants to touch it repeatedly often begging others to enjoy the sensations with her. The environment, therefore, is an important tool in shaping the young brain.

Synaptic connections are formed as the infant gains feedback from his environment. Right after birth the brain goes through an amazing growth spurt with experiences shaping the physical brain. Stimulation through all the senses causes connections to be made in the synapses within the brain. The growth of connections can happen within 48 hours of the stimulation (Jensen, 1998). The need to stimulate the brain through adult-infant interactions is imperative to healthy growth. Without these interactions, the infant brain becomes poorly developed (Kotulak, 1997).

Case studies of identical twins are used to try to determine the role of heredity and environmental influences. One such study (Byrne, Delaland, Fielding-Barnsley, Quain, Samuelson, Høien, 2002) was conducted by researchers in three different countries. The countries were the United States, Australia, and Norway. Researchers were attempting to "gain a longitudinal perspective on genetic and environmental influences on literacy growth" (Byrne et al., 2002, p. 50), as well as examining "genetic and environmental influences on cognitive, linguistic, and behavioral processes that are known to co-vary with reading ability and to do so in a design which may help disentangle causal relations among these processes and literacy levels themselves" (p. 51). Both monozygotic twins, twins sharing common genes, and dizygotic twins, twins with half their genes in common, were included in the study. The twins were given IQ tests, standardized tests, and also commonly used measures for pre-reading skills. A parental survey was used to determine the environmental similarities and differences. Three conclusions were drawn from the study. The studies showed evidence of genetic influences on phonological awareness (Byrne et al., 2002, p. 69). Secondly, researchers found a significant genetic influence on learning and memory processes in preschoolers

(Byrne et al., 2002, p. 69). The last conclusion drawn was that print knowledge and vocabulary measures indicated a strong influence from environment and little influence from genetics (Byrne et al., 2002, p. 69).

Bruer's (1997) article also addressed the third concept. It discussed the study of rats conducted by William Greenough (1987). This study showed that rats living in a complex environment (i.e. an environment more closely resembling their natural habitat), showed the ability to navigate mazes more quickly than those raised in a sterile environment. These rats also showed the ability to respond to their environment throughout their lifetime, not just during the critical development stage of increased synaptic increases. Diamond & Hopson (1998) describe Diamond's discovery about the environment's influence on lab rats. Successful and repeated lab studies showed rats raised in enriched environments grew a thicker cerebral cortex than rats raised in a more sterile environment. These studies found that interactions with the environment change the physical brain.

Neuroscience, Brain Research and Education

Brain research is important for education. Discovering what happens when students learn can only improve teaching. Cognitive psychology, behavioral science, and neuroscience all are researching the workings of the human brain from different aspects. The strength of neuroscience is when these findings enhance what other disciplines are discovering, just as cognitive psychology and education enhance each other. A connection between education and cognitive psychology has been well established for sixty or more years (Bruer, 1997). This is the kind of interfacing needed to understand the workings of the human brain. Katzir and Paré-Blagoev (2006) noted the expanding field of research and its interconnections.

As testament to the complexity of the brain, and the many methodological barriers that

> exist in the objective study of its structure and function, the development of the field has resulted in the development of many interdisciplinary neuroscientific activities, including neuropsychology, neurobiology, neuroimaging, and neurophilosophy. (p 54)

An example of how these disciplines work together is when the cognitive psychology model of learning breaks larger tasks into the smaller component skills and pieces needed to perform the larger task. This information is useful for neuroscientists when studying the physical functions within the brain. Bruer (1997) explains, "These cognitive analyses and models allow cognitive neuroscientists to formulate informative, testable hypotheses about how brain structures implement functions that underlie learning and intelligent behavior" (p. 10). Katzir and Paré-Blagoev (2006) also note that "Without these collaborations, the neuroscience may be relevant to learning broadly but is unlikely to directly address specific educational issues" (p. 71). Although a fairly new discipline, neuroscience is making a place for itself in educational brain research.

