Brain-Compatible Learning

Neuroscientists are mapping the pathways between body and brain, providing tangible evidence of the benefits of hands-on, experiential learning.

by **Jane McGeehan**

Photos: Brenda Russell

AS YOU read the latest findings in brain research in education journals, you may well find yourself wondering, "Is this just another fad to dance across the education landscape?" But understanding the workings of the human brain can be the catalyst for dramatic and needed changes in classrooms. While scientists caution that they are only beginning to unravel the secrets of how humans learn, what they have already uncovered provides groundbreaking insights for educational practice. For the first time in the history of formal schooling, we have the opportunity and challenge to understand and act on the biology of learning rather than simply following traditional practices. The current explosion of new knowledge about the brain is an invitation to examine our practice, commit ourselves to drop what is ineffective, and embrace promising new approaches that are brain-compatible rather than brain-antagonistic.[1]

I believe that environmental educators are uniquely poised to act on the findings of brain research, and in this article I invite you to take up the challenge yourself. Since students' mastery of the school curriculum happens primarily in the brain, it stands to reason that educators should be experts on the workings of that amazing organ. But just what do educators need to know from brain research findings? And what are examples of brain-compatible practices? Starting with a brief history of the influence of neuroscience on education, I will provide a summary of key brain research findings and their implications for your own approaches as an educator.

A brief history

As with most major shifts in our conceptions, recent advances in our understanding of the brain have arisen from the convergence of findings from different fields of research — in this case, neuroscience and psychology. Until about 20 years ago, much of what scientists knew about the human brain was based on experimental studies of rat brains or formal study of damaged human brains requiring surgical intervention. But the development of technologies such as positron emission tomography (PET) scanning and magnetic resonance imaging (MRI) finally made it possible to study healthy human brains. For the first time, neuroscientists and psychologists started to talk to each other and thus to make connections between what each understood about the human mind. The old idea that a brain arrives on the planet hardwired by genetics was rapidly replaced by the realization that brains are built before *and* after birth, that one's experience literally shapes one's brain for survival.

The designation of the 1990s as the "Decade of the Brain" in the United States spawned numerous articles about the brain in the popular press, as well as conferences on early childhood and the brain, and publicity campaigns such as the "I Am Your Child" effort spearheaded by television celebrity Rob Reiner. Leslie Hart was among the first authors to write about the brain from the perspective of education. His *Human Brain and Human Learning*, first published in 1983, angered many but it inspired even more. He coined the term "brain-compatible" to refer to education designed to match "settings and instruction to the nature of the brain, rather than trying to force [the brain] to comply with arrangements established with virtually no concern for what this organ is or how it works best."[2] Hart asserted that such learning environments would logically produce strikingly better outcomes. Educator Susan Kovalik was among the inspired who worked with colleagues to develop a brain-compatible model for education and teach others to implement it. Other influential educators and writers include Renate and Geoffrey Caine, Jane Healey, Robert Sylwester, and Pat Wolfe.

Some Brainy Definitions

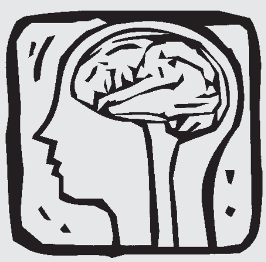
Amygdala: An almond-shaped structure in the middle of the brain, connected to the hippocampus, which detects the emotional content of sensory data and plays a role in the formation of emotion-laden memories.

Bodybrain: Term coined by Susan Kovalik to reflect the dynamic and integrated involvement of the entire human organism in the learning process.

Bodybrain-compatible: An expansion of "brain-compatible," a term used by Leslie Hart to refer to education that fits well with the nature and function of the human brain as currently understood. The word "bodybrain" reminds one that the whole body is involved in the learning process.

Cortex: The "bark" or neuron-packed outer layers of the brain in which conscious thought takes place.

Informational substances: A term used by neuroscientist Francis Schmitt to describe a variety of transmitters, peptides, hormones, and protein ligands that make up a chemical communication system among the body's cells.



