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Chapter XIII

Brain-Based Learning

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Abstract

Neuroscience research that explains how the brain learns is a dynamic field. Since the 1990s, there has been explosive growth in information about the neurophysiology of learning. A discussion of the neuroanatomy that is necessary to understand this research is presented first. Following the discussion of anatomy and physiology, current brain research is described, with particular focus on its implications for teaching adult students in an online environment. In addition, two instructional design theories (Gardner's multiple intelligence and Kovalik's integrated thematic instruction) that have a basis in neuroscience are examined. Recommendations founded on brain-based research, with a focus on adult education, follow, including specific activities such as crossed-lateral movement patterns and detailed online activities that can be incorporated into an online learning environment or a distance learning class (and face-to-face classroom) for adults. Comprehensive recommendations and guidelines for online learning design have been provided as suggestions for making maximum use of the brain-based principles discussed in this chapter.

Introduction

Neuroscience research findings are now scientifically confirming many learning theories first introduced during the educational reform efforts of the 1960s (Lackney, n.d.). Researchers have explored many different aspects of the brain, including anatomy, circulation, electrical activity, glucose metabolism, and neuronal growth. Even with the growth of scientific information, the human brain is, for the most part, still unknown, as the brain is extremely complex. The brain is the major controller of the body, similar to a computer's CPU (central processing unit). It is the information processor of the human body. The brain is capable of multitasking, and it "assembles, patterns, composes meaning, and sorts daily life experiences from an extraordinary number of clues" (Jensen, 2000, p. 12). The brain, in addition to being extremely complex, is a dynamic and adaptive system. The brain contains hundreds of billions of neurons and interneurons that produce an enormous number of neural nets, or groups of neurons working together, from which our daily experience is created (Lackney, n.d.).

The brain's activity is controlled by genetics, development, experience, culture, environment, and emotions, and it is constantly under stimulation to change (Gardner, 1999). Since the 1980s, significant scientific findings have emerged about how learning occurs. By the 1990s, the scientific community had started to increase dramatically with new information about the brain. Developments in technology have allowed researchers to see inside the brain, and visualize how the structures in the brain communicate. Common imaging techniques used by researchers include computerized axial tomography (CAT, or computerized X-rays), functional magnetic resonance imaging (fMRI), and positron emission tomography (PET). These tools have allowed scientists to learn more about the brain, and findings made through them are influencing the worlds of education, science, and medicine.

With advances in technology and knowledge about the brain, there has been the development of brain-compatible or brain-based learning. Brain-based learning is a new paradigm that has tremendous implications for educators and students. This chapter will define brain-based learning, and will provide an overview of the anatomy, brain chemistry, neuronal connections, and current neuroscience research that are important in understanding how learning occurs. Neuroscience research needs to be translated into brain-based learning strategies that can be used by educators, and instructional design theories need to be developed in response to the new brain-based information being discovered by scientists. These theories should attempt to translate the neuroscience research, and provide methods that help educators to develop instructional strategies. Following this discussion, recommendations will be made for the design and development of a distance learning or online course.

The Biology of Learning

According to Jensen (2000), brain-based learning is "learning in accordance with the way the brain is naturally designed to learn" (p. 6). Research about how the brain learns is being conducted across several disciplines, including psychology, neuroanatomy, genetics, biology, chemistry, sociology, and neurobiology (Jensen, 2000). Brain-based learning is biologically driven, and the conclusions developed to date have not been definitive. Research continues, and our understanding of brain-based learning will be subject to future changes. The brain-based learning approach is not a recipe for all learning, but it can be used to develop strategies that are based on the current available research.

Brain Anatomy, Chemistry, Structure, and Body Connections

To understand how the brain learns, a basic understanding of the anatomy and physiology of the brain is necessary. The largest portion of the brain is called the cerebrum. The cerebrum is the most highly evolved part of the brain, and is sometimes called the neocortex. Higher order thinking and decision making occurs here. The cerebrum is composed of two hemispheres that are connected by a neural highway, the corpus callosum. Information travels along the corpus callosum to each hemisphere so that the whole brain is involved in most activities. Each cerebrum is composed of four lobes: frontal, parietal, temporal, and occipital. Each lobe is responsible for specific activities, and each lobe depends on communication from the other lobes, as well as from the lower centers of the brain, to complete its jobs.