Educators have until recently lacked solid scientific evidence in the area of brain function to support and guide what they do. Wolfe (2001) states,

> The knowledge base from which we've generated our decisions has been limited by what the behavioral sciences could provide, which hasn't always been sufficient. Of necessity, we've operated intuitively. Intuition has worked well in many instances but has left us without the ability to articulate our craft to others. (p. 2)

The lack of hard, scientific support for teaching methods leaves the field of effective teaching and learning open for people outside of education: politicians, school boards and parents, to form opinions about areas of classroom management, learning and effective teaching methods and to view these opinions as equal to the opinions of educators (Wolfe, 2001). Politicians and school boards are in a position to make educational decisions based generally on their own experience which may not be the best practice to promote student learning. If neuroscience could offer sound scientific proof supporting good teaching practices, educators would be better able to answer the concerns of those in society interested in the education of students leading to better educational policy. Educators, therefore, find neuroscience alluring.

However, caution in implementing theories based on the brain needs to be exercised. Sometimes educators cause more problems than create solutions in the area of brain-based learning. If educators want to avoid accusations of being psuedoscientists, they need to be careful to study the research and avoid simplifications and over-generalizations. Without a clear understanding and careful study of the evidence, some educators have promoted teachings that were not accurate, often oversimplified and even misleading (Bruer, 1997). In his article, Bruer (1997) quotes Chipman (1986), "these ideas have been around for a decade, are often based on misconception and overgeneralizations of what we know about the brain, and have little to offer to educators" (p. 4).

An example of overgeneralizations promoted in the past is the myth of right and left-brained people. It was thought that the left side of the brain was analytical while the right side of the brain was more artistic. Neuroscience has refuted this misconception by finding that within each task performed by the brain there are components of the task that are performed some on the left side and some on the right side of the brain (Bruer, 1999). To complete a task both hemispheres of the brain are active. In her web article, Wolfe (2001) encourages educators to proceed with caution, "No one will consider educators true professionals unless we act like professionals in analyzing and applying the research" (p. 6). Educators need to understand the findings of science in order to be able to articulate the reasons why they use brain-based educational pedagogy.

Through brain research educators are learning more about what the brain needs in order to learn. In his book, Jensen (1998) addresses several factors which cause growth of thicker dendrite branches and increased neural connections, that is to say, factors which effect learning. An important factor is readiness to learn, including proper nutrition, exercise, and adequate sleep especially in teens. Teens are wide awake at midnight and groggy at 8:00 a. m. due to a "delayed accumulation of oleamide" (Jensen, 1998, p. 24). Jensen suggests high schools should have a later start time than elementary schools.

Educators have used studies of rats raised in enriched environments running mazes quicker and more successfully than rats raised in sterile laboratories to support the claim that early-enriched environments are essential to a child's development. Children need to be in a stimulating environment, and teachers are encouraged to provide a stimulating environment through bulletin boards, word walls, colorful displays, and engaging lessons in order to foster greater learning.

The brain takes in the entire stimulating environment and processes the information. Sousa (1995) explains how the brain handles the excess of stimuli as he discusses a model of learning, The Information Processing Model, which traces stimuli through to memory and recall. The model begins with the student in the environment. Stimuli enter the brain through the senses. "About 95 percent of all new learning during our lifetime is through sight, hearing, and touch" (Sousa, 1995, p. 10). Every moment the senses are collecting information from the environment. The brain would be completely overwhelmed if it gave equal attention to everything it perceives. Located in the brain stem is a perceptual or sensory register or the "reticular activation system (RAS)" (Sousa, 1995, p. 10). The job of the RAS is to determine if the data is important. Unimportant data from the senses is blocked and dropped out of the processing system. "The brain acts more like a sieve because there are several early stages where most data are dropped from the system" (Sousa, 1995, p. 12). The more important data passes through the RAS on to a temporary or short-term memory system.

There are actually two temporary memories. One is short-term memory which assists the RAS when it is overloaded and allows processing of stimuli to continue for a few seconds. It continues to work at the subconscious level. The second temporary memory is the working memory. This is used when conscious processing takes place. The model uses a work table to picture the working memory it is "a place of limited capacity where we can build, take apart, or rework ideas for eventual storage somewhere else" (Sousa, 1995, p. 13). From the working memory data is either dropped or transferred to long-term storage.