Neuron: A type of brain cell that receives stimulation from its branches, or dendrites, and communicates to other neurons by firing a nerve impulse along an axon.

Neurotransmitter: One of over 50 chemicals stored in neuronal axon sacs that transmit impulses from neuron to neuron across synaptic gaps.

Peptide/Neuropeptide: A chain of amino acids that serves as an information messenger for states, moods, and thinking as it travels throughout the body. Every peptide now known to be produced within the body has receptors in the brain, qualifying each to be considered a neuropeptide.

Receptors: Protein molecules located on the surface of all cells which receive chemical messages from other cells.

Synapse: The microscopic gap between the axon of one neuron and the dendrite of another.

Thalamus: A sensory relay station located deep within the middle of the brain.

Essential brain research findings

When delving into the biology of learning to understand the underlying neuroscience, it is easy to get lost in details that, while fascinating, do not suggest classroom applications. In the following summaries, I have chosen three key findings from brain research that can empower you and your students as learners: 1) emotion is the gatekeeper to learning; 2) intelligence is a function of experience; and 3) the brain stores most effectively what is meaningful from the learner's perspective. A few details about each of these areas of research will help you recognize what you already do and what you could do to provide more brain-compatible learning opportunities for your students.

Emotion: The gatekeeper to learning

As any teacher will attest, emotions in the classroom can be explosive and disruptive. This is especially true at the middle and high school levels where emotions seem to form the agenda of students. Today, thanks to the groundbreaking work of Dr. Candace Pert, the influence of emotion on learning can be examined scientifically. In her book *Molecules of Emotion: Why You Feel the Way You Feel*, Pert unveils a mind-bending view of learning as a true body-brain partnership. As the story unfolds, the neurotransmitters responsible for the synaptic leap between brain cells are but one category of "informational substances" that carry out the process we call learning. The "informational substances" of the second, parallel system are a variety of transmitters, peptides, hormones, and protein ligands. Travelling via intercellular pathways such as the bloodstream, these substances reach receptors on the outer surfaces of cells throughout the body. Some neuroscientists speculate that less than two per cent of neuronal communication actually occurs at the synapses between neurons of the brain. The rest of the communication occurs through these informational substances.

Just what are these "informational substances" and what is their role in learning and performance? These molecules are the basic units of a language used by cells throughout the body and brain to communicate across systems such as the endocrine, neurological, gastrointestinal, and even the immune system. As they travel, they inform, regulate, and synchronize. Peptides are the largest category of informational substances and one kind or another is produced in every cell in the body, not just by cells in the brain.

Furthermore, every peptide known to be produced in the body has receptors in the brain, thus qualifying each peptide to be considered a "neuropeptide." This means that the body talks back to the brain, giving it information that alters its messages back to the body. These findings overthrow the distinction traditionally made between body and brain, giving rise to a new concept of "bodybrain" which reflects the constant collaboration that takes place between mind and body.

An example of such back and forth conversation between body and brain occurs when a student is at the receiving end of a put-down or is humiliated by classmates' laughter upon making a public error. When the chemical and electrical communication systems of the bodybrain detect threat, an automatic sequence can be triggered that focuses all attention on the perceived threat and little or none on what a teacher may be saying or doing. Joseph LeDoux explains that potential threats to safety or survival are detected unconsciously through the activity of the amygdala, a structure deep within the brain that gauges the emotional content of sensory data.[3] A brain triggered by its amygdala has the power to override rational thought and orchestrate a rapid, reflexive response to prepare for fight or flight to assure survival. Imagine that a teacher intervening in a threatening situation tells a student to stop and breathe slowly and deeply. As soon as the breathing rate slows, the neuropeptides produced in the breathing center send out a message, "Hey, I'm slowing down, things aren't so bad and scary now." The brain, receiving the message, responds, "Not so bad and scary, huh? Oh, I see, yeah, a teacher is here and in control. It's safe now," and in turn sends out neuropeptides to the rest of the body saying the danger is over.

