It's *Never* Too Late! What Neuroscience Has To Offer High Schools

By Robert K. Greenleaf

Decades of educational banners have promoted "Early childhood," "Prevention," "Critical periods of development," and a host of other phrases that have focused the resources of dollars, programs, and time on the youngest of our charges in public schools. Is it really too late by the time youngsters get to high school? Don't bet your neurons on it!

Disclaimer: Common rhetoric all too often makes unfounded assertions, misrepresenting connections between the neurobiological research and the practices involved in educating human beings. As John Bruer (1997) states, "Our emerging understanding of the brain may eventually be able to contribute to education, but it will require us, at least initially, to take a different, less direct route, a route that links brain structures with cognitive functions and cognitive functions with instructional goals and outcomes." Though we cannot yet claim direct teaching prescriptions based on findings in brain studies, we can make significant inferences from the combined fields of neuroscience and cognitive psychology to inform practice.

A graphic of the three major fields in this discussion might look like this (see Figure 1). Note the absence of overlap between education and the neuroscience fields. Our challenge is to work on establishing the "bridges" between understanding in the fields of cognitive psychology, neuroscience, and education. In constructing these connections, we stand to gain much in terms of developing effective instructional experiences for our students.

Fundamentals: Let's get one thing straight. The term "brain-based learning" is redundant. Learning is what the brain does. The lungs breathe, the heart pumps, and the brain... "learns." We don't tell the lungs how to

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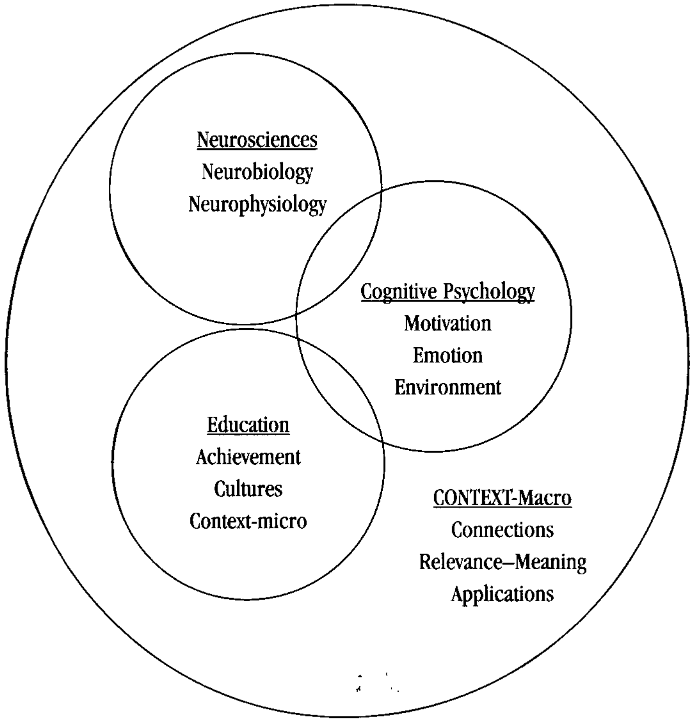
FIGURE 1

Model of Current Relationships



Purpose: To explore the fields of neuroscience, education, and psychology toward better understanding context, teaching strategies, individual and group dispositions/behaviors, environmental factors, cultural influences, and learning preferences... in order to best understand why, how, and when to assist youth in the learning process.

breathe any more than we can instruct the brain how to learn. The brain is ours to use. So-called "brain-based" instruction seeks to use it well (Greenleaf n.d.).

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A better question might be "How might we engineer circumstances that allow this apparatus to function most efficiently?" The endless complexity of the human brain is awesome. Though our understanding is meager, some early indicators are providing useful background on which to construct viable instructional strategies as well as ways to build meaningful context into our lesson design.

First, many educational terms—like "learning styles," "mixed abilities," "multiple intelligences," "emotional intelligence"—place emphasis on variations in the brain's way of interpreting information. *Second,* concepts like "engaging students," "differentiating instruction," "lesson design," and "integrating curriculum," provide names for our approaches to the way the brain interprets the sensory inputs we engineer via lessons. The excitement regarding brain-based learning (the attempt to merge the neurosciences, cognitive psychology, and instructional practices) lies in the inherent connections between these three perspectives. The good news is in the possibility that we may be moving, albeit cautiously, toward a more unified understanding of learning.

Among the recent abundance of research data are a few concepts critical to the "teaching by neuroscience" agenda. The following is a brief representation.

