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Brain-Based Learning: The Neurological Findings About the Human Brain that Every Teacher Should Know to be Effective

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Brain-Based Learning: The Neurological Findings About the Human Brain that Every Teacher Should Know to be Effective

Abstract

The purpose of this paper is to present the main neurological findings about the human brain that provide the basis for brain-based learning, and that represent a narrow field of cognitive science as a whole. The findings that are described were made primarily by neuroscientists who studied the structure and functions of the nervous system with the purpose of correcting abnormalities. Only recently have neuroscientists begun studying the brain-based learning processes of normal students in detail (Fenker, et al., 2008; Jonides, et al., 2008; Kellman, & Massey, 2010; and Swanbrow, 2011). The neurological findings about the human brain were used by researchers such as Hart (1975, 1983), Caine & Caine (1990, 1991), Cain et al. (2009), Jensen (2008), and Medina (2008) to develop brain-based learning strategies that promote learning in accordance with the way the brain is naturally designed to learn.

Keywords: brain-based learning, learning process, declarative memory, flow, optimal learning, guided-experience learning

Brain-Based Learning: The Neurological Findings About the Human Brain that Every Teacher Should Know to be Effective

The word *brain* only began to replace the word *mind* in popular self-help books as late as the 1970s. Examples include the very successful books *Use Both Sides of Your Brain* by Buzan (1974) and *Drawing on the Right Side of the Brain* by Edwards (1979). The concept of brain-based learning did not emerge until the 1980s, driven by the advances in neurobiology and cognitive neuroscience (Jensen, 2008).

One of the first researchers to establish the connection between brain functions and traditional education practices was Hart (1983), in his book *Human Brain and Human Learning*. In the preface to this book he wrote:

> We have many brilliant neuroscientists and neuropsychologists at work and their contribution in recent years have been magnificent. We have, too, many thoughtful, creative educators with intimate knowledge of schools and training – but no modern knowledge of the brain. My hope is that this book will help bridge the lamentable gap that exists between these two fields, and bring to educators some sense of the fresh, exciting new vistas that open up when one takes a brain approach to the problem of human learning (p. xii).

He also explained that the traditional classroom practices adopted in most schools have significantly impaired student’s cognitive processes.

Medina (2008) went even further with the critique of traditional classroom practices, writing that, from the perspective of brain studies:

> If you wanted to create an education environment that was directly opposed to what the brain was good at doing, you probably would design something like a classroom (p. 5).

He also acknowledged that to change this, it will be necessary to tear down the old classroom concept and start over.

Other researchers followed Hart’s (1975, 1983) cue and expanded the understanding of the brain functions into the context of learning. Examples include Gartner (1983), in his book *Frames of the Mind: The Theory of*

Multiple Intelligences, which made a connection between brain functions and new models of thinking, and Caine & Caine (1991) who made the connection between brain functions and classroom pedagogy in their book *Making Connections: Teaching the Human Brain*.

In the 1990s, brain-based learning gained widespread acceptance, and neuroscience and education where definitively linked with the publication of the peer-reviewed journal *Mind, Brain, and Education* (the official journal of the International Mind, Brain, and Education Society, published by Wiley) and with the master and doctoral programs in brain-based education offered at Harvard University Gradual School of Education. In today´s literature, the study of the brain´s capacity for processing information and for knowing (or more precisely, the process of being aware, thinking, learning, and judging) has come to be described by the domain known as cognitive science. This is the interdisciplinary branch of science that studies all aspects related to the brain, and embraces philosophy, anthropology, sociology, education, linguistic, neuroscience, and artificial intelligence.

This paper only covers the main neurological findings about the human brain that are the basis for brain-based learning, and which therefore represent a narrow field of cognitive science as a whole. The findings that are described were made mainly by neuroscientists who studied the nervous system with the purpose of correcting abnormalities in respect to its structure and functions. It is only in the last decade that brain studies have examined in any detail the learning process of normal people, particularly students (Jonides, et al., 2008; Fenker, et al., 2010; Kellman, & Massey, 2010; and Swanbrow, 2011). Authors such as Hart (1983), Caine & Caine (1991), Cain et al. (2009), and Jensen (2008) used the neurological findings to develop brain-based learning strategies, in order to promote learning in accordance with the way the brain is naturally designed to learn.

Self-help literature contains numerous prescriptions for improving learning and teaching that have no real scientific foundation, and therefore provide an inadequate foundation for rigorous research. Medina (2008) warned about these popular prescriptions:

> I occasionally would run across articles and books that made startling claims based on “recent advances” in brain science about how to

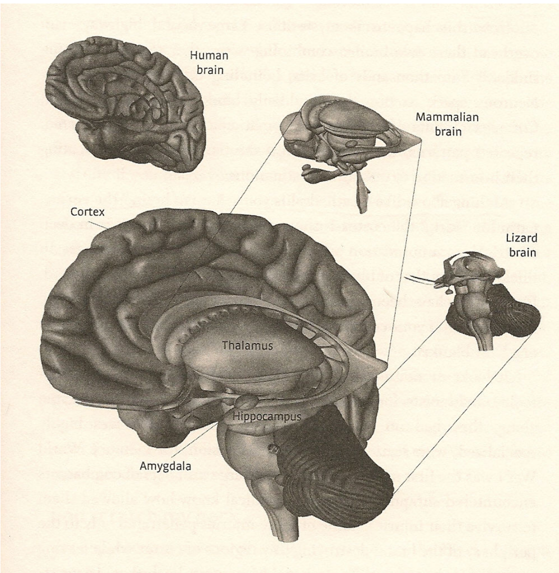
> change the way we teach people and do business. And I would panic, wondering if the authors were reading some literature totally of my radar screen. I speak several dialects of brain science, and I know nothing from those worlds capable of dictating best practices for education and business. In truth, if we even fully understood how the human brain knew how to pick up a glass of water, it would represent a major achievement (p.4).

