Middle School Journal Research Articles

Implications of Brain Research for Teaching Young Adolescents

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Research in the field of neuroscience has exploded in the past decade. During that time, educators have become fascinated with the implications of connecting knowledge of how the brain works with teaching and learning in the classroom. Conclusions as to how the brain works are based either on basic research conducted on rodents or the use of Magnetic Resonance Imaging (MRI) on patients who have some anomaly. While these methods are very different from educational research, educators can benefit by what neuroscience is discovering about the functioning of the brain. Two areas of current interest for middle level educators are brain maturation during the adolescent years and possible gender differences in how adolescents learn.

How the brain works

The central nervous system is made up of two major classes of cells, neurons and glia. Though glial cells outnumber neurons and have roles critical to proper brain function, neurons have been the major focus of most neuroscience research. *Neuronal* cells have special properties that allow them to receive and send information, encoded as patterns of electrical and chemical activity, within the brain. Special projections of neurons, called *dendrites*, receive signals from many other cells, integrate these signals over time and pass this information on to a specialized output process, the axon. Properties of the axonal membrane allow this information to be encoded in an electrical signal called an *action potential* that propagates down the length of the axon. Axons in turn make contact with the dendrites of many other neurons, thus beginning this process over in a new cell.

The point of contact between dendrites and axons is highly specialized and is known as a *synapse*. Synapses are of great interest to neurobiologists since it is at this point that information can be modulated before it is passed on to the dendrites of the next cell. Synaptic modulation is thought to be the basis for several complex properties of the brain such as learning and memory. Once an action potential reaches a synapse, it results in the release of chemicals called *neurotransmitters*. These transmitters cross the small space between axon and dendrite, bind to special receptors on the dendritic side of the synapse, and create electrical potentials in the dendrites.

Because synapses are central to the process of communication in the brain, neuroscientists have naturally investigated many of their characteristics including how they form in young, developing

brains. In fact, the number of synapses is taken as a measure of the complexity of neuronal circuitry. Research in monkeys has shown that the synapse number increases as they mature. Surprisingly, this work has also shown a subsequent and dramatic decline in synapse number during puberty (Bourgeois, & Rakic, 1993). Complementary research has found that young animals raised in "enriched" environments develop abnormally complex neurons with a higher than normal density of synapses (Jones, Klintsova, Kilman, Sireyaag, & Greenough, 1997; Volkmar & Greenough, 1972). Though neuroscientists do not have a full understanding of why this occurs, the general conclusion is that adolescent brains go through a period of circuit refinement, pruning unused connections and strengthening more heavily used synapses. For example, if an animal were to grow up in a visually rich, but silent environment, neuroscientists would expect to find a high level of complexity in the circuits of visual areas of the brain while the auditory areas of the brain would have simple or even abnormally reduced circuit complexity.

This growth spurt just before puberty and then the pruning of unused connections in human adolescence is most predominant in the prefrontal cortex, the part of the brain critical to information synthesis. Two other areas, the hippocampus and the amygdala, also increase in volume as children develop. Interestingly, hippocampal volume increases with age for females while amygdala volume increases with age for males (Giedd, et. al., 1996, p. 243). In contrast, many other areas of the brain, such as the temporal lobe, appear relatively stable in volume throughout late childhood and adolescence. Thus, the prefrontal cortex appears to be the last region of the brain to mature (Casey, Giedd, & Thomas, 2000), undergoing major changes throughout puberty—a finding with significant implications for classroom practice.

The prefrontal cortex is the area of the brain controlling planning, working memory, organization, and mood modulation. This area of the brain is not mature until about 18 years of age (Spinks, 2002). This finding may come as no surprise to middle level educators, but apparently it did to neuroscientists. The scientific hypothesis is that this growth and then pruning is an important stage of brain development that can influence learners for the rest of their lives (Casey et al, 2000; De Bellis, et al, 2001). The saying "use it or lose it" applies to brain growth during early adolescence. Giedd warned that "if a teen is doing music, sports or academics, those are the connections that will be hard wired. If they're lying on the couch or playing video games or MTV, those are the cells and connections that are going to survive" (Spinks, 2002, p. 2). Both parents and educators have an obligation to enrich adolescents' environment and to strengthen those connections that will be in teens' best interests later in life.

Many educators have tackled this new research and have posited strategies and methods they believe enhance learning and memory. Wolfe (2001) who has written extensively on brain research and methodology cautioned educators that "rarely does neuroscience prove that a particular classroom strategy works, but the information coming from the neurosciences certainly can provide a more informed basis for the decisions we make in our schools" (p. 11). Educators who write about brain-based instruction (Beamon, 1997; Brandt, 1998; Caine & Caine, 1994; Jensen, 1998; Sousa, 2001; Tileston, 2000; Wolfe, 2001) have provided educators with a wealth of information on how the brain works, how certain strategies can get and hold attention during instruction, and methods for improving memory storage.