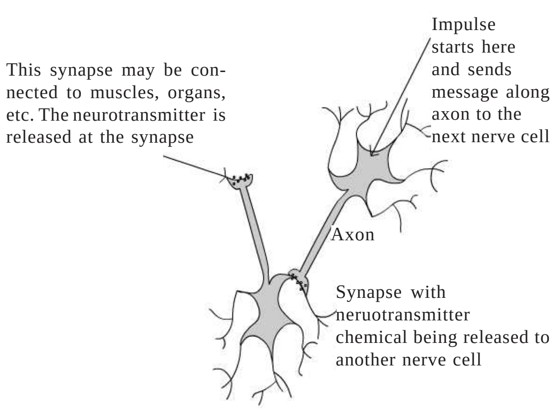
Every task that the brain completes requires communication and coordination among several of its parts. For example, use of the thumb requires input from the cerebellum, the midbrain, and the motor and sensory areas of the frontal and parietal lobes. The task of learning functions in a similar way, as multiple areas of the brain must communicate and work together for learning to occur.

The brain is composed of over 100 billion neurons that are interconnected by electrical circuits. Communication between neurons occurs as information is passed from one neuron to the next by an electrochemical process. Each neuron has an extension, the axon, which carries the electrochemical impulse to neighboring neurons (Figure 1). These axons carry information, on a one-way circuit, away from the cell body of the neuron. Axons connect with other neurons at synapses, which are connecting junctions. For example, every muscle is connected by axons to the brain. The brain initiates an impulse of energy that travels along the axon, which terminates at a synapse on the muscle and causes the muscle to perform the activity.

Axons modify and grow in response to any brain activity, such as learning. Learning puts demands on the brain, and the brain responds by developing new circuits to connect new information to current or past knowledge. According to Fishback (1999), "the creation of neural networks and synapses are what constitutes learning" (n.p.).

There are billions of neurons, and the number of synapses is more than 10,000 times the number of neurons (Hill, 2001). "A single neuron can have from a few thousand up to one hundred thousand synapses, and each synapse can receive information from thousands of other neurons. The resulting 100 trillion synapses make possible the complex cognition of human learners" (p. 74). Communication between neurons at a synapse is accomplished by the release of chemicals and electrical signals. At the synapse, an axon sends messages to the next organ or nerve by releasing hormones or neurotransmitters such as adrenaline and dopamine. These transmitters tell the organ or nerve what to do. For example, the axon of the sciatic nerve (thousands of axons bundled together in connective tissue) sends information from the brain to the legs. The sciatic nerve sends a

Figure 1. Nerve cell or neuron with synapse



Neurons or nerve cells that connect at a synapse neurotransmitter chemical across the synapse to the muscle that it innervates, causing a muscle contraction.

The midbrain area is deep inside the cerebrum and includes the limbic system, hypothalamus, hippocampus, and amygdala. This area works with the cerebrum, but is responsible for emotions, attention, sleep, body regulation, hormones, sexuality, and smell. This area of the brain is often called the "gatekeeper" because all incoming traffic (from the body) has to pass through it. The midbrain controls to where incoming information goes (Jensen, 2000).

The deepest part of the brain, the brain stem, is often considered the oldest and most primitive part of the brain. It is sometimes called the reptilian brain, and is responsible for our instinctual or survival behaviors. This area of the brain is the first to respond to trouble, and is the area of the "flight or fight" response. For example, the brain can "downshift" to the brain stem when a student feels threatened during a test. When that happens, the brain reacts to the situation, and it is no longer able to store or learn any information; thus, learning becomes impossible (Jensen, 2000). Both the midbrain and the brain stem will be explored further in the discussion of emotions and learning.

Neuroflexibility

Scientists once believed that the brain becomes rigid with age. It is now known that the brain is dynamic and flexible, even as one ages. In other words, the brain is plastic. The physical brain is literally shaped by experience; axonal circuits change, modify, and redevelop as human's age. "We now know that the human brain actually maintains an amazing plasticity throughout life. We can literally grow new neural connections with stimulation, even as we age. This fact means nearly any learner can increase their intelligence, without limits, using proper enrichment" (Jensen, 2000, p. 149).

In addition to adding new circuits, as axonal circuits age, pruning occurs. Pruning is the removal of connections that are no longer needed. The brain modifies its structure based on incoming information. "The brain changes physiologically as a result of experience and it happens much quicker than originally thought. The environment in which the brain operates determines to a large degree the functional ability of the brain" (Roberts, 2002, p. 282).

According to Lackney (n.d.), pruning occurs even in children, and research has shown that axons continue to grow throughout life. "You can teach old dogs a few new tricks after all. This is a huge discovery and has implications for life-long learning" (n.p.). Lackney provided an example of how this occurs in an adult who is learning how to drive a stick shift after having only driven an automatic automobile. At first, the task is frustrating and awkward for the learner, but eventually the skills become automatic. "This is a clear example of growing new neural connections and the principle of plasticity in connection with the development of body/kinesthetic intelligence" (Lackney, n.d., n.p.).