The neurological findings presented in the present paper, however, were double-checked to ensure validity: they were required to have been presented in a reputable peer-reviewed journal, and then successfully accepted and validated by other scientists. These important neurological findings, and their impact on learning processes, are now presented.

The Structural Organization of the Brain

The triune theory of the brain is one of the several models scientists use to describe the brain's overarching structural organization (MacLean, 1990; Caine & Caine, 1991; and Medina, 2008). According to this evolutionary theory, the structure of the brain took millions of year to evolve to its present form (Figure 1). The most ancient neural structure is the brain stem: the reptilian (R-Complex) or lizard brain. The brain stem or basal ganglia controls most of the body's housekeeping: its neurons regulate breathing, heat rate, sleeping, and walking.

Figure 1. Triune theory of the brain



Source: Molina, 2008, p. 41

Sitting atop of the brain stem is the limbic system or paleomammalian (P-Complex) brain, consisting of the septum, amygdala, hippocampus, and thalamus. The limbic system is responsible for animal survival, and most of its functions revolve around the four *F*'s: fighting, feeding, fleeing, and f…ing (reproductive behavior). The amygdala is responsible for both the creation of emotions (rage, fear, or pleasure) and for the memories they generate. The hippocampus converts short-term memories into long-term memories. The thalamus processes input from nearly every sensor, and then routes this to specific areas throughout the brain.

The outer portion of the brain consists of the neomammalian (N-Complex) brain: known as the neocortex, or simply cortex. This structure is found uniquely in mammals, and makes language (including speech and writing) possible. Much of the processing of sensory data occurs in the cortex. The cortex the makes formal thinking and planning for the future possible (Fuster, 2003; and Freiberg, 2008).

Evolution of the Brain

The ability to attribute mental states (such as beliefs, intents, desires, pretence, and knowledge) to oneself and others, and to understand that others have beliefs, desires, and intentions that are different from one's own, is called *theory of mind* (ToM). This ability to peer inside somebody's mental life and make predictions takes a tremendous amount of intelligence and, not surprisingly, brain activity (Astington et al., 1990; Diamond, & Hopson, 1998; Doherty, 2008; and Glatzeder, & Müller, 2010). Many researchers believe that a direct line exists between the acquisition of this skill by humans and the intellectual dominance of the planet: This allowed humans to cooperate, that is, to create shared goals by taking into account each other's feelings and motivations (Goldberg, 2001; Goldstein, 2007; and Medina, 2008).

According to Gardner (1983), human intellect is multifaceted, and each individual has specific intellectual talent. Given this idea, it makes little sense to use a learning system that expects every brain to learn in the same way as every other. The existing systems of learning are based on expectations that certain learning goals should be achieved by a certain age. The reality is that students at the same age show a great deal of intellectual variability (Gardner, 1983; and Medina, 2008).

Given that every student in a class has a different intellectual talent, the ability of the teachers to read the student's mind is an powerful tool for successful teaching: ToM is about as close to mind-reading as humans are likely to get. The conclusion can be made that teachers with advanced ToM skills possess the single most important ingredient for being effective teachers (Wellman, & Lagattuta, 2004; and Medina, 2008). Obviously, teachers can only use their ToM skills in smaller, more intimate learning environments. For this reason, smaller schools with fever students obtain better learning results, simply because the teacher can better keep track of how everybody is learning.

Classroom Learning-Process of the Brain

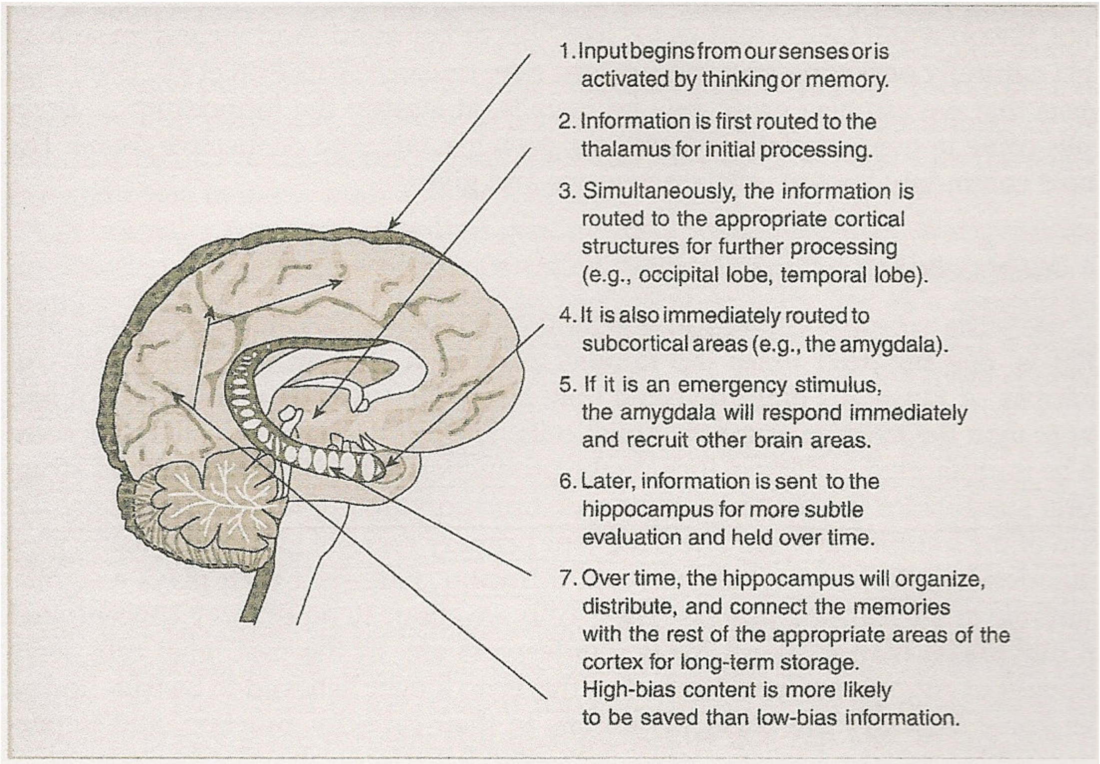
The brain processes different types of learning through different pathways. For this reason it is important to state that the description in this paper applies to the classroom learning-process (students learning new information in class), and assumes that the learning is overt and explicit. Students have the ability to remember or memorize information most strongly during the first few moments that it is transmitted.