Jensen (1998) equates long-term storage or memory to learning. He states, "After all, if you have learned something, the only evidence of the learning is memory" (Jensen, 1998, p. 14). For an item to be stored in long-term memory, the brain wants it to make sense and/or have meaning (Sousa, 1995). Making sense of the item means it needs to fit with the background knowledge of the student and is understandable. Making meaning refers to the ability of the brain to determine relevance. Sousa (1995) states, "meaning, of course, is a very personal thing and is greatly influenced by our experiences" (p. 16). Jensen (1998) also comments on the complexity of meaning, "PET scans reveal the experience of meaning has a biological correlate, but it depends on what type of meaning" (p. 91). PET scans show different areas of the brain light up with different types of meaning. These two criteria, sense and meaning, are not dependent on each other. Many people can remember details which make sense, but may not have any personal meaning for them. Making meaning is the more powerful for memory. The highest probability for transferring and item to long-term storage is when both sense and meaning are present.

Time is also necessary to transfer items into long-term storage. If an item has been stored, it will be recalled accurately after a period of time. A good guideline is 24 hours. Sometimes only parts of an item will be remembered. Memories are stored at different sites within the brain. Researchers do not know how many there are. "Researchers such as Steve Rose (1992) demonstrate that long-term memory is a dynamic, interactive system that activates storage areas distributed across the brain to retrieve and construct memories" (Sousa, 1995, p. 19).

With more information available educators will be better able to meet the needs of students. Several learning principles have been derived from neuroscience, cognitive and behavioral research. In their article Caine and Caine (1990) outline twelve principles gained through brain research. From these principles they have made applications to education.

Research has found that the brain is capable of performing many tasks at one time, and it is continually absorbing information from the environment. The brain of the learner is busy. The brain receives input, stimuli, which becomes a nervous impulse that is sent by way of neurotransmitters through connections to the sorting station, the hypothalamus, and then on to specific areas of the brain where it can be acted upon (Jensen, 1998). Pat Wolfe (1998) states, "There is actually no such thing as a student who is not paying attention. The student's brain is always paying attention to something although it may not focus on relevant information or on what the teacher intends" (p. 62). Jensen (1998) would agree that the brain is constantly processing stimuli from the environment. Therefore, the teacher should use a variety of methods in the classroom, drawing in those students who need a different modality of learning to allow the opportunity for all students' brains to function.

Schools and teachers are more and more addressing issues of health as well as education. Researchers are finding that learning engages the entire physiology, the second principle (Caine and Caine, 1990). A student whose brain is concerned about outside issues doesn't give the needed attention to learning. Emotions also influence learning by facilitating storage and recall. Therefore it is vital that the teacher and school system provide a safe and secure environment.

Principle three addresses the brain's need for challenge and relevance (Caine and Caine, 1990). As students seek to learn, their brains naturally seek meaning. If the material is viewed as irrelevant, the student will have difficulty learning it. The brain is naturally curious and wants challenge. Therefore the environment needs familiarity as well as novel challenges to show relevance and meaning. Jensen (1998) would agree that challenge is necessary and states, "Frequent new learning experiences and challenges were critical to brain growth" (p. 31). Challenge is increased with new information or new experiences. The author goes on to suggest challenge can be provided through problem-solving, thinking, surroundings, and motor stimulation.

The brain also searches for meaning through patterning and making connections to already learned material (Caine and Caine, 1990). This fourth principle declares that as the brain learns, it looks at complex skills and seeks to understand the parts that make up the skill while also understanding how each part is related to forming the whole skill. This is why the teacher needs to activate a student's prior knowledge, begin with concrete concepts and lead students toward more abstract concepts and application of new skills. It is also important to provide immediate, interactive feedback so that motivation stays high and students continue to strive for that understanding.

Emotions play an important role in learning. In the fifth principle, the authors discuss how strong emotions set events into memory. Focus is placed on the teacher-student relationship. When the classroom climate is respectful and supportive, learning will take place. Teachers cannot ignore the fact that emotions are necessary for learning.

