Advances in Brain Research: Implications for Educators

Paper presented at the Michigan Academy of Science, Arts & Letters

March 5, 2005

Sue A. Stickel, Ph.D.

Professor, Department of Leadership and Counseling

Eastern Michigan University

Ypsilanti, Michigan 48197

Abstract

Cognitive neuroscience will provide theoretical foundations for areas of educational policy and practice. Educators will benefit from knowledge in the basic sciences related to brain development and function. Brain development begins at birth and the brain remains capable of complex changes throughout the lifespan. Educators will want to be aware of advances in brain research and to work on effective instructional processes and policies supported by research.

During The Decade of the Brain (1990-1999), scientists expanded knowledge about how we learn and develop. 21st century educators will be able to use new information to improve educational practice. New knowledge will continue to revise our concepts of child development, instructional practice, and biocultural diversity. New understandings may influence educational policy in areas such as assessment, progress through the educational system, and intervention with educational problems. Educators will need to understand the terminology and general principles related to how the brain develops, brain architecture, and how these relate to school based learning. The emerging field of cognitive neuroscience may eventually provide theoretical foundations for areas of educational practice with implications for teacher education and continuing staff development.

Brain Anatomy

A detailed knowledge of the physiology of the brain is probably not necessary for educators, however a basic knowledge of brain anatomy provides a conceptual framework for how the parts of the brain function together. The triune brain model developed by the neuroscientist Maclean in the 1950's, which divided the brain into three parts, provides a simple framework (Sprenger, 2002). The brain stem located at the base of the skull controls survival functions such as heart rate, respiration, and "fight or flight" reactions. The limbic brain controls hormonal functions and emotions and also helps with memory storage. Factual material storage is facilitated by the hippocampus, emotional material by the amygdala. This part of the brain seeks homeostasis and until balance is achieved it will inhibit information from then flowing to the cerebrum. The cerebrum is divided into right and left hemispheres and has a coating of myelin. The neocortex covers the cerebrum and houses logic and reasoning and higher order thinking functions. Restak (1995) describes the brain as “modular”, a large number of separate elements that are linked together. The hemispheres are divided into the occipital lobe that processes visual information, the temporal lobes processing auditory information and some memory and the parietal lobe processing feeling and touch. The frontal lobe specializes in decision-making planning and problem solving.

Neurons are the fundamental cells of the brain and neuroscientists estimate that the brain contains between 100 billion and 1 trillion such cells (DuPont, 1997). Humans are apparently born with “prewiring” for certain abilities such as oral language and simple mathematics. At birth the brain is not a blank slate and not all neurons survive. Brain development is characterized by periods of “pruning”, a paring back of neurons, which continue through adolescence. Myelination, whereby a sheath speeding the transmission of chemical information is formed around each neuron, is also a maturational process continuing into young adulthood. Neurons communicate by means of chemical neurotransmitters. Communication takes place through a lock and key relationship specific to each neurotransmitter, which is then associated with specific brain functions. Neurotransmitters function as “local messengers” working from a single cell. Hormones produced in the midbrain are the “long distance messengers” carried by the blood stream to other areas of t he body. These chemical influences are complex.

The brain functions as a whole and many parts of the brain are involved when we perform even a simple act. For example, we now realize that that the notion that individuals specialize in either right or left brain functions is too simplistic (Sprenger 2003, Wolfe 2001). Through imaging technologies, we are now able to study the working brain in action and need no longer rely on information only from autopsies or specific brain damage. Scientists are now actively studying the non-damaged brain. Most students will have normally developing brains making this information eventually more widely useful. Berninger and Richards (2002) hypothesize that learning probably involves specific kinds of changes in the neuronal connections in the learner's brain. Learning becoming a complex process of rapidly changing connections and pathways involving which, how many, how loudly, and in what temporal and spatial configruations neurons are "talking" to each other. Sprenger notes that development of each area of the brain must be considered as we decide what to teach and how to teach it. For example, to get students attention we must first deal with parts of the brain that control emotions before reaching the frontal lobes where higher order thinking takes place.

Development

Brain development begins prior to birth and the brain grows in stages (Schenck, 2003). To date, research has not addressed a relationship between growth in-utero and learning. However, a developmental process involving the innate neuroplasticity of the brain begins at birth. Immense changes at the cellular level will underlie the child's capabilities (Schwartz & Begley, 2002). For example, newborns can hear all the sounds that make up languages, however with enough repititions of a sound synapses will be strengthened that respond specifically to that sound. The neonatal brain overproduces synapses, which are pruned away or strengthened by stimulation and other maturational processes through childhood and adolescence. The current belief is that those that are not used or underused become eliminated (Schenck, 2003), perhaps underscoring the need for appropriate stimulation. Greenberg and Snell (1997) note that there has been no experimental data illustrating how educational experience specifically alters brain structure, however education should be considered a critical influence and teachers seen as facilitating the continuing process of neural integration as the child develops.

In the process of brain development certain functions may have developmental windows or critical periods during which they are best learned. For example, binocular vision appears to have a critical period prior to age four (Berninger & Richards, 2002). They also note that reading may have a critical early developmental window when relevant sensory systems such as vision and hearing are developing. Blakemore and Frith (2005) note that a main research implication is the importance of identifying and treating children'sensory problems such as vision and hearing difficulties. Although the critical period for the development of sensory and motor systems may peak prior to formal schooling, the window for development in the brain's cortex is open during middle childhood and adolescence when teachers can make a difference in helping the development of higher level thinking skills.

