How Brain Research Relates to Rigor, Relevance, and Relationships

Willard R. Daggett, Ed.D., President, International Center for Leadership in Education
Paul David Nussbaum, Ph.D., Clinical Neuropsychologist and Adjunct Associate Professor Neurological Surgery, University of Pittsburgh School of Medicine

International Center for Leadership in Education
Rigor, Relevance, and Relationships for ALL Students

How Brain Research Relates to Rigor, Relevance and Relationships

Willard R. Daggett, Ed.D.
President, International Center for Leadership in Education

Paul David Nussbaum, Ph.D.
Clinical Neuropsychologist and Adjunct Associate Professor Neurological Surgery,
University of Pittsburgh School of Medicine

Emerging Evidence of the Ability to Manage "Brain Health"

Every day across America, skilled and dedicated educators attentively and creatively address the challenges of helping all students to achieve academically and reach their fullest potential. Partners in school improvement – such as the staff and consulting team of the International Center for Leadership in Education – work with thousands of educators and education leaders every year to enhance learning through rigorous and relevant curriculum and instruction based on sound relationships and active student engagement. Their messages are grounded in sound education research and guided by successful schools and best practices from across the nation.

Surprisingly, however, few connections have been made between the theory and practice of K-12 learning and the expanding wealth of new information being harvested from cutting-edge research on the human brain – how it works, how it acts, and how its health can be impacted. The frontiers of neurophysiology and neuropsychology hold great promise in informing educational practices. Understanding the human brain may lead to a better understanding of how and why students learn, why some of them struggle to learn, and how educators can assist them more effectively to learn.

In fact, many other segments of society are experiencing extraordinary interest in the human brain and brain health, including personal development, health care, business, media, and even religion. Information on brain health appears in major news outlets, popular magazines, peer-reviewed medical journals, business periodicals, initial public offerings, and even a television series. This shift indicates that the United States is prepared to begin the process of integrating brain health into our language, our culture, and, more importantly, into our daily health regimen.

Some of this interest may be steeped in fear of losing our intellect and memory as we grow older. The enthusiasm, however, is also based on an emerging desire for – and capacity to achieve – real "brain health" for Americans. Of special significance is the growing evidence that brain wellness, like wellness in general, can be addressed across human life stages and age groups, starting with the young. This notion has many applications, including helping children to develop cognitively, creatively, physically, emotionally, and academically to their fullest potential.

A 2006 survey of Americans on brain health, sponsored by MetLife Foundation and the American Society on Aging (www.asaging.org), found:

- Only 3% identified brain health as a leading health topic.
- A majority (88%) believe they can keep their brains fit and nearly 90% believe regular checkups for their brain are important.

What Scientists Know about the Human Brain

The Scarecrow in *The Wizard of Oz* asked the "great and powerful Oz" to give him a brain. But, like many of us, did the world's most famous straw man know exactly what he was asking for? To know how brain health can be managed, a quick and therefore oversimplified intro course on "Brain 101" is in order. A wealth of pertinent information is condensed into the following 10 key points:

1. An adult brain weighs 2 to 4 pounds.
2. The brain is comprised of at least 60% fat and is the fattiest system in your body.
3. Every heart beat provides 25% of the blood and oxygen to your brain.
4. The brain has a cortex and a subcortex.
5. The brain has a left hemisphere (primarily language functions, for most people) and a right hemisphere (non-language functions, for most people).
6. The hippocampus (or hippocampi for plural, since there is one in each hemisphere) encodes new information and initiates learning and memory.
7. You have millions of brain cells (called neurons) that can be shaped and increased in number with exposure to complex and novel environments – what the International Center has labeled "Quadrant D" learning.
8. Neurons communicate with each other chemically, in a process referred to as a synapse.
9. The more synaptic connections, the greater your brain reserve.
10. Brain reserve is thought to delay the onset of diseases such as Alzheimer's Disease.

The most important notion that emerges from this sprint through brain physiology is that the brain is dynamic and continues to be shaped and to develop throughout life.

- The brain has plasticity. As such, there is no finite capacity or limitation.
- In this way, every "normal" brain is distinct and actually much superior to the fanciest of all computers, because computers will always have built-in limitations and finite capacity.
- Every brain is shaped by environmental input across one's lifespan, beginning at conception.
- Contrary to some conventional wisdom, there is no critical period of brain development, unless one considers life itself to be the measure.
- The type of environmental input to a brain can make a difference with respect to the health of that brain.
- Some degree of control over this input is possible and therefore brain health can be promoted.

Brain Plasticity. The dynamic, constantly reorganizing, and malleable nature of the brain, called *brain plasticity*, means that the brain is not a rigid or static system with a limited capacity or finite critical period for development. Brain plasticity permits a lifelong and proactive program to nurture, grow, and promote brain health.