> Under certain conditions, emotions can enhance memory by causing the release of hormones that stimulate the amygdale to signal brain regions to strengthen memory. Strong emotions can shut down conscious processing during the event while enhancing our memory of it. Emotion is a powerful and misunderstood force in learning and memory. (Sousa, 1995, p. 13)

Principle six looks again at the complexity of brain functioning. The human brain can understand both parts and wholes. A teacher needs to be sure to break concepts down into it parts, as well as give students opportunity to work with the whole, creating new pieces. The school-aged student's brain burns glucose at 225% of the adult brain. It is necessary during this time of activity to provide stimulation, repetition, novelty. "Good quality education encourages the exploration of alternative thinking, multiple answers, and creative insights" (Jensen, 1998. p. 16). These are essential to laying a firm foundation for later learning (Jensen, 1998).

Learning involves the focus of students as well as nuances in the environment. Principle seven states that the brain is constantly processing information from all the senses as well as the subject upon which the student is focused. Focus therefore becomes important to education. It is also important to understand the cycles of attention which happen throughout the school day. The length of a cycle is about 90-110 minutes. Intense attention can only be sustained for approximately ten minutes. New learning needs to be introduced during times of high focus with time allowed for processing. The brain needs time for connections to form without competing stimuli. Students also need a five to ten-minute break every hour and a half (Jensen, 1998). Jensen (1998) points out that attention has two purposes: to promote survival and to extend pleasure. Since students' brains are consciously and/or unconsciously choosing what stimuli to attend to and what stimuli to suppress, learning needs to be relevant and satisfying to sustain focus. Body language becomes very important in this area. A teacher needs to infuse enthusiasm, acceptance, encouragement, and much more into interactions with students. The environment is constantly being processed, so students would benefit by objects, pictures, and posters that support the subject being taught. The brain is noticing all its surroundings so teachers should take full advantage.

Students are often unaware of all the processing taking place within their brains. A student may solve a problem but not be able to explain how he solved it or why the answer is correct. The eighth principle states that learning involves both conscious and unconscious processes. To help students key into the processes performed within their brains, reflection and metacognitive activities should be used. Learning is enhanced when students become aware of these processes. Reflective journals are one valuable tool to enable students opportunities for metacognition.

Principle nine explains the two types of memory. Spatial memory stores our experiences. It is always on the job. This memory does not require rehearsal or practice. On the other hand is the rote memory system. This is the storage of unrelated facts. Caine and Caine (1990) argue that to rely too heavily on this rote system is to cheat the learner. When learning takes place in the spatial memory system, understanding is the result.

Closely related to principle nine is principle ten. The brain recalls content and skills best when they are embedded in spatial memory. "Embedding is the single most important element that the new brain-based theories of leaning have in common" (Caine and Caine, 1990, p.69). Content and skills that are taught in real life situations are learned best. Educators need to include as many of these activities as possible.

Principle eleven is that learning is increased with challenge but decreases with threat. When the brain perceives threat, it must deal with it and the focus shifts to survival. Bullying has become an important issue in schools. Educators need to be alert to bullying and create a safe environment. While eliminating threat is important, challenging the brain is equally important. The brain is constantly striving to form meaning and if the material is seen as meaningless, learning decreases.

The final principle discussed in Caine and Caine's (1990) article is that each brain is unique. If everyone looks different, has a unique DNA, has different experiences shaping the brain, and that not two people are alike (Yero, 2001-2), it stands to reason that students will learn differently and will mature at different rates.

The number of genes and genetic variations that produce differences in physical appearance and ability are minuscule compared to the possible permutations in the way individual brains process information. Given that no two individuals have lived through the same experiences—experiences that modify both the neurons and their connections—the potential cognitive differences among human individuals is staggering. (Yero, 2001-2, pg 2)

Another important aspect of teaching and learning discussed in Jensen's book (1998) is motivation. In an experiment rats constantly sought new and novel experiences. Jensen refers to Restak's (1979) work showing that humans also seek novelty. New and novel learning catches the students' attention and builds intrinsic motivation. Sometimes students need help becoming motivated learners. Jensen (1998) suggests ways to improve student motivation, as well as, ways students are demotivated. The first step for a teacher to take is to eliminate threat. As already discussed, when a student feels threatened, parts of the brain are needed to deal with the threatening issue as opposed to dealing with learning. The environment needs to be a place where students can take risks without fear of humiliation. Past failures can be threatening and also contribute to a student's lack of motivation. The teacher and student need to rethink and build positive beliefs about himself as a learner. An important tool to build a positive self belief is goal-setting. Goals should be made small and obtainable. When the goal is reached, the student feels successful and is ready to tackle the next challenge. In addition, how a student pictures his future affects motivation. If education is seen as a means to a secure future, that student will build intrinsic motivation for his learning. A tool often used by teachers intending to increase motivation is a reward system. Jensen (1998) maintains that rewards demotivate rather than motivate. He points out that