It is a myth that more brain cell connections equal more learning. There are no studies showing a correlation between the rate of synaptic growth and the amount of learning taking place (Levitt 1999). The literature does indicate that brain cell (neuronal) connections (dendrites) between cells (across synapses) are rapidly generated (10,000–40,000 per second) from the second trimester of pregnancy until about age three. This is called synaptogenesis. From ages 3 to 12 years the growth rate develops in equilibrium (equivalent volume of new growth to offset the pruning), after which it declines until the late teens, when the "adult" level of total neuronal connections levels off.

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This has been misinterpreted to suggest there is a "critical period" in the first three years (Levitt, Reinoso, and Jones 1998), after which there is little possibility of developing certain capacities, such as acquiring a second language. There is no argument that the early stages in life are important in all species, but not to the exclusion of equally viable learning potential in the teen years—or adult years, for that matter! The total number of connections in the brain begins to stabilize around age three. This is the result of the brain's deletion (pruning) of connections it no longer needs. Pruning of outdated dendritic connections now begins to occur at the same rate at which new connections are formed. This results in an equilibrium of the total number of neural connections, but not by any means a diminished opportunity for learning.

Learning never ends.

Never.

Not at any age.

The saying "all students can learn" is educationally naive; all students already *do* learn. The question might be, "*What* are students learning?" A statement that "all students can learn" is based on a misunderstanding of the basics of what a brain is and what the mind does. Brains will learn, with or without us, and long before formal instruction ever begins. How well they learn in school should be the subject of investigation.

Emotion

All learning is emotional. That is, emotion is learning. Learning is an emotional response to a cue (Levitt 1999). Learners make personal meaning, based on whether they perceive something to be of relevance or importance *to them* (Levine 1997). Simply put, without emotion there is no long-term, stored, transferable, meaningful learning. One cannot effectively teach in an emotional vacuum, a context devoid of emotion.

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Understanding how to design an educational environment is an undertaking vital to the success of all learners. Orchestrating meaningful connections is inarguably prerequisite to content considerations. Thus, it is true at the cellular level that we are not teaching content so much as we are teaching youngsters!

The mental conclusion of "not important" suggests that little or no meaning (value) is indicated. That which has only a minimal impact on learners can, by definition, have no significant emotional base for retention. Salovey and Mayer (1990) have conducted numerous studies further identifying the integration of emotions with learning. "We view emotions as organized responses, crossing the boundaries of many psychological subsystems, including the physiological, cognitive, motivational, and experiential systems." They have concluded that humans possess an emotional intelligence that has an equivalent impact on learning to that of cognitive intelligence.

Movement

Studies have revealed some intriguing information. Fifty percent of all neurons are located in the cerebellum (small cauliflower-shaped apparatus in the lower rear of the cranium). The function of the cerebellum is to deal primarily with the components of movement and novelty. When gross or fine motor activity, spatial orientation via the senses, and new or unique first occurrences take place, the cerebellum is involved. If about half our learning brain cells are devoted to movement and novelty, how can "be seated and be quiet" be an effective teaching strategy?

Potential will better be realized when some form of movement accompanies learning situations in an integrated manner. This does not suggest that student activity must be on a large scale. Movement can be subtle; fingers pointing, changing direction of sight, tapping feet, teaching from a different place, and so forth. Robert Sylwester graphically sums it up saying, "How can one promote a curriculum that reduces the acceptable movement ... to one hand writing ... on a playing field the size of a sheet of typing paper?" (1998)

Context

All learning is contextual. This is part of the reason for the importance of movement and environment. Eric Jensen (1998) states, "...every life experience has to be, in some way, contextually embedded. Thus, all learning is associated with corresponding sights, sounds, smells, locations, touch, and emotions. You can't not be somewhere when you learn. All learning provides contextual cues."

Learners must experience connections between their personal understanding and the new ideas and information of the day. This means they must do the work of thinking and feeling the relationship between curriculum and meaning in their daily lives. Context provides the canvas upon which the medium of choice (paint, markers, ideas, facts, concepts) is worked, formed, and processed.

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Formal classroom lectures *can* be effective, but not as a sole or steady diet. We have a century's evidence that many students have learned quite well through lecture, but we also have evidence that too large a percentage do not thrive with this approach. Evidence suggests that a mix of teaching methods will better accommodate differing styles and dispositions. Even varied instructional approaches will fall short, however, unless the experience is engineered with the context as a prerequisite for instruction.

