A Compilation of Brain Research Articles

Creya has assembled a few of the brain research articles for your reference. Many learnings from research findings such as these about how brain research can be leveraged for improved learning form the basis for the design of Creya Curriculam and our programs

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Connecting Brain Research with Dimensions of Learning

By linking what we know about how the brain works with a framework for teaching and learning, we can improve the likelihood that various education reforms will actually help students learn—including students with special needs.

Mariale M. Hardiman

In the past 10 years, teachers have been bombarded by education reform initiatives, including standards-based instruction, teaching to students' learning styles, performance-based instruction, multiple intelligences, and, most recently, brain-based learning. In addition, during the 1990s, the Individuals with Disabilities Education Act (IDEA) mandated that students with disabilities have access to the general education curriculum. This mandate has resulted in more students with special needs being taught in general education classrooms (Lombardi & Butera, 1998).

Meeting the needs of diverse learners can be challenging enough for teachers without the charge of determining how to incorporate reform initiatives into practice. Merely superimposing reforms upon existing practices and requirements is generally ineffective. Education initiatives that link current practice with promising new research in neurological and cognitive sciences, however, offer real possibilities for improving teaching and learning, especially for students with diverse learning needs.

Scientists and researchers are making exciting new discoveries related to how the brain processes and stores information (Sousa, 1998). This research has the potential to unlock the mysteries of learning itself. For example, recent research highlights the differences in brain anatomy of students with learning disabilities and attention deficits that can shed light on their performance in the classroom (Semrud-Clikeman et al., 2000). Yet, despite the enormous implications of such research, it is not being effectively disseminated to education practitioners, who, among all professionals, need it most (Sousa, 1998).

How can we familiarize teachers with brain-based learning so that they can apply this latest research to meet the needs of all students, including those with disabilities, in the general education classroom? A basic precept of brain-based research states that learning is best achieved when linked with the learner's previous knowledge, experience, or understanding of a given subject or concept (Perry, 2000). Therefore, we can assume that the use of brain-based research would be most effective when combined with previously established frameworks for teaching and learning (Brandt, 1999).

One such framework that Roland Park Elementary/Middle School has used since 1994 is the Dimensions of Learning model (Marzano, 1992). Roland Park, a Blue Ribbon School of Excellence in Baltimore, Maryland, has steadily improved the achievement of its 1,350 students during the past six years. Our progress, in part, may be attributed to our use of Dimensions of Learning, which addresses the development of higher-order thinking skills. Robert Marzano describes the five dimensions as "loose metaphors for how the mind works during learning" (1992, p. 2). Linking the five dimensions with the latest brain research suggests a number of best practices for teaching all children—especially students with learning disabilities.

Dimension One: Positive Attitudes

Dimension One explains that a student's attitudes and perceptions serve as filters that enhance or inhibit natural learning. Although educators may have long suspected that attitudes affect learning, brain research clearly supports the link between emotions and cognition. Robert Leamnson (2000) explains that neural pathways connect the limbic system, the brain's emotional center, to the frontal lobes, which play a major role in learning. In addition, hormones alter the chemical makeup of the brain of a person under stress. When the person is threatened, chemicals are released that can impair memory and learning (Jensen, 1998).

Best Practices

■ Provide a challenging yet supportive classroom environment by reducing the stress that may come from embarrassment because of academic difficulties or peer rejection. At Roland Park, we make students feel more comfortable by assigning a "peer buddy" as a homework helper, arranging for tutoring in study skills and test-taking strategies, and providing special meetings outside of class time to encourage a trusting teacher-student relationship.

■ Teach peer acceptance and social behaviors explicitly. Students with learning disabilities may experience an added fear of rejection from the stigma of special education. Our teachers hold class meetings to encourage social acceptance and interaction, use literature and history to provide instructional materials that demonstrate acceptance of diversity, and model an attitude of acceptance and appreciation for those with different learning styles and needs.

■ To cement long-term memory, connect emotions to learning. Techniques such as dramatizations, humor, movement, or arts integration can arouse the emotional systems of the brain and stimulate peak performance. For example, teachers may tell a funny instructional story at the beginning of class to foster a relaxed yet supportive atmosphere.