The brain memorizes information using various types of memorizing systems, and many of these operate in a semi-autonomous fashion. The best known form of memorization is the *declarative memory* system, which involves information that can be declared and experienced in the student's conscious awareness (such as "the car is red" or "the sky is blue"). Students can also learn or memorize things like motor skills using what is known as the *non-declarative memory* system. Nobody can consciously remember the motor skills necessary to ride a bike, for example: This requires a memorization that does not involve a conscious awareness and so cannot be declared (Kandel, & Squire, 2008; and Medina, 2008).

The inputs (words, text, and pictures) to the brain of the students during classes are captured by their senses or generated internally by them (*step 1* in Figure 2). These inputs are initially processed in the thalamus, which is the "server" or central switching area of the brain (*step 2* in Figure

2). Simultaneously, these inputs are routed to other specific areas for processing (this routing is done instantly because the input may signal an emergency that requires instant action by the student): visual inputs are routed to the occipital lobe, language to the temporal lobe, and so on (*step 3* in Figure 2). Based on these instantaneous inputs, the brain immediately forms a rough sensory impression of the incoming information. If there is any threatening information, the amygdala (*steps 4 and 5* in Figure 2) is activated, and it will jump-start the rest of the sympathetic nervous system to enable a quick response (Jensen, 2008).

Figure 2. The human brain classroom learning process

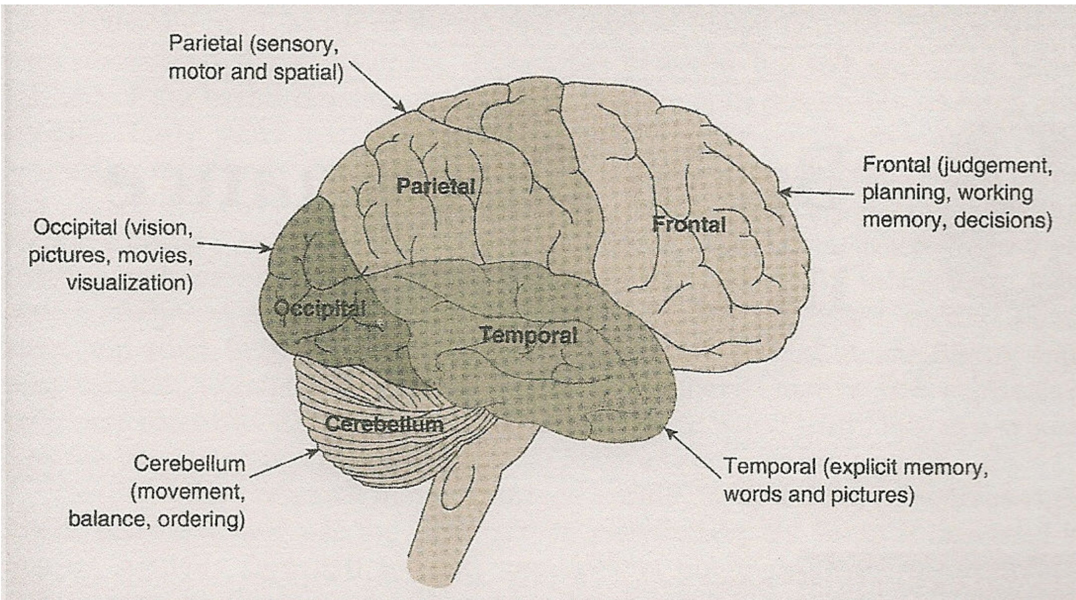


Source: Jensen, 2008, p. 11

Many of the new inputs are held in the frontal lobe (Figure 3) for short-term memory of 5 to 20 seconds. Most of these inputs are filtered, and then dismissed without being memorized, as the inputs may be irrelevant, trivial, or not compelling enough to be considered. If the inputs are considered relevant, the inputs are routed to and held in the hippocampus (*step 6* in Figure 2).

If the new learning is deemed important, it is organized and indexed by the hippocampus and later stored in the cortex (*step 7* in Figure 1). This is the bark-like surface (in Latin, cortex means *bark*) of the brain. The inputs (words, text, and pictures) are stored in the same lobe of the cortex that originally processes it: visual information in the occipital lobe, language in the temporal lobe, and so on (Figure 2). The original processing takes place at lightning-fast speeds, but the subsequent stages and storage process can take hours, days, and even weeks (Jensen, 2008).

Figure 3. Lobes of the human brain



Source: Jensen, 2008, p. 17

The unfortunate fact for teachers is that students forget, very quickly, most of what they have been taught in class. Hermann Ebbinghaus (1913) became famous for uncovering that students forget 90 percent of what they learn in class within 30 days. He further showed that the majority of the forgetting occurs within the first few hours after class. This has been confirmed in modern times with extensive studies (Medina, 2008).

The important neurological findings about how the human brain memorizes things that can be declared (declarative memory) will now be presented.

Declarative Memory Lifecycle

The lifecycle of the student's declarative memory can be divided into four sequential steps: encoding, storing, retrieving, and forgetting (Kandel, & Squire, 2008). Encoding occurs at the initial moment of learning, when the student's brain first encounters a new piece of declarative information. The brain is capable of performing several types of encoding. One type is *automatic processing*, which can be illustrated by asking students what they had for dinner last night. The students did not have to spend time and effort to memorize last night's dinner experience in order to be able to tell next day about it: this because the brain deployed the type of encoding called automatic processing. However, if the students are asked to repeat a list of dates from a history textbook, it is likely that they will only able to do it if they spend time and effort memorizing this information. This kind of encoding initiated deliberately, requiring conscious, energy-burning attention, is called *effortful processing*. The information is not bound together well at all, and learning requires substantial repetition by the students if they wish to be able to retrieve it with the ease of automatic processing (Hasher, & Zacks, 1979).