For example, a critical window for the most successful acquisition of a second language is perhaps prior to the 5th or 6th grade (Rushton & Larkin, 2001). They recommend that children need enhanced opportunities to interact with materials, peer, and ideas in order to build long-term memories. Hansen and Monk, (2002) have summarized the evidence which includes the following (a) maturation and changes occur in the brain up to late adolescence and early adulthood, (b) periods of growth may suggest that brain maturation is key to the timing of when individuals are ready for the "next stage", (c) children may be processing information differently at different stages of brain development, (d) there are suggestions of gender differences, and (e) increased myelination is being linked with improved cognitive processing. Blakemore and Frith (2005) describe the advantage in being exposed to more than one language from birth and the need for social interaction for new language learning following the critical window. Schenck (2003) developed an extensive table of developmental findings but cautioned that the entire table should be considered as tentative, subject to constant revision as new findings become available.

Biocultural Diversity

Berninger and Richards (2002) note that teachers are not able to undo the diversity that nature has woven into both our brains and our social environments. We have tended in schools to focus on student's talents in literacy and numerancy as the foundation of a basic education. Schenck (2003) explains that Spearman's g, as the traditional measure of intelligence, has been a major gatekeeper for advancement in our school systems. However these measures are able to predict only 15% to 25% of an individual's academic success. Gardner's multiple intelligences probably provide a better conceptualization of the brains complexity and the wide variety of ways in which humans learn. Given this complexity and brain modularity, Sprenger (2003) incorporates these eight intelligences along with visual, auditory, kinesthetic modes of learning and "memory lanes" such as semantic memory (e.g. lists and words) and episodic memory, a type of factual memory.

Goleman's (1995) book Emotional Intelligence brought to the forefront the strong influences of emotion with learning and the importance of developing skills to manage emotional lives in order to become productive citizens. These skills involve reading and understanding our own emotions, those of others and how these operate in a cultural context. From what we know of brain development, the frontal lobes which control much of reason, logic and emotional control are the last to reach maturity, perhaps as late as a person's early 20s. Greenberg and Snell (1997) summarize the implications for educators including: (a) the quality of both teacher and peer to peer interactions impacts brain development, (b) education is a critical influence on strengthening neocortical control and self awareness, maintaining attention and managing affect, and (c) patient attention to children's emotions will lead to improved personal and academic outcomes.

The notion that developmental disorders are caused by subtle brain abnormalities is not yet generally accepted (Blakemore & Frith, 2005). However, brain scans have noted differences in activity in students diagnosed with depression and attention deficit disorder (Sprenger, 2002). Casey, Giedd, and Thomas (2000) point to the importance of the development of the prefrontal cortex with regard to implications for disorders that are identified with cognitive processes of memory and attention such as Attention Deficit-Hyperactivity Disorder, and Autism. Teicher (2002) noted that recent research has indicated that early experiences of abuse and neglect can result in permanent damage to the neural structure of parts of the brain regulating memory and emotion. Teicher hypothesizes that adequate nuturing and the absence of intense stress permits the brain to develop in a way that is less aggressive, more emotionally stable and more capable of building more complex interpersonal structures.

The day may come when brain-imaging techniques will become common in diagnosing the brain differences that result in educational problems (Wolfe, 2001). To date Fast Forward, a reading program developed from research on brain plasticity and processing of spoken language has shown success with students diagnosed with a specific kind of learning disability (Brandt, 1999). However current reality more closely approximates Schenck's observation that diagnostic processes are often lengthy and costly and still are often unable to tell us what to do or what to avoid. He as well as Blakemore and Frith (2005) favor the notion that we must search out alternative pathways and avoid teaching and assessing in only one way. Students can better demonstrate knowledge and skills with several ways to both retrieve information and demonstrate their knowledge. Sprenger (2002) underscores the importance of locus of control as one of a student's basic needs. The more that teachers and students collaborate on goals of learning and performance the more optimal the learning environment.

Educational Policy

Bruer (1997) cautioned that we cannot as yet go directly from brain research to lesson plan or conversely to educational policy in a single leap. However, new knowledge of such magnitude will undoubtedly support certain practices and transform others. Berninger and Richards (2002) identify among others, school entrance age, educational diagnosis, and teacher education as areas of impact from brain research. Sousa (1998) identifies the need for more public funding for early childhood education, the need for schools to be physically and emotionally safe, engaging and interesting. As the rate of knowledge increases exponentially, the notion that learning how best to learn is more important that learning a particular knowledge base especially when learning everything is impossible (Sprenger, 2002). School structures will need to accommodate advancing knowledge of how learning takes place through different stages of development and a fuller understanding of human differences in how learning takes place.

Ultimately knowledge of the neurobiology of the brain will provide foundations for more of our educational theory. Blakemore and Frith (2005) point to a new interdisciplinary science of learning informed by neurophysiology, psychology, and education. Berninger and Richards (2002) describe how medical education benefited early in the 20th century from the addition of coursework in basic sciences such as biology and chemistry. Medical practice became more effective and enjoyed increased status. Those who understood the basic scientific principles rose to the top of the medical hierarchy as science-based practices became effective. Despite the fact that brain research is not yet able to guide practice and that we will pursue unproven routes, pre-service teachers will benefit from coursework in such basic sciences as cognitive science, neuroscience and linguistics. Berninger and Richards (2002) advocate this foundation as providing a stronger conceptual framework for understanding the learning process and generating classroom alternatives. As we are struggling for ways of improving student achievement and coping with challenges in student behaviors and learning differences we may have tapped out innovations that could come from current models.

Brandt (1999) notes that information from brain research cannot provide definitive answers to practical educational queries such as. why students are unable to remember what they have been taught, transfer learning from one situation to another, or do things for reasons they are not completely aware of. However, as educators we will need to be increasingly aware of the rapid advances in brain research and work to develop the instructional processes that are most effective based on this research. For now research seems to be telling us that the brain is enormously complex and that learning is a developmental lifelong process involving growth, individual variation, creativity and the capacity to change.

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