Dimension Two: Acquiring and Integrating Knowledge

Dimension Two pertains to the acquisition and integration of knowledge. Marzano (1992) proposes that learning new information must occur within the context of what the learner already knows and must be adequately assimilated so that the information can be used easily in new situations.

Much of brain-based research has focused on how the brain acquires, stores, and uses information (Valiant, 1998). Learning occurs through the growth of neural connections, stimulated by the passage of electrical current along nerve cells and enhanced by chemicals discharged into the synapse between neighboring cells. The more often the "trail is blazed," the more automatic a task or memory becomes (Buchel, Coull, & Friston, 1999). Therefore, the more a student repeats a learning task, the greater the connectivity. Researchers also point out that different parts of the brain store particular parts of a memory (Fishback, 1999). For example, one part of the brain might store the lyrics of a song and another part, the melody. Further, Leamnson (2000) explains that the brain must reconstruct a memory each time the person recalls the memory. Learning thus requires both the acquisition of information and the ability to retrieve and reconstruct that information whenever necessary. Evidence from brain-mapping technology indicates that individual differences in learning styles affect this retrieval process. In a study that investigated the differences between normal and disabled readers in visual-perceptual tasks, Richard S. Kruk and Dale M. Willows (2001) found significant processing differences that affected the rate of visual processing for students with reading disabilities. Jean Robertson (2000) suggests that the inability to shift control from the right to the left hemisphere of the brain may cause early reading disorders.

Best Practices

■ Present new information within the context of prior knowledge and previously learned content (Perry, 2000). For example, students may better understand the bicameral system of U.S. government by comparing it with their own student government.

Photo courtesy of Jason Jones

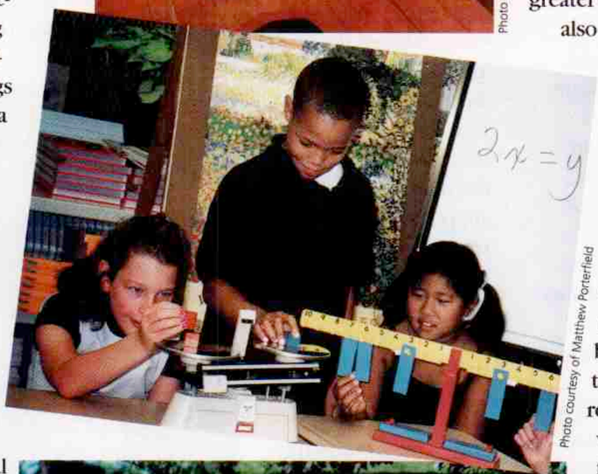

Photo courtesy of Matthew Porterfield

Photo courtesy of Matthew Porterfield

Above: Second graders learn about the earth's tilt and rotation through movement and dance (Dimension Two).

Middle: Third grade students use a balance scale to visualize algebraic equations (Dimension Two).

Below: Third graders apply the formula for the area of a rectangle by designing and measuring a garden (Dimension Four).

■ Allow students to repeat learning tasks to cement them in memory (Sprenger, 1998). This is especially important for activities that require an automatic response, such as blending phonemes into words (Shaywitz, 1998) or mastering math facts.

■ Use mnemonics, which can significantly increase the memory of content (Carney & Levin, 2000), especially for students with special needs (Lombardi & Butera, 1998). For example, telling students to "write with their FEAT" can remind them to use the transition words "for example" or "according to" to introduce supportive text in their writing.

■ Use visually stimulating material and manipulatives to activate the right hemisphere of the brain and text presentation to activate the left hemisphere (Robertson, 2000). The right brain's visual-spatial skills can be activated with features such as a balance scale to help visualize algebraic equations or pictures and graphs to enhance the meaning of text.

■ Integrate art, music, and movement into learning activities to activate multiple parts of the brain and enhance learning (Rauscher et al., 1997; Vogel, 2000). For example, students can learn how the earth's tilt and rotation create seasons through body movements—tilting the body toward the center of a circle to simulate spring; turning and tilting away from the center to simulate fall.