The inputs from the different sensory sources are registered in separate brain areas. The information is fragmented and redistributed the instant the information is encountered. A complex picture, for example, is instantly extracted by the brain into diagonal lines and vertical lines and stored in separated areas. The same instantaneous extraction and separate storage occur with colors. If the picture is moving, the fact of its motion will be extracted and stored in a place that is different than if the picture were static (Livingston, & Hubel, 988; Robertson, 2003; and Medina, 2008).

The process by which the brain brings all these fragmented pieces together to allow the students to remember the original information is called *binding* (Treisman, 1996; and Robertson, 2003). Medina (2008) writes:

> The binding problem, a phenomenon that keeps tabs on far flung pieces of information, is a great question with, unfortunately, a lousy answer. We really don´t know how the brain keeps track of things (p. 109).

Despite this lack of understanding, scientists have found that all encoding process of information by the brain have some common characteristics. Medina (2008) explains four that are important for teachers:

1. The more elaborate we encode information at the moment of learning the stronger the memory (Craik, & Tulving, 1975). The trick for teachers is to present bodies of information so compelling that the audience does this on their own, spontaneously engaging in deep and elaborate encoding. This can be best accomplished by the liberal use of relevant real-world examples embedded in the information and constantly illustrating learning points with meaningful experiences (Palmere et al., 1993). This works because it takes advantage of the brain's natural predilection for pattern matching (Nummela, & Rosengreen, 1986; Caine, & Caine, 1990, 1991; and Caine et al., 2009).
2. Introduction is the most important single factor to enhance learning. The first time students are exposed to a given information stream plays a disproportionally important role in their ability to accurately retrieve the information later (Fenkel et al., 2008). This because the memory of an event is stored in the same places that were initially recruited to perceive the learning event. The more brain structures are recruited by the initial interest, more cues are created in the brain at the moment, and easier it is to remember the transmitted information.
3. A memory trace appears to be stored in the same parts of the brain that perceived and processed the initial input (LeDoux, 2002; and Kandel, & Squire, 2008). The neural pathway initially used to process new information can become a permanent pathway if the brain reuses the stored information. For this reason repetition enhances remembering (Jonides, et al., 2008; and Swanbrow, 2011).
4. Retrieval may best be improved by replicating the conditions surrounding the initial encoding. This because the environment makes the encoding more elaborate and so creates more cues that facilitate future retrieval of the information (Godden, & Baddeley, 1975).

Thus, students remember information when it is elaborate, meaningful, and contextual with meaningful real-world examples. The quality of the early moments of the learning experience by students determines the quality of the encoding of their brains, as the many cues that are created will enhance their capabilities to retrieve the learned information in the future.

Short Attention-Span of the Brain

These studies indicate that better attention always equals better learning. We also know that students don't learn if they are stressed-out, despondent, or otherwise distracted with their computers or smartphones. Teachers have to learn to prompt them into positive state for learning, where they naturally perform effectively. Csikszentmihalyi (1991) in his book *Flow: The Psychology of Optimal Experience* describes a state of consciousness he calls *flow*, which is the primary criterion for optimal learning. Although it is impossible to merely will this uninterrupted state of concentration into existence, this happens when students "lose themselves" in a learning activity. When students are in flow, all self-consciousness and awareness of time fades, and what is left is the pure pleasure of absorbing the learning experience.

Csikszentmihalyi (1991, 1996, and 1997) suggests that individuals or groups can reach flow if a meaningful goal emerges spontaneously as the result of pleasurable activity and interaction in which attention, challenges, and skills are aligned (rather than being imposed). Creativity and learning occur in an accelerated fashion when learners are encouraged to enjoy themselves to and define and refine their own learning challenges, as this allows them to reach flow. This process allows learners to adjust their learning experience to suit their individual intellectual capabilities, to adjust challenges to their individual skill level, and to take responsibility for their learning in a relaxed state of alertness (Caine, & Caine, and 1991; Caine, et al., 2009).

The problem is that it is very difficult to for students to reach flow in a classroom; The flow approach works better for individual or teamwork environments. Medina (2008), based on his class experience, writes that before the first quarter-hour of a lecture to a class is over, students typically *check out*. He states that nobody knows why the brain seems to be making choices according to some stubborn timing pattern. Students (especially *generation M* [multitasking] students) seem to be constantly distracted by their laptops, iPods, or smartphones (Figure 4).

Research also demonstrates that the brain cannot multitask. The brain naturally focuses on concepts sequentially, one at a time. Studies show that a person who is interrupted takes 50 percent longer to accomplish a task. Not only that, he or she makes up to 50 percent more errors. The reason is very simple: People interrupted tend to lose track of previous progress and need to start over each time they switch tasks (Ramsey, et al., 2004; and Wallis, 2006).

Figure 4. Generation M (Multitasking)

Source: Time, March 27, 2006

Medina (2008) created a way to keep the attention of students in a lecture. He called this the *10-minutes rule*. In this method, each lecture is given in discreet modules that last only 10 minutes. Each module covers a single core concept: always large, always general, always repeating with gist, and always explainable in one minute. The remaining 9 minutes in the module are then used to provide a detailed description of the single general concept. Thus, a 50 minute class would cover five large concepts.

Given that the students begin losing attention after 9 minutes, Medina (2008) introduces compelling content to overcome the 10-minutes barrier. He uses emotional competent stimuli (ECS) to trigger an emotion (such as fear, laughter, happiness, nostalgia, or incredulity). This ECS has to be relevant to the provided content, and is placed between modules (it can be relevant for the beginning or end of a module). Medina (2008) noted that halfway through a lecture, after deploying two or three ECS, he found that he could skip the fourth and fifth ECS, and yet the students' attention would remain fully engaged.