> Neuroscientists take a different view of rewards. First, the brain makes its own rewards. They are called opiates, which are used to regulate stress and pain. These opiates can produce a natural high, similar to morphine, alcohol, nicotine, heroin, and cocaine. (Jensen, 1998, p. 65)

Achievement releases chemicals that make a student feel good.

Discussion

Summary

Neuroscience is making great strides in uncovering the secrets of the brain. The most relevant and amazing aspect of the brain is its plasticity and the fact that experience changes the brain causing the cortex to thicken with dense dendrite growth and numerous synaptic connections which are protected and strengthened with a myelin sheath. People can continue to learn throughout life. We now have a better idea of learning and what it takes to move knowledge into long-term memory.

Researchers urge caution when generalizing the findings of neuroscience to the general public. More evidence and testing needs to be done in many areas before this can be done. Educators need to look deep into the research and understand what the results of experiments are really showing before application can be made. However, when this knowledge is combined with known facts learned from other disciplines studying the working of the brain, educators have a powerful tool to use in the classroom.

Implications

Experience is a great teacher. We've all heard this saying many times and probably have even said it ourselves. For it is a true saying. In his book, *Disappointment with God*, Yancy

(1988) discusses the historical account in the book of Genesis and narrows the theme down to "God learns to be a parent (p. 61)." My first reaction to that was to disagree with his statement. After all, how can an omniscient God learn? The traditional concept of learning has the idea of not knowing something before discovering truth.

Learning as experience was the idea Yancey (1988) was driving at when he said the God 'learns'. In his footnote he explains himself.

> A phrase like "God learns" may seem strange because we normally think of learning as a mental process, moving in sequence from a state of not-knowing to a state of knowing. God, of course, is not bound by time or ignorance. He 'learns' in the sense of taking on new experiences, such as the creation of free human beings. Using the word in a similar sense, Hebrews says that Jesus "learned obedience from what he suffered". (p. 61-2).

The look inside the brain through neuroscience has given educators a different definition of learning. Experience changes the physical brain by building and pruning synaptic connections.

Children are created by a loving God with a vast potential. As parents, teachers, or role models, adults are responsible to guide those whom God has placed in their lives. Since life experiences shape the child's brain, the job before Christian teachers is an awesome task. The task calls for a skillful understanding of the needs of students. The study of the brain has given teachers important information and tools to use in their craft.

Three of the concepts gleaned from neuroscience are synaptogenesis, critical periods and enrichment. It is important to recognize that throughout life the brain continues to build new and strengthen already existing connections while pruning unused ones. Each time a connection is made, the stronger it becomes. Therefore, repetition is necessary: Repetition isn't just rote repetition. Students need to interact with material in a variety of ways, such as reading about the subject, then writing something about it, and even using the material in problem-solving.

Children are at an advantage in learning, and can learn with more ease than older people. Even in upper elementary grades the rate of building synaptic connections is much greater than later in life. With this in mind, the curriculum should be rigorous and challenging for the young brain.

The environment in the classroom needs to be safe for the student. If the student feels threat, the brain will downshift. A student will be unable to think or will be unwilling to take risks to learn in a threatening environment. As image-bearers, students are valuable and precious. The teacher needs to communicate through her actions and words acceptance and love to students in the classroom. The teacher also needs to keep the curriculum high in challenge but low in threat.

The classroom environment also needs to be an enriched environment. An enriched environment provides the stimulation needed to grow and learn. Enrichment can happen through several avenues using a variety of modalities. Processing material through as many modalities as possible allows the brain to build meaning, make connections to prior knowledge, and build synaptic connections.