Dimension Three: Extending and Refining Knowledge

Extending and refining knowledge requires examining it in a deeper, more analytical way by doing such things as comparing, classifying, inducing, deducing, analyzing errors, constructing support, abstracting, and analyzing perspective (Marzano, 1992). The thinking skills involved in Dimension Three require that the brain use multiple and complex systems of retrieval and integration (Lowery, 1998). Ron Brandt (2000) states that brain research supports thinking-skills programs that have students compare and classify familiar concepts. He explains that

> neurons that often fire at the same time as certain other neurons become more likely to fire whenever those other neurons fire. . . . We use less brain energy when performing familiar functions than when learning new skills. (p. 75)

Best Practices

■ Design tasks that allow students to use prior knowledge to learn new information. For example, students use their prior understanding of photosynthesis to explain the differences between plant and animal cells.

■ Offer students an opportunity to compare their performances with model responses and to analyze their error patterns. For example, when asking students to write an essay, provide a model paper that clearly identifies the main idea, supporting details, transition words, and conclusion. Let students use the model to organize their own writing.

■ Teach students to identify general patterns that underlie concepts. For example, compare the leadership characteristics of current leaders with those of successful leaders of the past.

Dimension Four: Using Knowledge Meaningfully

Marzano (1992) states that we learn best when we need information to accomplish a goal. Using Dimension Four thinking strategies, students apply information in activities that require them to make decisions, investigate, conduct experiments, and solve real-world problems. Brain research confirms that this type of experiential learning activates the area of the brain responsible for higher-order thinking (Sousa, 1998). Moreover, enriched instruction has been shown to produce significant chemical changes in the brains of students with learning disabilities—changes that indicate less exertion of effort in learning (Richards et al., 2000). A similar study (Bower, 1999) indicated that reinforcement of active learning tasks improves brain efficiency.

Leamnson (2000) warns, however, that merely providing students with hands-on activities does not guarantee learning. Teachers must pair physical activities with problem-solving tasks to connect the "acting modules" of the brain—the motor cortex—with the "thinking modules"— the frontal lobes. Such experiences increase memory and learning, thereby modifying brain structures (Kandel & Squire, 2000).

Photo courtesy of Matthew Porterfield

Seventh graders build on their understanding of photosynthesis as they differentiate between plant and animal cells (Dimension Three).

Best Practices

■ Assign students active, hands-on tasks that require them to investigate, analyze, and solve problems using real-world applications (Green, 1999). For example, students can apply the formula for the area of a rectangle by determining how much paint it would take to paint a room given the dimensions of walls, doors, and windows.

■ Allow students to use multiple ways to demonstrate learning, such as inventions, experiments, dramatizations, visual displays, music, and oral presentations. For instance, assigning groups of students to write scripts and perform skits to represent each of the 12 labors of Hercules makes this myth come alive.

Dimension Five: Habits of Mind

Dimension Five describes the mental habits that enable students to facilitate their own learning. These habits include monitoring one's own thinking (*metacognitive thinking*), goal setting, maintaining one's own standards of evaluation, self-regulating, and applying one's unique learning style to future learning situations. Understanding and facilitating one's own learning style is especially important for students with learning disabilities. According to Martin Languis (1998), brain-mapping tests reveal individual differences in brain organization and structure that relate to specific differences in learning style. Studies showed that students who were more skilled in spatial-visualization tasks such as visualizing three-dimensional objects demonstrated different brain-processing patterns compared with less-skilled students. Students, however, significantly improved their scores in spatial-visualization assessments after taking courses that taught them specific learning strategies such as the use of imagery, graphic organizers, and puzzles.

Best Practices

■ Provide ways for students to engage in metacognitive reflection. Students benefit from the use of think logs, reflective journals, and group discussions within a cooperative learning setting.

■ Include reflective discussions of lessons to foster the habit of reflection on learning. Ask students to record one important concept that they learned from the lesson and several important facts.