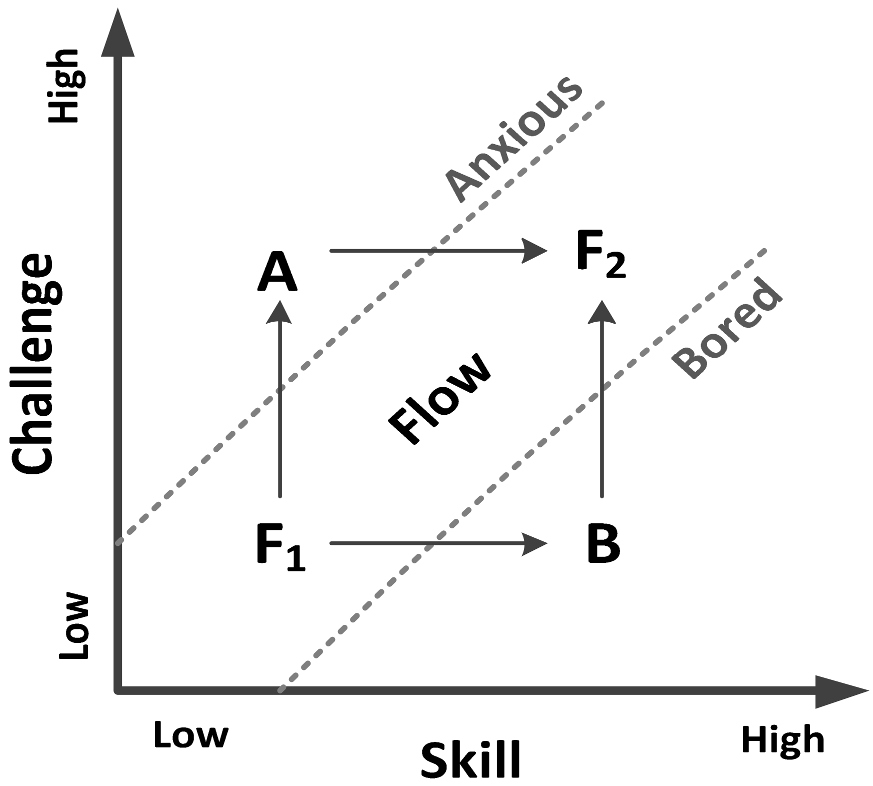
Brain under Stress

Stress is the body's reaction to a perception rather than to the reality of an actual event. It occurs when experience of an adverse situation occurs in such a way that control is lost and the desired goals are compromised. Stress is, for example, the sensation caused by getting late to an important appointment because of a traffic jam; The perception of the consequences of arriving late causes stress, and so changing this perception of the consequences reduces the level of stress.

There are, in general, two types of stress that students perceive. One type is useful stress (*eustress*), which occurs in short bursts and is not chronic and acute. This type of stress occurs when the student feels moderately challenged and believes that they can rise to the occasion. The eustress releases chemicals in the brain such as cortisol, adrenaline, and norepinephrine, which heighten the student's perception, increase their motivation, and strengthen their bodies: all conditions that enhance their learning (Caine, & Caine, 1991; and Jensen, 2008).

Csikszentmihalyi (1991) called the challenge that forces students to learn new skills an *optimal learning experience* (Figure 5). He explains that if challenge is too easy for the students (does not require to develop skills to perform), the students become bored with the subject. On the other hand, if the challenge is too difficult for the students (who don´t have the required skills to rise to the challenge) they become anxious, frustrated, and adversely stressed.

Figure 5. Optimal Experience



Source: adapted from Csikszentmihalyi, 1991, p. 74

Students living an optimal experience are continuously in flow. Each time the student develops the required skills to meet the challenge (*student moves from F1 to B* in Figure 5), the teacher has to grow the challenge proportionally in order for the student to return to flow (*student moves from B to F2* in Figure 5). If the challenge is too great for the student's capabilities, and they are unable to develop the required skills, they become anxious, frustrated, and stressed (*student moves from F1 to A* in Figure 5), and will (in most cases) abandon the optimal experience or require coaching to develop the required skills to return to flow (*students moves from A to F2* in Figure 5).

The negative form of stress (*distress*) occurs when students feel threatened by an emotion (such as danger, intimidation, embarrassment, loss of prestige, fear of rejection or failure, unrealistic time constrains, or perceived lack of choice). When this happens, the brain focuses selective attention and instigates a chain of reactions. The initial recognition of uncertainty causes the amygdala to send a message to the hypothalamus, which begins the chemical cascade to the adrenals, and soon the glucocorticoids (e.g., cortisol) and amines (e.g., noradrenaline) prepare for the event. The frontal lobe also monitors the event. Cortisol is a hormone that provides a temporary source of energy, and for a short period (or even a few hours) it can be helpful. However, over the course of days, weeks, or months, chronically high levels of cortisol wreak havoc on the brain (Jensen, 2008).

Hart (1983) refers to the condition wherein the focused selective attention of brain functions is caused by distress as *downshifting*. MacLean's (1990) triune theory of the brain (Figure 1) indicates that the brain literally "shifts down" from the cortex into the older, more automatic, mammalian and lizard brains. The lizard brain does not reason: it reacts automatically to any form of threat. When the brain downshifts it undergoes several changes: it loses the ability to correctly interpret subtle clues from the environment; it reverts to familiar, tried-and-true behaviors; it loses some of its abilities to index, store, and access information; it becomes more automatic and limited in its responses; it loses some of its ability to perceive relationships and patterns; it becomes less able to use higher-order thinking skills; it loses some long-term memory capacity; and it trends to overreact to stimuli in a phobic-like way (Caine, & Caine, 1991; Jensen, 2008; and Caine et al., 2009).