Understanding of brain plasticity has its roots in animal brain research conducted in the 1950s, which was designed to investigate whether environment had any effect on the structure and function of the animal brain. Researchers designed a study of rodents raised in two distinct environments: enriched and un-enriched. The animals raised in un-enriched environments were kept in isolation and had no running wheels or toys to play with. When the two groups of rodents were compared following autopsy, results yielded significant differences in their brains. The rodents raised in an enriched environment had a larger cortex, more cellular connections (synapses that lead to brain reserve), and the formation of new brain cells (neurogenesis) in the hippocampus (the structure critical to new learning and memory).

A review of this research (see Nussbaum 2003 and 2007, which also took the research as applied to humans further, adding two additional factors: nutrition and spirituality, broadly defined to include reflection and introspection) suggested three factors were critical to the enriched environment:

1. socialization: animals had other animals in the environment
2. physical activity: animals had a running wheel for exercise
3. mental stimulation: toys were provided to play with.

While the research offered highly significant and important findings regarding the effect of the environment on brain structure in animals, the critical issue of whether the same findings could be established for humans remained unknown until 1998.

Brain Plasticity and Neurogenesis. A 1998 landmark study (Eriksson, et al., in *Nature Medicine*) found that the human brain had the ability to develop new brain cells. This research challenged the prevailing theory that the human brain was a rigid system with no ability to generate new brain cells. Previously, most experts believed the humans were born with all of their brain cells, that we lose brain cells on a daily basis, and that our brains do not generate or replace the lost cells with new ones. The study also indicated that new brain cells were generated in the human hippocampus, the same area in which neurogenesis was found in the animal brain. Today, research is ongoing to determine if neurogenesis occurs in other regions of the human brain or if it is something specific to the hippocampus.

New brain cell development is one outcome of brain plasticity– dynamic, constantly reorganizing, and malleable. The human brain therefore is now thought by many to possess the same type of neural plasticity as the rodent brain. Interestingly, the animal studies were conducted on rodents across their lifespan with an equivalent human age of seventy or eighty. A human brain that generates new brain cells mandates curiosity about how this wonderful adaptive ability occurs.

Further research will likely provide some answers to this question, but recall that an enriched environment led to new brain cell development in the hippocampus of the animals studied. Also remember that the three critical factors important to the enriched environment include socialization, physical activity, and mental stimulation. It makes good sense, therefore, to ask if the human brain can be similarly affected by environment and if enriched environments promote positive brain changes in humans. In short, there is good reason to believe that:

- the human brain benefits from a novel and complex environment
- the first potentially enriched environment is the womb
- the type of environment the brain is exposed to has consequences at every age - through childhood, into adolescence and across a lifespan.

Brain plasticity therefore does not apparently end at a particular age. Indeed, the human brain probably does not know its chronological age and will demand and benefit from enriched environments at every age. The key point for educators is that students need to be exposed to the novel and the complex every day.

Lastly, consider the additional implications of brain reserve, which refers to a build-up of brain cell connections (synaptic density) which serves to assist the brain in the battle against neurodegenerative diseases. To better understand brain reserve, consider the following scenario:

> You are flying in an airplane 1000 feet above the ground. Looking down, you see two distinct scenes. The first scene is a jungle with so many trees you cannot see the ground. The second scene is an island with one palm tree blowing slowly in the wind.

A healthy brain should be like the jungle, with a tremendous number of synaptic connections. This is referred to as synaptic density and is a direct measure of brain reserve. A brain should not look like the island with one palm tree. The reason is simple. Alzheimer's Disease (AD) and other types of dementia will invade the brain and begin to cut down the neurons and synaptic connections, like a weed-whacker cutting through the weeds around your house. If the brain looks like a jungle, filled with synaptic connections, AD and other diseases will take a long time to show their ugly clinical face. However, if the brain looks like the island with one palm tree, the clinical signs of AD will manifest quickly because there is no reserve to fight it off.

Indeed, some research has shown that even though brains are diagnosed with AD at autopsy due to the presence of neuropathological changes, a significant number of these persons never demonstrated the clinical aspects of the disease in life. This is explained one way using the brain reserve concept. That is, persons who never manifested AD in life, even though they had the neuropathological characteristics in their brains at autopsy, had built up brain reserve to fight off or delay the onset of the disease.

The power of brain reserve is further supported by findings that relate higher educational attainment and occupational levels to lower risk of AD. For those with high education or occupation levels who do manifest AD, their presentation of the disease occurs later than those without similar backgrounds; and once the disease manifests, the person dies soon after. The reason for this is that the when the disease presents itself clinically, it is already advanced into the final stage because the person's brain reserve had been fighting it off.