Putting the Research to Use

Although most researchers agree that our understanding of the human brain is in its infancy, the explosion of research in the field of neurology and cognitive sciences in the past 10 years can and should play an important role in education reform, especially for students who demonstrate differences in their thinking and learning patterns. If teachers combine brain research with a thinking skills framework such as Dimensions of Learning as we have at Roland Park Elementary/Middle School, the research will translate more effectively into practice. Our use of this model has resulted in exciting learning experiences for students as well as increased scores on our state performance assessment every year since 1994. Moreover, the potential of brain research to provide new approaches to teaching students with information-processing difficulties makes its use all the more vital in classrooms today. Students with learning differences, including those with learning disabilities who are in general education classrooms, deserve to have available to them a program of research-based instruction to nurture and enhance both thinking and learning. ■

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12 Design Principles Based on Brain-based Learning Research
By Jeffery A. Lackney, Ph.D.
Based on a workshop facilitated by Randall Fielding, AIA

1. Rich-simulating environments – color, texture, "teaching architecture", displays created by students (not teacher) so students have connection and ownership of the product.
2. Places for group learning – breakout spaces, alcoves, table groupings to facilitate social learning and stimulate the social brain; turning breakout spaces into living rooms for conversation.
3. Linking indoor and outdoor places – movement, engaging the motor cortex linked to the cerebral cortex, for oxygenation.
4. Corridors and public places containing symbols of the school community's larger purpose to provide coherency and meaning that increases motivation (warning: go beyond slogans).
5. Safe places – reduce threat, especially in urban settings.
6. Variety of places – provide a variety of places of different shapes, color, light, nooks & crannies.
7. Changing displays – changing the environment, interacting with the environment stimulates brain development. Provide display areas that allow for stage set type constructions to further push the envelope with regard to environmental change.
8. Have all resources available – provide educational, physical and the variety of settings in close proximity to encourage rapid development of ideas generated in a learning episode. This is an argument for wet areas/ science, computer-rich workspaces all integrated and not segregated. Multiple functions and cross-fertilization of ideas are primary goal.
9. Flexibility – a common principle in the past continues to be relevant. Many dimensions of flexibility of place are reflected in other principles.
10. Active/passive places – students need places for reflection and retreat away from others for intrapersonal intelligence as well as places for active engagement for interpersonal intelligence.
11. Personalized space – the concept of home base needs to be emphasized more than the metal locker or the desk; this speaks to the principle of uniqueness; the need to allow learners to express their self-identity, personalize their special places, and places to express territorial behaviors.
12. The community-at-large as the optimal learning environment – need to find ways to fully utilize all urban and natural environments as the primary learning setting, the school as the fortress of learning needs to be challenged and conceptualized more as a resource-rich learning center that supplements life-long learning. Technology, distance learning, community and business partnerships, home-based learning, all need to be explored as alternative organizational structures for educational institutions of the present and future.

This list is not intended to be comprehensive in any way. The brain-based learning workshop track offered participants the ability to explore implications in an open and reflective way. The intention for these workshops was primarily to start the public dialogue concerning the implications of research on brain-based learning in the design of school environments.

A second caveat to presenting these design principles for brain-compatible learning environments concern the need to use as many of these principles in combination in the design of a school building as possible. Many principles reinforce each other in providing a coherency and wholeness often lacking in buildings designed around a single concept/fad, like open schools or house concepts. School designs that incorporate a variety of these principles will by definition have the flexibility to accommodate a wide array of learning styles.

Workshop Summary Narrative:

The objectives of the brain-based workshop track of the CEFPI Midwest Regional Conference were to: (a) understand the latest developments and findings from brain research; (b) discuss how these findings may educational curriculum and instruction for learning; and (c) explore what the implications these findings may have on school design.

Facilitators in the first two workshop sessions on Thursday, April 30th included Karen Holicky-Michaels, L.J. Menzel and Cheri Lunders. Facilitators in the second workshop session on Friday, May 1st included Burton

Cohen and Peter Hilts. Randy Fielding & Jerry McCoy acted as moderators, Jeff Lackney acted as reporter and Paul May acted as note taker throughout all three sessions.

After a very selective summary of what is known from brain research about how the brain learns, implications were drawn concerning the influence this new knowledge may have on how schools are planned and designed to support brain-based learning.

What do we know from brain research about how we learn?

