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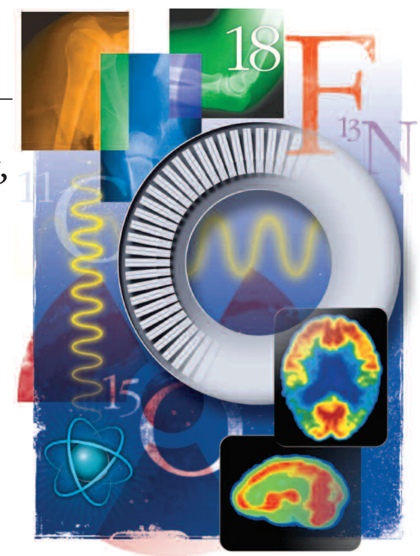
Building a Bridge From Neuroscience to The Classroom



Knowledge of the underlying science, Dr. Willis argues, will enable educators to make good use of all that neuroscientists are learning about our brains, young and old. It is also the best defense against misleading assertions put forth by opportunists.

BY JUDY WILLIS, M.D.

NEUROSCIENCE and cognitive science relating to education are hot topics. They receive extensive but simplified coverage in the mass media, and there is a booming business in "brain-booster" books and products, which claim to be based on the research.

Eric Jensen advocates more collaboration among scientists from the full variety of disciplines engaged in brain research. This collaboration, with corresponding evaluations using cognitive and classroom research, can offer educators more coherent knowledge that they can use in teaching. And educators want this knowledge, as shown by a communication I received from Lisa Nimz, a fifth-grade teacher in the Chicago suburb of Skokie, in response to my May 2007 *Kappan* article.

> We know how important it is for relevant research from the scientific community to be shared with and used in the education community. We are anxious for neurological research to become more a part of educators' thinking and wonder how to make it so. There seem to be only a few people in the unique position of being able to understand the research, figure out its implications for the classroom, and use those implications to direct their teaching. We are actively pondering how a sturdy and wide enough bridge can be built between the scientific community and the education community.
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> There are many obstacles to building such a construct. Reading the primary sources of neurological research can be challenging even for the brightest of us. And even if someone can comprehend these primary sources, there are many highly educated people who don't seem to approach scientific evidence with the caution and skepticism necessary to make fair judgments about the implications of that evidence. There are also many members of the scientific community and academia who haven't studied pedagogy. We are thankful for books, articles, and presentations that mitigate some of that disconnect.

Ms. Nimz' quandary reflects educators' increasing concern about how to keep up with the exponential growth of the body of information coming from the varied scientific specialties about the structure and function of the brain with regard to learning and memory. Of equal concern is how to interpret the multitude of claims, usually by nonscientists, that the effectiveness of various "brain-based strategies" has been "proven by brain research."

The interdisciplinary collaboration of neuroscientists, molecular geneticists, cellular biologists, cognitive scientists, and education professionals can be the "wide, sturdy bridge" Ms. Nimz seeks to connect scientific

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knowledge of the human brain to applications of that research in the classroom. But before that bridge is completed, we need to allow some flexibility. In order to help educators make sense of the massive amounts of information, I propose a two-tiered structure in which factual, collaborative brain research is designated as such and educational strategies strongly *suggested* by neuroscientific data are identified as *interpretations* of that research. The resulting structure will change with time because the interpretive tier will become more concrete as initial interpretations are supported or contradicted by subsequent neuroscience.

The first step is to debunk the neuromyths. Even some of the purest, most accurately reported neuroscience research has been misinterpreted. People trying to capitalize on research with their elixirs, books, cure-all learning theories, and curriculum packages have perpetrated much of the damage. Other folks have unintentionally made errors of interpretation when they have been unfairly asked for scientific evidence to support the strategies they have been using successfully for years.

But it is important to understand that some research findings can be applied to education now. For example, a review of neuroplasticity research shows how collaboration across fields, with certain checks and balances, can lead to classroom strategies that can add to teaching success.

Brain research has not yet provided a direct connection between classroom interventions and brain function or structure, but that does not mean it is irrelevant. Its use is akin to the "off-label" uses of medications by doctors. While Food and Drug Administration regulations require that the label information and advertising of a medication indicate the drug's use only for specific, approved conditions, physicians, based on their *knowledge and available current information*, may prescribe a medication for a use not indicated in the approved labeling. In the same way, educators should use their understanding of brain-learning research to evaluate, develop, and use strategies that are neuro-*logical*, based on *knowledge and available current information*.