Learning is also due to input to the brain. Sensory information (e.g., aural, visual, and tactile information) enters the brain along multiple nerve receptors. Sensory input causes axons to react by budding, branching, and reaching out to other neurons, thus, leading to the development of new connections in the brain. If the information is novel, the brain needs to develop these budding new pathways. It is when an axon grows and meets up with another neuron that learning occurs. This explains why adult students need consideration of their prior experiences. Adults need to connect new information with old information. As they do this, their neural pathways change to connect new information to the older pathways already developed in the brain. Neural circuits continue to grow, even with age.

Neuronal growth, which is initiated by learning, explains scientifically what happens with assimilation and accommodation. The terms *assimilation* and *accommodation* are associated with cognitive learning theory. In assimilation, incoming information is changed to fit into existing knowledge structures (i.e., neuronal structures that already exist) (Ally, 2004). Accommodation occurs when an existing cognitive structure (i.e., current neuronal circuits) is changed to incorporate new information (Ally, 2004). Research on the neuroscience of learning is providing scientific evidence to support the learning theories that have been used for years.

Learning and the Brain

Everyone's brain is uniquely shaped by genetics, the environment, social phenomena, and experience. The interconnections, or the existing neural networks, are unique for each person. The connections between neurons are developed because of the individual's experiences, and form a "personal cognitive map" (Jensen, 2000, p. 15).

According to Leamnson (2000), our genes control what cells do and how they do it. However, after birth, chance plays a larger role than genetic code in determining whether one budding neuron will grow to another. "Genetics determines only the types of cells that get connected. The actual axonal connections are said to be "epigenetic," meaning that they are beyond, or independent of, genetic instructions" (n.p.). Epigenetic development can be seen in identical twins who have different fingerprints as well as different vein patterns, yet have identical DNA. Leamnson (2000) reported:

It happens that the connections that growing axons make upon contact with a permissive cell are often temporary. There have long been microscopic evidences of axons degenerating or withering away (just the axons, not the cells from which they grew). It is also now known that newly formed synapses are weak, or labile, and if nothing more happens the axon usually retreats, or degenerates, and the neuron starts over with a new budding axon. (n.p.)

Use is required to strengthen the neuronal connections. The more a connection is used, the larger the network grows, and the more secure the links become. The number of synaptic connections may also increase. Thus, the old adage "use it or lose it" is true of the brain (Jensen, 2000). Jensen explained that learning is defined as changing the structure of the brain. An individual's neural wiring changes as he or she learns activities. If an activity is new, the brain will respond slowly and start to develop new connections. As the activity is practiced, the pathways get more efficient, and transmission speed increases. The pathways may become permanent as the skill becomes integral to the brain, and is held in long-term memory. Neuroscience research confirms that practice improves performance.

Fishback (1999) reported that all new information is incorporated into existing neural networks. The human brain is always looking to make associations between incoming information and experience. In fact, the brain helps screen out some memory. If people remembered everything they saw, there would be too much information, and they would experience overload. "Memories are not stored intact; they are separated and then distributed in different regions of the brain" (n.p.). As information comes in and enters short-term memory, the brain must decide whether it will be consolidated and stored in long-term memory. This process of consolidation suggests that different sections of the brain must work together for learning to occur.

Brain imaging has revealed that the longer certain areas of the brain are stimulated, the better information is remembered. In addition, personal experience intensifies activation, focus, and concentration. The more elaborate a memory is (in terms of sound, touch, vision, etc.), the easier it is to access. Repetition is also important, as it causes neural connections to reactivate and increases the chance of retaining the memory (Fishback, 1999).

Neuroscience can now explain why adults need to see the link between what they are learning and how it will apply to their lives. By doing this, they strengthen their neural connections and integrate incoming information and experience into their existing wiring. Adults also need opportunities to test their learning as they go along; they should not receive only background theory and general information. They should be able to use their current neuronal circuits in order to strengthen the new pathways that are being developed as they learn new information.

The Cerebellum

Hansen and Monk (2002) researched the cerebellum and its relation to learning. The cerebellum is deep in the brain, under and behind the cerebrum. For years, it has been known that the cerebellum is responsible for coordination and balance activities, but it was only recently that the cerebellum's involvement in the learning process was discovered.