The brain is a vastly complex and adaptive system with hundreds of billions of neurons and interneurons that can generate an astronomical number of neural nets, or groups of neurons acting in concert, from which our daily experience is constructed. Many findings seem obvious and intuitive, as one outsider asked me, "isn't all learning brain-based?" For example, we all know intuitively that the best age to learn a new language is during our early childhood; what neuroscientists call the principle of windows of opportunity. We can accept that all brains are unique and a product of interactions with different environments, generating a lifetime of different and varied experiences; what scientists call plasticity. We can accept the notion that either you use it, or you lose it; new neural pathways are created every time we use our brains in thinking through problems, but are lost forever – are pruned – if we do not use them.

Yet, with all we know now scientifically, and claim we have known intuitively, why do so many people, educators and design professionals make instructional and physical design decisions that contradict these findings?

The findings from neuroscience are now validating scientifically much of the new instructional strategies being advocated in educational reform efforts since the 1960s. Individualized instruction for instance is validated by findings concerning the importance of intrapersonal intelligence. Activity-based learning is now on solid footing with what we know about body-kinesthetic intelligence. Cooperative learning strategies are a logical extension of the growing body of knowledge about the importance of interpersonal/social intelligence and brain development.

Yet, it was the consensus of many participants at the brain-based workshop that brain-based learning and the strategies that are emerging from that research are still at a buzzword stage. Gardner's Multiple Intelligences theory that posits a number of dimensions of intelligence (linguistic, logical/mathematical, spatial, musical, body/kinesthetic, interpersonal, and intrapersonal) is just one of a number of equally valid theories about intelligence and brain-based learning. Gardner himself has been frustrated by what he sees as reductionist thinking of many educational practitioners that talk the language, but walk using their old instructional strategies, dividing up learning activities into distinct learning modalities to the exclusion of other dimensions. Brain-based learning requires a more systemic way of conceptualizing how learning takes place and how to facilitate it.

Another concern with knowledge emerging from neuroscience is the need for translation into brain-based learning strategies that can be used by educators. Over ninety percent of all neuroscientists are alive and still practicing today. Interpreting the rapidly growing information on brain research generated by these scientists, especially when some of that information is contradictory, can be a daunting task

The conclusion reached by both facilitators and general participants was that we should use caution when applying the findings of brain-based research, but at the same time move ahead with what we know. We should not wait; we need to act on what is known today knowing that some of this will change in the future. One example that was brought up during the workshop was that scientists used to think that the brain was hardwired at a very early age and set for the rest of life, what is called pruning. This assumption is only partially true today. Pruning does take place at an early age, but research has confirmed that nerves continue to grow throughout one's life. You can teach old dogs a few new tricks after all. This is a huge discovery and has implications for life-long learning. When we learn a skill later in life, such as when we learn stick shift driving or skiing, we find the learning process to be frustrating and awkward at first, but soon these skills become automatic. This is a clear example growing new neural connections and the principle of plasticity in connection with the development of body/kinesthetic intelligence.

As with any new learning, frustration seems to follow, as in the case of learning to drive stick shift. There is a period of time when we can't get our body to do what our mind wants it to do. We get emotional. From brain research we know now that when we get emotional about a task we are involved in learning. Brain research has confirmed that emotions are linked to learning by assisting us in recall of memories that are stored in our central nervous system. Emotions originate in the midbrain or what has been termed the limbic system and the neo-mammalian brain. Sensory information is relayed to the thalamus in the midbrain, which acts as a relay station to the sensory cortex, auditory cortex, etc. When sensory information reaches the amygdala, another structure in the midbrain, that sensory information is evaluated as either a threat or not, creating the familiar fight or flight response – the physiological response of stress. This information is only then relayed to the frontal cortex, our higher cognitive functions, where we take the appropriate action. How does information from the midbrain reach the frontal cortex? Chemicals, neurotransmitters, are released into the endocrine system, which is connected to synapses, altering, coloring and intensifying our conscious experience of a situation. Emotions aid in memory retention (learning) of this situation as being good or bad. Decreasing threat ("driving our fear", mistrust, anxiety and competition) through cooperation, providing safe places, and providing a motivational climate for positive emotions ensure that learning will be retained.