Education is an environment and a process that can be enriched or not enriched and therefore affects brain health. To the extent that an educational environment – or other settings – becomes rote and passive, brain reserve will not be as developed and the overall health benefit for a brain is not as great. It is the responsibility of all educators, therefore, to expose themselves and their students to novel, complex, and enriched environments on a daily basis. Studies suggest that the earlier in life a person is exposed to an enriched environment, the greater the benefit to brain health, even late into life. This finding is supported by research that demonstrates clear relationships between:

- poverty in childhood and increased risk of AD later in life
- higher cognitive abilities in childhood and young adulthood and reduced risk of AD later in life
- language development in young adulthood and reduced risk of neuropathological changes in the brain at autopsy
- passive lifestyles in one's 40s and increased risk of AD later in life.

Such findings support the idea that brain disease in the later years may actually begin early in life. Further, these findings suggest that involving young children with a proactive lifestyle that promotes brain health (i.e., learning) helps to reduce the risk of AD and related dementias. It is important to prioritize a proactive lifestyle for brain health regardless of age, to embrace the power of brain plasticity and development of brain reserve, and to have fun – all in the process of caring for oneself and especially for the children entrusted to the support of educators and other caregivers.

Implications of Brain Research for Instruction, Curriculum, Relationships, and Student Engagement

Ongoing research on the brain and brain health holds out the significant promise of direct applications in education. In particular, brain plasticity and the related characteristics of neurogenesis and synaptic density open doorways to a wealth of potential implications both for the learning process and for the school learning environment.

The research on brain plasticity during the 1950s, which has been supported by more recent findings, clearly showed that mammalian brain plasticity is connected to environmental richness: the richer the environment, the more brain growth and the higher the synaptic density.

Moreover, the factors identified as contributing to environmental richness – socialization, physical activity, and mental stimulation – are, of course, tied closely to the notion of enriching school environments. In varying degrees, these factors can all be accommodated within the school day and within school schedules and programs. They also reflect, and provide evidence in support of, what many education leaders believe about students and learning: rigorous and relevant curriculum and instruction, supported by strong relationships and a welcoming learning environment, matter.

Brain Health and Education: Schools as Brain Health Centers

Current brain research on factors contributing to environmental richness supports the Rigor/Relevance Framework developed by Dr. Willard R. Daggett in 1992 based on observations of successful schools and their best practices and widely embraced by educators. The Rigor/Relevance Framework is a powerful tool for explaining that learning is optimized when students are involved in activities that require both complex thinking (higher along Bloom's Taxonomy) as well as the application of knowledge to real-world situations (higher along what is called the Application Model continuum). In the zone where both are maximized – Quadrant D on the Rigor/Relevance Framework – mental stimulation is maximized. Quadrant D thinking also relates to "association areas" of the human brain, where the highest levels of cognitive processes may occur. Students learn the skills and acquire the knowledge most readily when they understand the concepts, recognize their relevance and are thus mentally connected to the learning.

The Rigor/Relevance Framework also supports the use of instructional strategies designed to maximize mental stimulation and cooperative learning instead of isolated rote memorization of facts. Rather than lecture and other traditional instructional techniques, educators are encouraged to employ strategies that engage students, treat them as active learners rather than empty receptacles into which knowledge can be delivered, and make school a place where students work and teachers observe, not the other way around. Rather than being sedentary, passive, and aligned in neat rows of desks, learners are allowed to be tactile, experiential, interactive, and social and to move purposefully around the classroom as part of the learning process. Active learning provides multi-sensory stimuli to the brain.

Furthermore, in its more recent work with educators and schools across the nation, the International Center has recognized the importance of supportive relationships to underpin rigorous and relevant learning. Most successful schools have created learning environments that are not only rigorous and relevant, but also safe, secure, engaging, and caring for staff and students. Leaders in these schools know that humans are social creatures and that socialization based on strong relationships – between and among students, among students and staff, and with the larger community outside the school – are critical to optimizing growth for every individual. Socialization is also critical in language development, in the sharing and interchange of ideas, and in fostering creativity. Socialization matters, whether a part of everyday classroom learning or in the more subtle but critical learning that takes place elsewhere in the school, whether in arts and music programs, clubs, extracurricular activities, or through coaching and

mentoring. Ensuring that every student feels cared about, valued, and respected by the adults in the school is key.

The new understandings being developed by neuropsychologists and others who study the brain and its functions are highly consistent with the rubric of school performance and achievement developed by the International Center called the *Learning Criteria*. This widely used tool for helping schools to self-assess their strengths and their growth in effectiveness includes the traditional academic attainment-based metrics of school success but goes beyond those basics into a broader definition of school quality. Schools also use the rubric to determine student involvement in learning and how well the school is preparing students for their future roles and responsibilities. This broader context is highly consistent with the "whole child" findings on brain health.