Based on this, Caine, & Caine (1991) wrote a strong warning to educators:

> In practice, many of the demands that we impose on students, ranging from placing unreasonable time limits on learning and restrains on individual thinking to excessive competition and motivation by means of shame and guilt, will cause all but the most resilient of students to downshift. In fact, by this definition we suggest that most schools maintain most students in a downshifted state and prevent them from engaging in the complex learning that we profess to be desired and needed (p. 75).

Brain Learning through Experience

Students acquire knowledge (that is, they learn) by processing experience (Dewey, 1998). Thus, living an experience (digesting, thinking about, reflecting on, and making sense of experience) is the best way for students to acquire knowledge or to consolidate and internalize information in a way that is both meaningful and conceptual coherent for them (Caine, & Caine, 1991).

The most effective approach to teaching, according to Caine et al. (2009), is guiding students to live an experiences, with the appropriate learning challenges to encourage them to reach flow (as described in Figure 5), in a richly stimulating teaching environment. This approach will develop a student's knowledge by motivating them to make sense of the experiences, with strong use of what Goldberg (2001) called *actor-centered adaptive decision-making*.

This emphasis on actor-centered adaptive decision-making aims to develop the student's executive functions by capitalizing on the innate need to know or acquire skills. Understanding and knowledge grows out of answers to questions the students ask themselves, which are driven by their own purpose, interest, and need to search for meaning.

The guided experiences must be real-world projects with an embedded academic curriculum, driven by the student's choices and interests. The purpose is to go beyond normal academic standards through ongoing questioning, investigation, and documentation. The approach is determined by the students based on experts in the chosen field. However, this approach will only work only if the teacher acts as a leader and the students establish an authentic partnership (or team) with shared procedures and expectations. The teacher must have a clear sense of the essential skills and knowledge that the students will need to master to succeed, and thus coach the students to reach these goals (Caine et al., 2009).

Using the guided experiences approach, learning does not occur via the traditional method of direct transmission from the person who knows (the teacher) to the one that doesn´t (student). Learning is, instead, embedded and consolidated by the student's processing of the experiences.

Knowledge and skills are developed by the student's search for meaning and answers to his or her own questions.

Caine et al. (2009) developed some simple and practical guidelines for the use of the guided experiences approach to learning (Figure 6). They point out that applications of the approach will always be different in many ways, but that the described phases of the learning cycle will be present regardless of subject matter, focus, or discipline. They also emphasize that the approach will work only in a richly stimulating teaching environment, and when authentic teamwork is developed between the teacher and the students.

Figure 6. Guidelines for the guided experiences learning approach

Teachers Preparation	**Learning Cycle**	**Active Processing**
Know the standards to succeed	Create authentic teamwork	Process continuously to achieve standards
Identify the critical concepts that learners need to master	Develop global experience	Critical concepts
Know all the critical facts and skills to be mastered	Engage research questions	Critical facts and skills
	Organize preliminary research groups	
	Develop rubrics for research	
	Allow for learners research	
	Support in-depth research	
	Assist in planning documentation of research	
	Develop rubrics for documentation	

Source: adapted from Caine, et al., 2009, p. 269

Conclusion

Since Hart (1983) emphasized the connection between brain functions and traditional education practices, much researched on brain-based learning has been undertaken. This paper has highlighted the findings that influence learning and teaching, to provide insights that every teacher should know to be effective. The findings demonstrate that there is great need for change in the traditional teaching approach, and the relationship between teachers and students. The findings also suggest that the most effective approach to teaching is the guided-experience learning model proposed by Caine et al. (2009).

These findings are presented without going to deeply in to the description of the neurological intricacies of the functioning of the human brain on which they are based. For those interested in more details on each relevant finding these details can be found in the reference material.

References

Astington, J. W., Harris, P. L., & Olson, D. R. (Eds.). (1990). Developing theories of mind. New York: Cambridge University Press. (Original work published 1988)

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. Spence & J. Spence (Eds.), The psychology of learning and motivation (Vol. 2, p. 89–195). New York: Academic Press.

Bennett, E. L., Diamond, M. C., Krech, D., & Rosenzweig, M. R. (1964, October 30). Chemical and Anatomical Plasticity of Brain. Science, 146(3644), 610-619 . Retrieved from http://www.sciencemag.org/content/146/3644/610.citation

Buzan, T. (1974). Use both sides of your brain. New York: E. P. Dutton.

Byrne, J. H. (Ed.). (2009). Concise Learning and Memory: The Editor's Selection. London: Academic Press.

Caine, R. N., & Caine, G. (1990, October). Understanding a brain-based approach to learning and teaching . Educational Leadership, 48(2), 66-70. Retrieved from http://www.ascd.org/ASCD/pdf/journals/ed_lead/el_199010_caine.pdf

Caine, R. N., & Caine, G. (1991). Teaching and the human brain. Alexandria: Association for Supervision and Curriculum Development.

Caine, R. N., Caine, G., McClintic, C., & Klimek, K. J. (2009). 12 brain/mind learning principles in action: Developing executive functions of the human brain (2nd ed.). Thousand Oaks, Cl: Corwin Press. (Original work published 2005)

Craik, F. I., & Tulving, E. (1975, September). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104(3), 268-294. Retrieved from http://psycnet.apa.org/journals/xge/104/3/268/

Csikszentmihalyi, M. (1991). Flow: The psychology of optimal experience. New York: Harper Perennial. (Original work published 1990)

Csikszentmihalyi, M. (1996). Creativity: Flow and the psychology of discovery and invention. New York: Harper.

Csikszentmihalyi, M. (1997). Finding flow: The psychology of engagement with everiday life. New York: Basic Books.

Degen, R. J. (2010, May). Teaching entrepreneurship students to become knowledge-agents for innovation (Monograph No. 64). Retrieved from http://econpapers.repec.org/paper/pilwpaper/64.htm

Degen, R. J. (2011, March). Review of the current knowledge of brain- /mind-based learning to present the optimum climate for, and the guided experience approach to teaching (Monograph No. 73). Retrieved from http://econpapers.repec.org/paper/pilwpaper/73.htm

Dewey, J. (1958). Experience and nature (2nd ed.). New York: Dover Publications.