An important tool for stimulation is verbal interaction. Students need to be provided with opportunities to process information verbally either in cooperative groups with other students or through classroom discussions. Also, adult-student interactions are important for healthy growth. Some other places to enrich the environment would include movement, problem-solving, music, or art. Enrichment is also provided through a relevant and challenging curriculum.

Some children find it difficult to sit in a hard chair all day long. Physical activity needs to be included in lessons to allow for those who need enrichment through movement. Role-playing is an excellent way to include movement into a lesson.

The brain is bombarded continuously with stimuli through all the senses. As messages from the stimuli are sent to the brain, it sorts through the stimuli and distinguishes between the information, determining which to ignore and which to attend to. Included in each lesson should be a mechanism for guiding that attention. A guiding question or a mention of something to look for helps the student focus on the relevant information. Activating prior knowledge gives the brain 'hooks' to hang new information on.

The brain also seeks sense and meaning. By making sense, we mean, is it understandable and does this new learning fit with what is already known. Meaning is referring to the relevance to the student's life. I appreciated Jensen's (1998) point about making meaning when he suggested that less time be spent on planning the sequence of the lessons and more time spent on making meaning. With the uniqueness of individual children instruction needs to be varied and differentiated. The use of data to drive instruction allows for lessons to be tailored to the students' needs. With the brain's need for sense and meaning, time for students to explore and build meaning needs to be implemented.

Curiosity is an important element to learning. It holds a student's focused attention which is important to the learning process. Children actively ask questions and seek answers to satisfy this curiosity. A teacher needs to tap into the curiosity of the children. Student choice allows for this. In addition, the teacher should model his or her own curiosity to pull in the reluctant learners. Whenever possible, lessons should include engaging real to life activities which holds a natural allure for students.

Students are the best monitors of their own learning. Time needs to be given for reflection and metacognition. Students also need immediate feedback on their work. Feedback allows students to reflect intelligently on their work as well as boosting confidence and reducing threat.

Along with the new definition of learning and the understanding about forming connections in the brain comes the knowledge that every student whom God places in a teacher's classroom can learn. Not all children learn at the same rate or even build the same knowledge, but all of them can learn. A teacher should never give up on a child.

Limitations

Neuroscience is giving support for principles of learning. The discovery of the role of environment fuels the discussion about early childhood education.

While neuroscience is making many strides towards understanding the workings of the human brain, it still has many limitations. The tools used in research are not good enough to see exactly what is going on in the brain. PET and fMRI while they provide a spatial resolution of millimeters, the speed is slower than the human brain. The EEG, ERP, and MEG's do the opposite. They record changes quickly but the spatial resolution is only in centimeters (Bruer, 1997). In order to see the workings of the brain in real time, the tools will need to become more sophisticated.

Another limitation is that the use of these machines requires a radioactive solution to be introduced into the bloodstream of the patient or test subject. Ethically, scientists are bound to do nothing harmful. Therefore, much of the research is conducted on patients who have a disease or a condition requiring these tests. Using information gained from unhealthy subjects requires much care when generalizing the findings to the general public.

Neuroscience is such a new field of research that scientists are unsure of the implications for education. Time is needed to continue running tests. The scope of discoveries hasn't yet begun to address the entire realm of brain functions during learning.

The recent discoveries, however, are exciting and encouraging. Cognitive and behavioral sciences have given educators many effective pedagogies. New discoveries from neuroscience can only enhance our understanding of learning.

References

Abbeduto, L. (2002). *Taking sides: clashing views on controversial issues in educational psychology. (2nd Ed).* Guilford: McGraw/Hill.

Behavioral science. (n.d.). *The American Heritage Dictionary of the English Language, Fourth Edition.* Retrieved July 24, 2009, from Dictionary.com website: http://dictionary.reference.com/browse/behavioral science.

Blakemore, S. (2007, August 10). Why it's never too late to grow. *Times Educational Supplement*, Retrieved August 19, 2009, from Teacher Reference Center database.

Bruer, J. (1997). Education and the brain: a bridge too far. *Educational Researcher*, vol. 26, No 8, 4-16. Retrieved June 6, 2006 from EDSCO Publishing online database.

Bruer, J. (1999, May). In search of …brain-based education. *Phi Delta Kappan*, 649-657. Retrieved June 6, 2006 from EDSCO Publishing online database.