The Learning Criteria is arranged in four data categories:

- **Core Academic Learning** – Achievement in the core subjects of English language arts, math and science and others identified by the school.
- **Stretch Learning** – Demonstration of rigorous and relevant learning beyond minimum requirements, such as participation and achievement in higher level courses, specialized courses, and so forth.
- **Student Engagement** – The extent to which students are motivated and committed to learning, have a sense of belonging and accomplishment, and have relationships with adults, peers and parents that support learning.
- **Personal Skill Development** – Measures of personal, social, service, and leadership skills and demonstrations of positive behaviors and attitudes.

Core Academic Learning and Stretch Learning are the most easily measured and have the highest profile of the four areas. The International Center believes that both are critical but not sufficient indicators of excellence. Personal Skill Development and Student Engagement are more difficult to measure and are frequently overlooked in school improvement efforts. Yet, they may be critical to achieving success in the academic areas. Moreover, the competencies and characteristics that fall under Student Engagement and Personal Skill Development are necessary for success in all aspects of a meaningful adult life.

The Learning Criteria was developed in partnership with the Council of Chief State School Officers (CCSSO) as part of a five-year initiative to identify and analyze the nation's most successful high school practices and policies for achieving a rigorous and relevant curriculum for all students. To learn more about the Learning Criteria and view sample data indicators, please visit www.leadered.com.

Conclusion

Scientific understanding of brain function and brain development and the applications of that research to education are just beginning. The field of neuropsychology is as complex as the object of its study. The brain remains a magnificent and complex tapestry, one yet to be fully unfolded and appreciated, but always to be marveled at.

Nonetheless, the evidence related to brain plasticity in humans is encouraging. It speaks of promise for everyone concerned with their lifelong brain health and for those, including educators, who are charged with nurturing the brain health of others. Further study of the brain and brain health could – and very likely will – inform theory and practice across K-12 education in a host of areas, such as:

- nutritional aspects of brain health, especially the impact of healthful living and diet on children
- support for children with physical, cognitive, and learning challenges

- dominant learning styles
- the Millennial generation's uncanny ability to multi-task in virtual environments and its impact on traditional thinking about attention span, focus, and single-tasking
- the impact of online social networking on brain health and development
- the implications of a sedentary "wired" and "on-line" lifestyle on child development and socialization
- the use of instructional technologies
- the importance of physical activity
- the impact of meditative-type states on learning
- higher order cognitive prototypes for learning
- an understanding of the long term effects of learning on brain health.

For educators whose mission is to help each young person under their care to develop to the fullest of his or her potential, the phenomenon of a dynamic and changeable brain – whose health can, at least to some extent, be cultivated and nurtured – reinforces an intuitive understanding that schools can and do make a difference and that they may represent brain health centers.

When schools:

- create a culture that facilitates positive socialization within a safe, secure, and caring learning environment
- provide opportunities for students – in school and outside of school – to see the value of participation in physical activity and a healthful lifestyle
- engage and stretch every student in active, rigorous, and relevant learning that flexes mental muscles and nurtures retention, understanding, and achievement

the impact on brain health, given the evidence for brain plasticity and the related characteristics of neurogenesis and synaptic density, is positive. The more that is learned about the phenomenon of brain health, the greater the potential benefit will be to education. Equally as important, the more that is learned about education and its relationship to brain function, the greater the impact the education system can have on brain health.

The potential is compelling.

References

Eriksson, P. S., Perfilieva, E., Bjork-Eriksson, T., Alborn, A. M., Nordborg, C., Peterson, D. A., and Gage, F. H. (1998). "Neurogenesis in the adult human hippocampus," *Nature Medicine,* 4, 1313-1317.

Nussbaum, P. D. (2003). *Brain Health and Wellness*. Tarentum, PA: Word Association Publishers.

Nussbaum, P. D. (2007). *Your Brain Health Lifestyle*. Tarentum, PA: Word Association Publishers.

About the Authors

Willard R. Daggett, Ed. D, is the founder and president of the International Center for Leadership in Education. Bill is a nationally recognized education leader, keynote speaker, and consultant on school improvement. For more information about the Rigor/Relevance Framework or the Learning Criteria, visit the International Center at www.LeaderEd.com.

Paul David Nussbaum, **Ph.D**, is a Clinical Neuropsychologist and Adjunct Associate Professor of Neurological Surgery, University of Pittsburgh School of Medicine; and International Consultant on Aging and Brain Health. He educates the general public on the basics of the human brain and how to keep it healthy over the entire lifespan. He provides keynote presentations across the nation as well as consultation on brain health. He is keynoter and senior adviser for the International Center. For more information, visit his Web site at www.paulnussbaum.com.