Context for educators is both macro (school or classroom *environment*) and micro (*lesson* embedded). From an environmental or macro standpoint, the overall classroom context must be free of physical, social, and emotional interference (distractions that consume primary mental attention). On the micro side of lesson design, the content must be embedded in transferable concepts that allow/help learners to personalize their understanding, explore connections with meaning, and make use of their learning through application. An example is provided.

Applications

Let's begin a geometry unit of instruction on parallel lines. Prior to lesson 1 in the text, we begin with context, personal meaning, connections

TABLE 1

Learning Example

Teacher	Student	Comment
"Class, today we begin a unit of study on parallel lines. Please place two fingers parallel to one another."	Moves two fingers in some manner that shows parallel.	• Movement: a simple task, done at one's seat. • Visual feedback to the teacher provides evidence of understanding.
"I will be seeking two ideas or examples for each question today."	Learners understand that each question will be asked at least twice. Even though a response may be given by another student, s/he may still be asked to participate on the same question.	• Learners are provided with "wait time"—the *second* wait time, which comes after an initial response takes place. This is the more powerful time with respect to processing and making connections. While some thinkers come up with ideas quickly, others need time to think, knowing they may be asked to participate following the first person's response (Greenleaf)
"Who can give an example of where parallels like this exist in the world of nature?"	"In a grove of trees."	• Context: The concept of parallelism is being solicited from within each student's experiential world within the category of nature. • Concept integrated with nature. • Ideas are plentiful.
The teacher acknowledges the response, clarifying that two trees may well be growing reasonably parallel to one another, and then prompts for the second example, "What else?" or "Jamie, where do you find parallels in the world of nature?"	"The legs of a chicken when it is standing still."	• Student-generated examples. Students do the work of making connections and generating ideas in terms of their understanding. Examples stemming from their repertoires are far more likely to be retained than less personalized ones.

FIGURE 2 (Continued)

Learning Example

Teacher	Student	Comment
"O.K. Who can identify parallels in geography… land and/or water formations?"	"The sides of a river."	• Context: The concept of parallel is being solicited from within the category of geographical configurations.
"O.K. Another?"	"Lines of sediment in rock or dirt."	• Student-generated examples • Concept integrated with geography
"Who can tell me of an athletic event that does NOT have parallel lines associated with it?"		• Novelty through *reversing* the question.
Silence follows for a time. After sufficient time, the teacher may choose to restate the original question, prompting further ideas.	Students guess, "golf." "The sides of the fairway," "The edges of the club shaft," "The golfer's feet when s/he prepares to swing."	• Student generated examples. • In each mind, students think about golf and objections arise … minds search for examples of parallels in golf. • Concept integrated with athletics
"Where, in the world of music, theater, and art do you find parallels?"	"The lines on the staff." "The strings of a guitar." "The frame of a painting."	• Concept integrated with the fine arts. • Student generated examples.
"Tonight's homework is to find an example of parallels on your favorite CD cover."		• Personal connections • Context—home application

to student experience, and movement/novelty. Two strategies are used to ensure student engagement—students do the majority of the work, not the teacher.

1. It is imperative that the teacher solicit two responses whenever requesting input from students. If not, the message to the class is that the first and only respondent to a query has either been called on or has chosen to offer a response—and the rest of the class doesn't have to engage. We need students to process actively yet seldom have time to call on each student. By always requiring a second student response or example, each learner knows that while the first person is "working" the opportunity for another will surely follow—and the second query could involve him or her. This is what I call "passive attention" (keeping all minds attentive to the task).
2. Students will generate their own responses (internal and external), from their experiences and understanding (context) prior to any instructor-generated examples. This allows them to make personal connections and demonstrate (to themselves) the relevance of the concept to be studied.

The actual example follows in table 1.

Several things have taken place in this example. *First,* students are doing the work of identifying examples, making connections to the world as they see it. *Second,* even though not every student has participated aloud, the teacher has engaged each mind by asking for at least two examples from each context area. *Third,* by varying the areas of context (nature, geography, sports, the arts) the teacher has helped learners to integrate their understanding of the concept across multiple areas of knowledge. *Fourth,* learners of varied abilities are all able to participate. By soliciting two examples, and by using contexts to accommodate differing student experiences, interests, and styles, each can take part.

This exercise takes anywhere from 3 to 10 minutes, depending on how far the teacher wishes to pursue it. Orienting learners as to how the concept ties into their daily lives is motivating and relevant. It builds a context laden with connections to personal experiences, ideas, and examples on which to construct new knowledge.

The search for pattern is one of the mind's primary modes. When we build a lesson context that fuels what the brain naturally does, material to be taught is learned more readily, with greater ease, motivation, and recall.~***B***

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Other Resources

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