Bruer, J. (1998). Brain science, brain fiction. *Educational Leadership*, *56*(3), 14. [Electronic Version]. Teacher Reference Center database.

Byrne, B., Delaland, C., Fielding-Barnsley, R., Quain, P., Samuelson, S., Høien, T., et al. (2002). Longitudinal Twin Study of Early Reading Development in Three Countries: Preliminary Results. *Annals of Dyslexia*, *52*49-73. Retrieved from Professional Development Collection database.

Byrnes, J., & Fox, N. (1998, September). The educational relevance of research in cognitive… *Educational Psychology Review, 10*(3), 297. Retrieved June 15, 2009, from Teacher Reference Center database.

Caine, R., & Caine, G. (1990, October). Understanding a brain-based approach to learning and teaching. *Educational Leadership*, 48(5), 66. Retrieved June 6, 2006 from EBSCO Publishing online database.

D'Arcangelo, M. (1998, November). The brains behind the brain. *Educational Leadership, 56*(6), 20. Retrieved June 6, 2006 from EBSCO Publishing online database.

Diamond, M., & Hopson, J. (1998). *Magic Trees of the Mind.* New York: A Plume Book.

Flohr, J., Miller, D., &Debeus, R. (2000, September), EED studies with young children. *Music Educators Journal,*87(2), 28. Retrieved June `5, 2009, from Teacher Reference Center database.

Goswami, U. (2004, December 1). Neuroscience, Education and Special Education. *British Journal of Special Education 31*(4), 175-183. (ERIC Document Reproduction Service No. E1685444) Retrieved June 15, 2009, from ERIC database.

Jensen, E. (1998). *Teaching with the brain in mind.* Alexandria, VA: Association for Supervision and Curriculum Development.

Katzir, T., & Paré-Blagoev, J. (2006, January 1). Applying Cognitive Neuroscience Research to Education: The Case of Literacy. *Educational Psychologist, 41*(1), 53-74. (ERIC Document Reproduction Service No. EJ733703) Retrieved June 15, 2009, from ERIC database.

Kotulak, R. (1997). *Inside the brain revolutionary discoveries of how the mind works*. Kansas City, MO: Andrews McMeel Publishing.

Kwon, Y., & Lawson, A. (2000, January 1). Linking brain growth with the development of scientific reasoning ability and conceptual change during adolescence. *Journal of*

Research in Science Teaching, 37(1), 44-62. (ERIC Document Reproduction Service No. EJ598052) Retrieved August 11, 2009, from ERIC database.

Mackey, A. (2006, June 1). Epilogue: From introspections, brain scans, and memory tests to the role of social context: advancing research on interaction and learning. Studies in Second Language Acquisition, 28(2), 369-379. (ERIC Document Reproduction Service No. EJ777397) Retrieved august 11, 2009, from ERIC database.

Restak, R. (1979, 1988). *The brain.* New York: Warner Books.

Sousa, D. (1995). *How the brain learns.* Reston, VA: National Association of Secondary School Principals.

Wolfe, P. (2001). Brain research and education: fad or foundation? *Brain Connection*. Retrieved June 16, 2006 from the World Wide Web: http://www.brainconnection.com/content/160

Wolfe, P. (1998, January 1). Revisiting effective teaching. *Educational Leadership, (56)*3, 61-64. (ERIC Document Reproduction Service No EJ575234) Retrieved August 11, 2009, from ERIC database.

Yancey, P. (1988). *Disappointment with God.* Grand Rapids, Michigan: Zondervan.

Yero, J. (2002). Myths about learning. *Teacher's Mind Resources.* Retrieved June 16, 2002 from the World Wide Web: http://www.TeachersMind.com

Lisa J. Ihnen

4815 NW Irvindale
Ankeny, IA

Education

Reading Endorsement K-6, Upper Iowa University (2007)

B.A. Elementary Education, Faith Baptist Bible College (1988)

Academic Employment

Teacher (5), Van Meter Community Schools, Van Meter, IA (2006-present)

Teacher (varied grades), Ankeny Christian Academy, Ankeny, IA (1995-2006)

Academic Awards

Teacher of the Year (2000)

Professional Memberships

Professional Educators of Iowa