Other manifestations of bodybrain "conversations" include a "gut feeling" about something, a first impression of someone as untrustworthy, a restless sense that something is wrong before you can put your finger on it, a spark in the eye that says "I get it even though I can't yet explain it," a passion for learning in a particular field, deep love of the beauty of nature, the contentment of a quiet hour spent with a special friend. An important piece of evidence supporting this new view of learning as a bodybrain activity is the discovery that in locations where information from our senses (sight, sound, taste, smell, and touch) enters the nervous system, there are high concentrations of receptors for information substances. According to Candace Pert, such regions, called nodal points or hot spots, seem to be designed so that they can be accessed and modulated by almost all neuropeptides, causing unique neurophysiological changes as they go about their job of processing and prioritizing information. Thus peptides filter the input of our senses, significantly altering our perception of reality and selecting which stimuli will be allowed in. "Emotions and bodily sensations," says Pert, "are thus intricately intertwined, in a bidirectional network in which each can alter the other."[4]

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A surprising twist to this story is that several of the key emotion molecules such as endorphins can be found in single-celled animals (as well as on up the evolutionary trail). Such peptides, it turns out, have been carrying information since before there were brains, leading researchers such as Antonio Damasio to assert that "emotion is the highest part of our mindbody survival kit"[5] because one of its key roles is to tell the brain what is worth attending to and the "attitude" with which one attends. As Dr. Robert Sylwester puts it, "Emotions drive attention which drives learning, memory, and just about everything else."[6] Thus when it comes to learning, the body and brain are inseparable and interdependent.

Classroom Application: Emotional states result from a complicated system of chemical messaging throughout our bodies that in turn affects what we perceive and where we focus our attention moment to moment. Emotions are thus the gatekeepers to learning. A safe and predictable emotional climate begins with positive relationships among teachers and students. Such relationships can flourish where there is a common language describing the ways in which people agree to interact respectfully. Students thrive when the teacher, classmates, and administration obviously care about them personally. Plan activities that build team spirit and mutual understanding to foster caring and trust. Use clear procedures to let students know what to do, thus eliminating the risk of embarrassment from unintended misbehavior. Build a sense of community by creating safe ways, such as classroom meetings, for students to say what they need and want. Post agendas so that students have a picture of what is coming each day.[7] Teach students constructive ways to resolve conflict and to encourage one another. When you use such strategies, you increase the likelihood that your students will be in an emotional state that allows them to focus full attention on the learning experiences that you have designed.

A teacher can influence the kinds of input students receive, but only students can make meaning from incoming sensory information, and the meaning they make is based on their own prior experiences as encoded in networks of communicating neurons. Teachers cannot know what is meaningful to students unless they know their students.

Intelligence: A function of experience

Assuming a desirable emotional climate in the classroom, we can now turn to the neuroscience findings that help us to understand the central role of experience in human learning. New experiences physically change the brain by causing neurons, the brain cells principally involved in cognition, to sprout new branches, or dendrites, and thus increase communication among neurons across microscopic gaps called synapses. The synaptic leap of an electrical impulse between the axon of one neuron and the dendrite of another is the physical basis of learning and memory. When a pathway of communication within a network of neurons is used repeatedly, it becomes increasingly efficient and we say that we have learned something. Consider that an adult brain has about 100 billion neurons and you can begin to appreciate what a complex and busy place a brain is!