NEUROMYTHS

We study history, in part, so that we can learn from the mistakes of the past. Analyzing the errors in interpretation that led to brain-learning myths helps us evaluate the interpretive strengths and limitations of neuroimaging and other current neuroscientific research and avoid misinterpretation.

I go through the research in my fields of neuroscience and education with the goal of finding scientific studies that relate to learning and that adhere to the medical model of limiting the variables and confining interpretation to objective data. Then I seek cognitive testing of the conclusions neuroscientists make from their data. Do the study's data about how the brain responds to a specific input or stimulus correlate with the cognitive test? When I find a valid fit between the neuroscience and the cognitive testing, I go in search of the holy grail: objective evaluation of the effect of the intervention on statistically appropriate numbers of students in their classrooms. To my knowledge, there has not yet been a strategy or intervention that has made it through all three of these filters.

Misinterpreted neuroscientific data have led to beliefs that some people cling to despite objective evidence to the contrary. For example, it has taken more than a decade to debunk the left brain/right brain oversimplification of learning styles, even though neuroimaging studies have, for more than a decade, demonstrated that human cognition is far too complex to be controlled by a single hemisphere. We now know that although parts of the brain are particularly active during certain memory or learning activities, these regions do not work in isolation. There are networks throughout both hemispheres of the brain that constantly communicate, and even these neural networks change in response to genetics and environment throughout our lives.

In the December 1999 *Kappan*, John Bruer reviewed several decades of biological and neuroimaging research and revealed important unconnected dots between laboratory findings and the theories that hitchhiked on the research. For example, Bruer took on the popular assumptions "correlating" synaptic-density growth, high brain metabolism, critical brain-growth periods, and their proposed long-range effects on intelligence and found several weak foundations. He pointed out the flaws in the assumption that critical brain-growth periods of rapid synapse formation are windows of opportunity for instruction geared to those parts of the brain. He reported contradictory research, such as findings that brains build knowledge and store memories with no drop in efficiency long after peak rates of synaptic, axonal, and dendritic growth have leveled off in adolescence.

Bruer also questioned whether increased cortical-glucose metabolism, as measured by PET scans, is direct evidence of rapid growth in synaptic density during the so-called critical periods. This, in turn, called into question the correlations between high metabolic activity measured by neuroimaging and periods of increased potential for learning that were the basis for claims that brain research *proved* that increased environmental stimulation of students during critical brain-growth phases resulted in more learning.

NEUROPLASTICITY AND PRUNING

It is important for educators to remember that the absence of a positive correlation between neuroimaging data and environmental stimulation does not mean that stimulating classrooms are not valuable for learning. It is likely that environmental stimulation does influence learning. However, that theory has not yet been proved by brain research. I remain hopeful, as does Bruer, that the indirect evidence from neuroimaging and other neuroscience research has the potential to suggest teaching strategies and environmental stimuli that are valuable for learning. One promising area of ongoing study is neuroplasticity and pruning.

One longtime misconception held that brain growth stops with birth and is followed by a lifetime of brain-cell death. Now we know that, though most of the neurons where information is stored are present at birth, there is lifelong growth of the support and connecting cells that enrich the communication between neurons (axons, dendrites, synapses, glia) and even some brain regions that continue to form new neurons (neurogenesis) throughout life, such as in the dentate nucleus of the hippocampus and the olfactory cortex.[1] Even after the last big spurt of brain growth in early adolescence, neurotrophins (growth-stimulating proteins) appear elevated in the brain regions and networks associated with new learning and memory formation.[2]

Neuroplasticity is the genetically driven overproduction of synapses and the environmentally driven maintenance and pruning of synaptic connections.[3] Once neural networks are formed, it is the brain's plasticity that allows it to reshape and reorganize these networks, at least partly, in response to increased or decreased use of these pathways.[4] After repeated practice, the connections grow stronger, that is, repeated stimulation makes each neuron more likely to trigger the next connected neuron.[5] The most frequently stimulated connections also become thicker with more myelin coating, making them more efficient.[6]

While active cells require blood to bring nourishment and clear away waste, cells that are inactive do not send messages to the circulatory system to send blood. This reduced blood flow means that calcium ions accumulate around the cell and are not washed away. This calcium ion build-up triggers the secretion of the enzyme calpain, which causes cells to self-destruct, in what is called the pruning process.[7] When unused memory circuits break down, the brain becomes more efficient as it no longer metabolically sustains the pruned cells.