But, brain research also suggests that the brain learns best when confronted with a balance between stress and comfort: high challenge and low threat. The brain needs some challenge, or environmental press that generates stress as described above to activate emotions and learning. Why? Stress motivates a survival imperative in the brain. Too much and anxiety shuts down opportunities for learning. Too little and the brain becomes too relaxed and comfortable to become actively engaged. The phrase used to describe the brain state for optimal learning is that of relaxed-alertness. Practically speaking, this means as designers and educators need to create places that are not only safe to learn, but also spark some emotional interest through celebrations and rituals.

Another general finding from brain research is that the brain is a pattern maker. Pattern making is pleasing (emotional content) for the brain. The brain takes great pleasure in taking random and chaotic information and ordering it. The implications for learning and instruction is that presenting a learner with random and unordered information provides the maximum opportunity for the brain to order this information and form meaningful patterns that will be remembered, that will be learned. Setting up a learning environment in this way mirrors real life that is often random and chaotic.

The brain, when allowed to express its pattern-making behavior, creates coherency and meaning. Learning is best accomplished when the learning activity is connected directly to physical experience. We remember best when facts and skills are embedded in natural, spatial memory, in real-life activity, in experiential learning. We learn by doing. The implications of applying the findings of neuroscience related to coherency and meaning suggest that learning be facilitated in an environment of total immersion in a multitude of complex interactive experiences which could include traditional instructional methods of lecture and analysis as part of this larger experience.

Interaction of the brain with its environment suggests that the more enriched environment, the more enriched brain. As one observer suggests, we need to enrich like crazy. According to Ronald Kotulak in his 1996 book "Inside the Brain", an enriched environment can contribute up to a 25% increase in the number of brain connections both early and later in life. Our environments need to allow for active manipulation.

To summarize, there are at least twelve principles of brain-compatible learning that have emerged from brain research.

1. Uniqueness – every single brain is totally unique.
2. Impact of threat or high stress can alter and impair learning and even kill brain cells
3. Emotions are critical to learning – they drive our attention, health, learning, meaning and memory.
4. Information is stored and retrieved through multiple memory and neural pathways
5. All learning is mind-body – movement, foods, attentional cycles, drugs and chemicals all have powerful modulating effects on learning.
6. The brain is a complex and adaptive system – effective change involves the entire complex system
7. Patterns and programs drive our understanding – intelligence is the ability to elicit and to construct useful patterns.
8. The brain is meaning-driven – meaning is more important to the brain than information.

9. Learning is often rich and non-conscious – we process both parts and wholes simultaneously and are affected a great deal by peripheral influences.
10. The brain develops better in concert with other brains – intelligence is valued in the context of the society in which we live.
11. The brain develops with various stages of readiness.
12. Enrichment – the brain can grow new connections at any age. Complex, challenging experiences with feedback are best. Cognitive skills develop better with music and motor skills.

What might be some school design principles that support brain-based learning?

Burton Cohen and Peter Hilts took the material we discussed in the previous two workshops and challenged the group to think about how as planners and designers we might begin to create places for learning that support what they referred to as optimal learning experiences. What would a brain-forming environment look like?

The first caveat we recognized, as a group was that attempting to link research literature on brain research in neuroscience, first, to interpretations about this research forming principles of brain-based learning, and second, to facility implications is a very tentative exercise at best. With this in mind, we attempted to outline what we felt were a dozen sound principles for design. Interestingly, many of these principles seemed intuitively right – principles any good designer would use. If this is so, then why we asked do most schools appear to work against brain-forming? What makes these principles new is the way in which they have been framed: as brain-forming principles based directly on what we know about the neurophysiology of the brain and optimal learning environments.

Embracing the concept of "place" and place making – a opposed to space design -- is critical to understanding the way in which design principles for optimal learning environments are intended to be approached. When designing for optimal learning environments, design must be approached in a holistic, systemic way, comprising not only the physical setting, but also the social, organizational, pedagogical, and emotional environments that are integral to the experience of place. Reducing these design principles to "physical" design solutions negates the potential for creating authentically brain-compatible learning environments. This point cannot be stressed strongly enough. Designing successful brain-compatible learning environments will require us as educators and design professionals to transform our traditional disciplinary thinking and challenge us to think in much more interdisciplinary ways – just as cognitive scientists have had to do to address the complexity of brain research.