Implications for the classroom

If the activity in the prefrontal cortex is where memory, attention, and inhibition are altered as a result of synaptic pruning, certain strategies and methods seem feasible to apply to classroom

instruction. Inhibition here means that the brain actually uses inhibition to eliminate distracters when it does want to pay attention. Paying attention by screening outside distractions then leads to better memory storage. Neuropsychologists agree that the way to hold attention in young adolescents is through sensorimotor experience (Davis, 2001; Kolb, 2000; Wilson, 2001). Teachers need to engage the senses and emotions to gain students' attention for learning, not just for the moment, but also for interest throughout an entire unit of study. Music, smell, touch, and emotion can focus students on learning. Another approach combined with sensorimotor engagement is that of inquiry or problem-based learning (Kwon & Lawson, 2000; Montgomery & Whiting, 2000), which teachers can use by encouraging students to ask questions that interest them after initially engaging in the problem of the unit. Using essential questions to frame the unit, incorporating the senses and emotions to focus the learning, and then facilitating students in finding multiple ways to solve problems can focus adolescent learning while building complex neuron connections within the brain.

Classroom activities that are most compatible with attention and memory are

- Designing project-based units of study where students ask critical questions and then develop their own projects to find the answers, such as interviewing people who have experienced the Great Depression or the Holocaust.
- Using simulations to involve students in understanding various points of view or discussing complex ethical issues.
- Playing music that links memory to specific learning tasks. Rythmic patterns are effective memory tools for learning, and music is a great medium for facilitating young adolescents to make sensorimotor connections.
- Having students write reflectively every day to reiterate and consolidate learning.
- Posing visual and word problems or puzzles to challenge thinking so that students learn that there are many ways to solve a problem or puzzle. This type of thinking strengthens the neural connections and gives students more confidence in their abilities to tackle problems.
- Using physical challenges to solve problems and build collaboration. Low ropes courses and other physical/mental problem solving involve the mind and body in learning and team building.
- Involving students in real-life apprenticeships. Students shadow workers in various jobs or learn skills in a short internship that either connects to an area of study or helps them understand one of the problems they have posed themselves and are interested in finding answers.
- Using peer collaboration or cooperative learning helps broaden students' understanding of issues and promotes group problem solving.
- Developing integrated curriculum that encourages students to raise issues and concerns and then weaves those thematically into all disciplines.

These recommended practices (Beamon, 1997; Brandt, 1998; Caine & Caine, 1994; Jensen, 1998; Sousa, 2001; Tileston; 2000; Wolfe, 2001) have been implemented in middle school classrooms for many years as ways to connect the curriculum with the personal experiences of young adolescents. Relevance has always made intuitive sense to teachers; an awareness that relevance also has a practical and logical connection to the process by which the brain makes meaning supports the use of such practices.

Gender, competition, and stress

Studies on the differential effects of stress on the brain for adolescent males and females (Nishio, Kasuga, Ushijima, & Harada, 2001; Shors, Chua & Falduto, 2001; Wood & Shors, 1998) may have important implications for middle level classroom instruction. Exposure to stress seems to have opposite effects on males and females. Testing on rodents has demonstrated that in females, stress inhibits learning, yet it actually facilitates learning in males (Wood & Shors, 1998). Many teachers set their classrooms up to use competition as an incentive for learning. For males, if this competition creates stress, the implication is that they would be more receptive to the learning. For females in puberty, that same stress may produce a negative response to the learning experience. Timed math games, for instance, may produce the desired effect on boys, but inhibit learning in girls. In addition, prolonged stress apparently can produce long-term negative responses (Shors, Chua & Falduto, 2001) and lead to structural changes in neurons in the hippocampus that may facilitate learning in males but inhibit it in females

Simply knowing the different responses to stress should cause educators to rethink the way they structure the classroom environment. For all students a physically and emotionally safe environment is essential (Brandt, 1998; Jensen, 1998; Wolfe, 2001). Free from belittling and humiliation, students should find it acceptable to make mistakes or take risks in the classroom. Teachers should not judge students by their mistakes, but by their successes.

Stress can be used with those who seem to thrive on it—and this may not always be males vs. females—by choosing them to participate in any competitive events the teacher may structure. Certainly competitive games can be fun in the classroom and knowing that they also facilitate learning justifies their use. But the teacher should also be careful that she does not overuse these strategies so that the females in the class become discouraged or freeze up when the competition is threatening their ability to learn.

Conclusion

Adolescence is an important time to provide students with rich and complex experiences. It is imperative for middle level educators to continue to learn about brain research and the implications this emerging body of information may have for classroom instruction. What educators have learned from neuroscience is that the adolescent brain is still developing, sensorimotor stimulation creates stronger synaptic connections, and stress during learning may aid males and inhibit females. Educators can use these findings to create powerful, varied instruction in a safe, stimulating, and exciting classroom.

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