As neurological research provides information about various stages of brain maturation through neuroplasticity and pruning, we come full circle to Jean Piaget's theories regarding the developmental stages of the thought processes of children. If neuroplasticity and pruning represent stages of brain maturation, this may be indirect evidence in support of Piaget's theory that, until there is maturation of brain neural networks, children do not have the circuitry to learn specific things or perform certain tasks.[8]

These neuroplasticity findings allow us to consider which strategies and classroom environments promote increased stimulation of memory or strengthening of cognitive neural networks. For example, appealing to a variety of learning styles when we review important instructional information could provide repeated stimulation to multiple neural networks containing this information. Each type of sensory memory is stored in the lobe that receives the input from that sensory system. Visual memory is stored in the occipital lobes, auditory memory is stored in the temporal lobes, and memories of tactile experiences are stored in the parietal lobes. There could be greater potential for activation, restimulation, and strengthening of these networks with practice or review of the information through multisensory learning, resulting in increased network efficiency for memory storage and retrieval.

OFF-LABEL PRESCRIBING

Jensen cautions, "Brain-based education suggests that we not wait 20 years until each of these correlations is proven beyond any possible doubt." The toll of one-size-fits-all education with its teaching to the standardized tests is so high that it calls for a compromise of the pure medical research model. We do need to take some temporary leaps of faith across the parts of the bridge that are not yet sturdy and try interventions before the research is complete.

When a patient has exhausted all the regular treatments for epilepsy or a brain tumor, neurologists try investigative therapies or "off-label" uses of medications. While off-label medications have not completed FDA testing for the condition in question, the physician believes, through experience and knowledge of pharmacology, that the risk is worth taking in order to treat the patient's disease. For students at risk in our schools, we should use a similar strategy, that is, trying new methods even though they are not yet proven.

However, educators need to use these methods prudently. We need to discuss our successes and acknowledge what doesn't work. Our successful strategic interventions may not yet be proven by brain research, but that doesn't mean they are not valuable. Nevertheless, educators need to beware of opportunists who claim that their strategies are proven by brain research.

UNTIL THERE IS HARD EVIDENCE

The brain-research evidence for certain instructional strategies continues to increase, but there still is no sturdy bridge between neuroscience and what educators do in the classroom. But educators' knowledge and experience will enable them to use the knowledge gained from brain research in their classrooms. For example, choice, interest-driven investigation, collaboration, intrinsic motivation, and creative problem solving are associated with increased levels of such neurotransmitters as dopamine, as well as the pleasurable state dopamine promotes.[9] Novelty, surprise, and teaching that connects with students' past experiences and personal interests and that is low in threat and high in challenge are instructional strategies that appear to be correlated with increased information passage through the brain's information filters, such as the amygdala and reticular activating system. Lessons in which students are engaged and invested in goals they helped to create have the potential to stimulate and restimulate networks of new memories as students actively process information in the construction of knowledge.[10] These instructional strategies date back to theories developed decades before neuroimaging. But they are consistent with the increasing pool of neuroimaging, behavioral, and developmental psychology.

We can look forward to a time when human brain mapping, correlated with the other areas of neuroscience, will reveal additional brain mechanisms involved in memory and learning to help us define the most successful teaching strategies for the variety of learners we teach. We are likely to have neuroimaging tools to identify presymptomatic students at risk and genetic testing that will isolate the precise genes that predispose children to such conditions as ADHD or the various dyslexias. With these powerful diagnostic tools, cognitive and education professionals will be able to design strategies to provide at-risk children with the interventions needed to strengthen areas of weakness before they enter school and to develop differentiated instruction allowing all learners to achieve to their highest potentials.

University psychology and education departments are already obtaining neuroimaging scanners. This will increase educators' influence on what is studied. Teachers will communicate with researchers about the strategies they find successful, so researchers can investigate what is happening in students' brains when those strategies are used. Researchers will need to make their data accessible to teachers who can develop new strategies that bring the fruits of the research to the students in their classrooms.

With time, collaboration, and greater integration of the neuroscience of learning into schools of education and into professional development, educators who stay on top of the science will play leading roles in designing and implementing curriculum and classroom strategies that are effective and consistent with the discoveries of how the brain learns best.

For now, the most powerful asset we educators have to influence the direction of education policy is our up-to-date knowledge and understanding of the most accurate, collaborative, neuroscientific research. With that knowledge, we can remain vigilant in our scrutiny of any premature or misleading assertions about interventions claimed to be proven by brain research. And we will be ready to create, evaluate, and implement the best, truly brain-based instruction in our classrooms. These will be important challenges to meet, but the next decade will reward us with extraordinary opportunities. It may not seem like it now, but we are on the brink of the most exciting time in history to be an educator.

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