Dewey, J. (1998). Experience and education. Indianapolis: Kappa Delta Pi. (Original work published 1938)

Diamond, M., & Hopson, J. (1998). Magic Trees of the mind: How to nurture your child's inteligence, creativity, and healthy emotions from birth through adolescence. New York: Dutton.

Doherty, M. J. (2008). Theory of mind: How children understand others' thoughts and feelings. Oxford: Taylor & Francis.

Ebbinghaus, H. (1913). Memory: A contribution to experimental psychology. New York: Teachers College, Columbia University. (Original work published 1885)

Edwards, B. (1979). Drawing on the right side of the brain. Los Angeles: J. T. Tarcher.

Eriksson, P. S., Perfilieva, E., Björk-Eriksson, T., Alborn, A.-M., Nordborg, C., Peterson, D. A., & Gage, F. H. (1998, November). Neurogenesis in the adult human hippocampus. Nature Medicine, 4(11), 1313-1317. Retrieved from http://www.icb.ufmg.br/prodabi/prodabi5/homepages/hugo/Hugo/neurogenesis.pdf

Fenkel, D. B., Frey, J. U., Schuetze, H., Heipertz, D., Heinze, H.-J., & Duzel, E. (2008, June). Novel Scenes Improve Recollection and Recall of Words. Journal of Cognitive Neuroscience, 20(7), 1250-1265. Retrieved from http://www.mitpressjournals.org/doi/abs/10.1162/jocn.2008.20086

Freiberg, H. J. (Ed.). (1999). Perceiving, behaving, becoming: lessons learned . Alexandria, VA: Association for Supervision and Curriculum Development.

Fuster, J. M. (2003). Cortex and mind: Unifying cognition. New York: Oxford University Press.

Gardner, H. (1983). Frames of mind: The theory of multiple inteligences. New York: Basic Books.

Glatzeder, B., Goel, V., & von Müller, A. (Eds.). (2010). Towards a theory of thinking. Berlin: Springer-Verlag.

Godden, D. R., & Baddeley, A. D. (1975, August). Context-dependent memory in two natural environments: On land and under water. British Journal of Psychology, 66(3), 325-332. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.2044-8295.1975.tb01468.x/abstract

Goldberg, E. (2001). The executive brain: frontal lobes and the civilized mind. New York: Oxford Univesity Press.

Goldstein, E. B. (2007). Cognitive psychology: Connecting mind, research and everyday experience (2nd ed.). Florence, KY: Cengage Learning.

Greenough, W. T., & Anderson, B. J. (1991, August). Cerebellar synaptic plasticity relation to learning versus neural activity. Annals of the New York Academy of Science, 627, 231-247. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.1991.tb25927.x/abstract

Hart, L. A. (1975). How the brain works. New York: Basic Books.

Hart, L. A. (1983). Human brain and human learning. New York: Longman.

Hasher, L., & Zacks, R. T. (1979, September). Automatic and effortful processes in memory. Journal of Experimental Psychology: General, 108(3), 356-388. Retrieved from http://psycnet.apa.org/journals/xge/108/3/356/

Hayek, F. A. (1976). The sensory order: An inquiry into the foundations of theoretical psychology. Chicago: The University of Chicago Press. (Original work published 1952)

Hebb, D. O. (2002). The organization of behavior: a neuropsychological theory. Mahwah, NJ: John Wiley. (Original work published 1949)

Jacobs, B., Schall, M., & Scheibel, A. B. (1993, January). A quantitative dendritic analysis of wernicke's area in humans. II. Gender, hemispheric, and environmental factors. The Journal of Comparative Neurology, 327(1), 97-111. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/cne.903270108/abstract

James, W. (2007). The principles of psychology (Vol. 1). New York: Cosimo. (Original work published 1890)

Jensen, E. (2008). Brain-based learning: The new paradigm of teaching (2nd ed.). Thousand Oaks, CA: Corwin Press.

Jonides, J., Lewis, R. L., Nee, D. E., Lustig, C. A., Berman, M. G., & Moore, K. S. (2008). The mind and brain of short-term memory. Annual Review of Psychology, 59, 193-224. Retrieved from http://www-personal.umich.edu/~jjonides/pdf/2008_8.pdf

Kandel, E. R., & Squire, L. R. (2008). Memory: From mind to molecules (2nd ed.). Greenwood Village, Colorado: Roberts & Co. (Original work published 1999)

Kellman, P. J., & Massey, C. (2010, Spring). Integrating conceptual foundations in mathematics through the application of principles of perceptual learning. Retrieved from Psychology Department of the University of California, Los Angeles website: http://illusory.psych.ucla.edu/PLM/articles/SnC_PLM_desc_results.pdf

Kennedy, B., Ziegler, M. G., & Shannahoff-Khalsa, D. S. (1986, March 31). Alternating lateralization of plasma catecholamines and nasal patency in humans. Life Sciences, 38(13), 1203-1214. Retrieved from http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6T99-4751WHX-349-1&_cdi=5109&_user=10&_pii=002432058690175X&_origin=browse&_zone=rslt_list_item&_coverDate=03%2F31%2F1986&_sk=999619986&wchp=dGLzVzz-zSkWA&md5=bcc5be0d7194623fe54512a8d6418df3&ie=/sdarticle.pdf

Klein, R., & Armitage, R. (1979, June 22). Rhythms in human performance: 1 1/2-hour oscillations in cognitive style. Science, 204, 1326-1328. Retrieved from http://www.sciencemag.org/content/204/4399/1326.full.pdf?sid=1bc0e885-fe34-4c60-adf1-ad12de30c4d3

LeDoux, J. E. (2002). Synaptic self: How our brains become who we are. New York: Viking.

Livingstone, M., & Hubel, D. (1988, May). Segregation of form, color, movement, and depth: anatomy, physiology, and perception. Science, 240, 740-749. Retrieved from http://www.sciencemag.org/content/240/4853/740.abstract?sid=9f640e32-bc6f-4eea-a746-7d596bf3da88

Luria, A. R. (1973). The working brain: An introduction to Neuropsychology. New York: Basic books.