The findings of neuroscientists affirm the importance of experience in the development of dendrites and, by extension, in the results of this development which we call learning and observe as intelligence. Increases in dendritic growth can be measured as increases in the thickness of the cortex, the part of the brain in which conscious thought takes place. Marian Diamond carried out studies in her lab at the University of California at Berkeley to understand the impact of a so-called enriched environment on the brains of infant rats. She placed a group of three mothers and nine pups in a large cage without toys (control group) and another group in a large cage with toys (enriched group). Then she compared both groups to a single rat family housed alone in a small cage without playthings. In as little as eight days' time, the enriched youngsters developed cortexes that were from 7 to 11 per cent thicker than those of the other infants.[8] Researchers Scheibel and Simonds at the University of California in Los Angeles analyzed the brains of children who had died between the ages of three months and six years. They observed that dendritic branching increased immediately after birth as sensory and motor experiences came in torrents from the baby's environment.[9] Illustrations of such growth show that by "twenty-four months of age a child's frontal cortex is a true enchanted thicket of neural trees with busy dendrites and billions of shimmering spines."[10]

Classroom Application: Experiences that provide rich sensory input well beyond the capacity of a book or a worksheet have the greatest chance of sparking dendritic growth and increased synaptic connections. First-hand experiences in the world outside the school and with real things inside the school evoke such rich sensory input to the brain. Visiting the pond, inspecting an earthworm up close, observing a seed become a plant — these are the experiences that enhance neural networks. Learning that starts with a "being-there" experience gives added power to all other kinds of input whether it be immersion, hands-on with real objects, hands-on with models, second hand, or symbolic.[11] Understanding that neural networks, which are the substrate of human learning, depend on first-hand experiences gives educators new and strong reasons for orchestrating a lively classroom that begins with the real world.

Personal meaning: The key to memory

The bodybrain is designed to make meaning out of the chaos that is the thousands of bits of sensory data humans process each minute. In fact, part of the definition of learning is "the extraction, from confusion, of meaningful patterns."[12] Learning is essential for our survival as a species. The brain efficiently pays attention to what is relevant to daily life, always asking "What is going on?" and "How is it important to me?"

returned it weeks later. You wonder if it is possible that you actually wrote this set of responses that now appears completely foreign. For information to carry meaning for a student, the learner must be able to form a personal and emotional connection.

Robin Fogarty reminds educators that a human brain is much like a sieve,[13] letting go of much of the estimated 40,000 bits of information per second collected by the senses. Although neuroscientists have not yet uncovered exactly how a new memory is formed, they have described the pathway that new information follows:

> "Education is discovering the brain, and that's about the best news there could be. Anyone who does not have a thorough, holistic grasp of the brain's architecture, purposes, and main ways of operating is as far behind the times as an automobile designer without a full understanding of engines."
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> **— Leslie Hart, 1983**

> First the sensory stimuli hit the neurons in the appropriate sensory cortex. These crude sensations are then relayed through the thalamus and sent to the sensory association area of the neocortex where they are put together into objects we recognize. Next (and almost simultaneously) the information is sent to the amygdala for emotional evaluation and to the frontal cortex for content evaluation. On the basis of its analysis of physical features of the stimuli, the brain begins to construct meaning.[14]

Essentially the brain asks, "Does this make sense?" and "Do I care?" New input must carry emotional value and useful content or the brain efficiently ignores it. As Robert Sylwester points out, "A memory is a neural representation of an object or event that occurs in a specific context, and emotionally important contexts can create powerful memories."[15] Conversely, when information lacks personal meaning and an emotional hook, the neural networks needed to create long-term memories are not formed.

For proof, just consider how you may have crammed for a test in college, filled a blue book, and then been amazed at its contents when the professor

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Fortunately, understanding the real world and what makes it tick is the target of many key topics in our curriculum. Such understanding is also fundamental to becoming a responsible citizen. How can students apply their newly mastered knowledge and skills to improve their communities? By associating new information and skills with things students care about, teachers increase the opportunities for students to make the kind of meaning that becomes a long-term memory.

Looking at schooling from the perspective of the brain calls for a different approach to curriculum. Base your curriculum on overarching concepts that help students understand and predict what is going on around them at school and in their communities. Tie skill instruction to service projects such as cleaning up a nearby stream, helping to restore a community

increase of 8.43) on the reading comprehension portion of the Stanford 8. Seventy per cent of the students improved their percentile scores (overall increase of 9.29) on the science part of the same test.