MacLean, P. D. (1990). The triune brain In evolution, role In paleocerebral functions . New York: Springer.

McClelland, D. (1967). The achieving society. New York: The Free Press. (Original work published 1961)

Medina, J. (2008). Brain rules: 12 principles for surviving and thriving at work, home, and school. Seatttle, WA: Pear Press.

Miller, E. K., & Cohen, J. D. (2001, March). An integrative theory of prefrontal cortex function. Annual Review of Neuroscience, 24, 167-202. Retrieved from http://www.annualreviews.org/doi/abs/10.1146%2Fannurev.neuro.24.1.167

Miller, F. P., Vandome, A. F., & McBrewster, J. (Eds.). (2010). Executive functions: Psychology, neuroscience, brain, attention, cognitive neuropsychology, nonverbal learning disorder, working memory, frontal lobe. Beau Bassin, Mauritius: Alphascript Publishing.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63(2), 81-97. Retrieved from http://www.psych.utoronto.ca/users/peterson/psy430s2001/Miller%20GA%20Magical%20Seven%20Psych%20Review%201955.pdf

Miller, G. A. (2003, March). The cognitive revolution: A historical perspective . Trends in cognitive sciences, 7(3), 141-144. Retrieved from http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VH9-481FYND-1&_user=10&_coverDate=03%2F31%2F2003&_rdoc=1&_fmt=high&_orig=browse&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=6f3d1db645eac622d791808b9337563e

Molfese, D. L., & Molfese, V. J. (Eds.). (2002). Developmental variations in learning: Applications to social, executive function, language, and reading skills. Mahwah, NJ: Lawrence Erlbaum.

Mumford, M. D., & Caughron, J. J. (2007, May). Neurology and creative thought: Some thoughts about working memory, the cerebellum, and creativity . Creativity Research Journal, 19(1), 49 - 54 . Retrieved from http://www.informaworld.com/smpp/content~db=all~content=a787962542

Nummela, R. M., & Rosengren, T. M. (1986, May). What's happening in students' brains. Educational Leadership, 43(8), 49-53. Retrieved from http://www.ascd.org/publications/educational-leadership/may86/vol43/num08/toc.aspx

O'Keefe, J., & Nadel, L. (1978). The hippocampus as a cognitive map. Oxford: Clarendon Press.

Orlock, C. (1998). Know your body clock. New York: Barnes&Nobles.

Ornstein, R. E., Sobel, D., & Crnstein, R. (1999). Healing brain: Breakthrough discoveries about how the brain keeps us healthy . Malor Books. (Original work published 1987)

Palmere, M., Benton, S. L., Glover, J. A., & Ronning, R. R. (1983, December). Elaboration and recall of main ideas in prose. Journal of Educational Psychology, 75(6), 898-907. Retrieved from http://psycnet.apa.org/journals/edu/75/6/898/

Perner, J. (1993). Understanding the representational mind. Cambridge, MA: MIT Press. (Original work published 1991)

Price, H. H. (1940). An essay concerning human undestanding: The argument from illusion. In A. J. Ayer (Ed.), The fundations of empirical knowledge (Vols. Book IV, ch 2, pp. 1-57). Retrieved from http://library.du.ac.in/dspace/bitstream/1/800/6/Ch1%20the%20argument%20from%20illusion.pdf

Ramsey, N. F., Jansma, J. M., Jager, G., Van Raalten, T., & Kahn, R. S. (2004, March). Neurophysiological factors in human information processing capacity. Brain, 127(3), 517-525. Retrieved from http://brain.oxfordjournals.org/content/127/3/517.full

Robertson, L. C. (2003, February). Binding, spatial attention and perceptual awareness. Nature Reviews Neuroscience, 4(2), 93-102. Retrieved from http://www.nature.com/nrn/journal/v4/n2/pdf/nrn1030.pdf

Rosenfield, I. (1988). The invention of memory: a new view of the brain. New York: Basic Books.

Rosenzweig, M. R., Love, W., & Bennett, E. L. (1968, November). Effects of a few hours a day of enriched experience on brain chemistry and brain weights. Physiology & Behavior, 3(6), 819-825. Retrieved from http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T0P-483SPM1-PR&_user=10&_coverDate=11%2F30%2F1968&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1562241685&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=a1d817b62a0db12902d954bba9d64138&searchtype=a

Simon, H. A. (1996). The sciences of the artificial (3rd ed.). Cambridge, MA: MIT Press.

Sodian, B. (2005). Theory of mind: Case for conceptual development. In Young Children's cognitive development: Interrelationships among executive fuctioning, working memory, verbal ability and theory of mind (pp. 95-130). Mahwah, NJ: Lawrence Erlbaum.

Sodian, B., & Kristen, S. (2010). Theory of mind. In Towards a theory of thinking (pp. 189-202). Berlin: Springer-Verlag.

Swanbrow, D. (2011, June). A brain training exercise that really does work. Michigan Today. Retrieved from http://michigantoday.umich.edu/2011/06/story.php?id=8006&tr=y&auid=8513683

Treisman, A. (1996, April). The binding problem. Current Opinion in Neurobiology, 6(2), 171-178. Retrieved from http://www.sciencedirect.com/science/article/pii/S0959438896800705

Wallis, C. (2006, March 27). genM: The multitasking generation. Time. Retrieved from http://www.time.com/time/magazine/article/0,9171,1174696,00.html

Wellman, H. M. (1992). The child's theory of mind (Paperback ed.). Cambridge, MA: The MIT Press. (Original work published 1990)

Wellman, H. M., & Lagattuta, K. H. (2004). Theory of mind for learning and teaching: The nature and role explanation. Cognitive development, 19, 479-497. Retrieved from http://www.ub.unimaas.nl/fdp/Studenten/CognDevArticle.PDF

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