Consider why students made such consistent learning gains from the perspective of bodybrain-compatible learning. Students were excited about the trips to the ecosystems they studied and welcomed frequent guest speakers into their classroom as experts (emotional hook and rich sensory experiences). They learned the fun of working together as effective members of a team to get important work completed (emotional hook and personal meaning). Understanding the river and lagoon ecosystems contributed to students' ability to make sense of the world around them, and their work to improve these ecosystems gained them approval from adults in the community (emotional hook and personal meaning).

ecosystem in distress, or developing a nature study area on the school's grounds. Awaken students' natural search for meaning with questions that point to the connections between what happens inside and outside the classroom; as Kovalik and Olsen recommend, students should "study the science and mathematics used today in the fields of their interest, in solving problems faced by their community, and in enriching their own lives."[16] Constantly ask and answer the question "So what?"

Bodybrain learning and EE: A natural partnership

Educators who involve their students in meaningful ways with the world around them increase their students' learning. As a case in point, consider a recent project that was led by environmental educators Barbara Norris and Brenda Russell at Lewis Carroll Elementary School in Merritt Island, Florida. Students Environmentally Aware of Our Shores (SEAS) was an interdisciplinary study conducted by sixth-grade students of the barrier island and lagoon ecosystems in their Florida community. The project gave students a host of first-hand experiences that included testing water quality, cleaning up shorelines, and planting mangrove seedlings to help to restore those distressed ecosystems. Norris and Russell addressed reading, writing, science, social studies, and math learning goals through an integrated year-long theme connected by overarching concepts. Each student also conducted an individual research project to support the theme study. During the course of the project, 66 per cent of the students improved their percentile scores (overall

The dialogue among educators, neuroscientists, and others who are seeking to understand the biology of human learning is really just beginning. But already there is much to inform our practice. You can begin by acting on three of the key findings so far: the role of emotions in focusing attention, the importance of providing many first-hand experiences, and building in personal meaning from the student's point of view. Through their use of hands-on, field-study approaches, many environmental educators are already a step ahead in acting on the research about the magical ways in which the body and brain work together to learn. However, knowing how what you do aligns with the findings of neuroscientists can give you more powerful ways to assure student success and to build support for vital programs.

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Notes

1. Leslie Hart, *Human Brain and Human Learning* (Kent, WA: Books for Educators, 1999), p. xi.

2. Hart, p. xi.

3. Joseph Le Doux, *The Emotional Brain* (New York: Simon & Schuster, 1996).

4. Candace Pert, *Molecules of Emotion: Why You Feel the Way You Feel* (New York: Simon & Schuster Touchstone, 1999), p. 142.

5. Antonia Damasio, *Descartes' Error: Emotion, Reason and the Human Brain* (New York: G.P. Putnam Sons, 1994), p. 164.

6. Robert Sylwester, *A Celebration of Neurons: An Educator's Guide to the Human Brain*, (Alexandria, VA: Association for Supervision and Curriculum Development, 1995), p. 72.

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8. Marian Diamond and Janet Hopson, *Magic Trees of the Mind: How to Nurture Your Child's Intelligence, Creativity, and Healthy Emotions from Birth Through Adolescence* (New York: Penguin Putnam, 1998), p. 104.

9. Roderick Simonds and Arnold Scheibel, "The Postnatal Development of the Motor Speech Area: A Preliminary Study," *Brain and Language* 37, 1989, pp. 42-58.

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11. Kovalik, 1997, pp. 79-84.

12. Hart, p. 127.

13. Robin Fogarty, *Brain Compatible Classrooms* (Arlington, IL: SkyLight Training and Publishing, 1997), p. 36.

14. Pat Wolfe, *Mind, Memory, and Learning: Translating Brain Research to Classroom Practice* (Napa, CA: Self-published trainer's manual, 1997), p. 8.

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16. Karen Olsen and Susan Kovalik, "How Emotions Run Us, Our Students, and Our Classrooms," *National Association of Secondary School Principals (NASSP) Bulletin*, May 1998, p. 96.