It appears that the cerebellum stores routines so that the cerebral cortex is free to deal with novel features rather than the routine….The "chunking" of routines so that the short term memory can cope with the empirically derived, short term memory space of seven bits of information is reported in all introductory texts on psychology. (Hansen & Monk, 2002, p. 346)

The "chunking" of information long described by cognitive learning theory is actually based on a physical, measurable phenomenon that researchers are just starting to understand. Many of the features of brain-based learning explain, scientifically, what is occurring at the cellular level. When learning theories evolved and developed, their principles were based on the end product, or learning. These theories were tested and researched, but they still had no measurable scientific explanation for the phenomenon being studied. It has only been recently that the underlying, physical mechanism responsible for learning has begun to be understood. As this paper continues to discuss brain-based learning, there will be scientific, measurable, objective explanations for much of what is known about learning today. However, there is still much to learn.

Preexposure and Pattern Making

Preexposure, or priming, has been shown to be important to learning. The greater the amount of a priming stimulus, the more the brain extracts and "compartmentalizes (lateralizes) the information" (Jensen, 2000, p. 81). Mechanisms of preexposure to the information presented in a course might include the following: a course description mailed out prior to the start of the course, the opportunity to talk to past participants, reading books on the subject, transparencies previewed at the beginning of the course, or a workbook (Jensen, 2000).

Preexposure to new information allows the brain to detect and create patterns of meaning. "The brain's capacity to elicit patterns of meaning is one of the key principles of brain-based learning" (Jensen, 2000, p. 82). Pattern making depends on past information or experience. The brain takes in the new information and searches for a meaningful pattern that is already in the brain with neural pathways in place. As this new information comes in, new pathways develop based on the model in the brain. "We never cognitively understand something until we can create a model or metaphor that is derived from our unique personal world" (Jensen, 2000, p. 82).

Jensen (2000) recommended the use of mind-maps, graphic organizers, advance organizers, models, or paintings of course material. The key is to get the learner to relate the information to his or her personal life. "Unless connections are made to students' prior learning, comprehension and meaning may be dramatically lessened. Before starting a new topic, ask students to discuss what they already know about the subject; do role plays or skits; make mind-maps; and brainstorm its potential value" (p. 85).

Preexposure and priming are important for adult students. Adult students need scaffolding to be provided by the instructor. *Scaffolding* is a term used by Lev Vygotsky in his social learning theory. He presented the concept of the *zone of proximal development,* which represents the gap between a student's actual level of independent problem-solving ability and the potential level that s/he could reach with knowledgeable guidance. An instructor guides students in thinking through problems and making connections. In scaffolding, the instructor first models, then coaches, then gradually withdraws help, as the learner becomes more confident and competent. Modeling by the instructor is vital, and should be part of preexposure and patterning efforts, as it allows students to see a problem solved, and then to relate new problems to a pattern that they have developed.

Biocognitive Cycles and Environmental Influences

Individuals have their own personal cycle or circadian rhythm. Research has found that everyone has an optimum time of day for learning (Jensen, 2000). The brain's right and left hemispheres alternate their cycles of efficiency. Individuals shift and use either the right or left hemisphere in a cycle during the day. This cycling activity, or lateralization, may develop a problem, and the cycle may get "stuck" in one hemisphere. This often happens in classrooms when students listen passively to a lecture. The brain's cycle may become nonresponsive, and the cycle will be altered. Jensen (2000) recommended that to "unstick" a student, an instructor should use cross-lateral activities to energize thinking and stimulate the brain to work more efficiently. An example of such an activity is using the

Table 1. Crossed-lateral activities

1. Take the left hand and touch the right shoulder. At the same time, touch the right hand to the left shoulder. Put both hands back with the right hand flat on the right thigh and the left hand flat on the left thigh. Alternate which hand is on top as they go to touch their shoulders again. Repeat several times. Other parts of the body can be used in this activity, rather than the shoulders. Touch with alternate hands the hips, knees, ankles, ears, and so forth.
2. Adding onto exercise number one, have them touch more than one body part, and alternate different body parts such as the shoulders and knees, and so forth.
3. Sit with feet flat on the ground. Look straight forward with hands in lap. Touch the right foot toes to the left side of the left foot. Move the right foot back to the original position. Alternate feet by putting the left toes on the right side of the right foot. Repeat several times.
4. Put hands on opposite shoulders as in exercise 1 and have students rotate to look to the right and then the left. Make sure that the whole trunk is turning and not just the neck and head.

right hand to touch the left leg. Another activity that could be performed in the classroom involves marching in place while patting opposite knees and touching opposite eyes, knees, elbows, and heels. Table 1 was developed to provide several examples of cross-lateral activities that could be used.

According to Jensen (2000), "Learning is best when focused, diffused, then focused again. Constant focused learning is increasingly inefficient. In fact, the whole notion of 'time on task' is in conflict biologically and educationally with the way the brain naturally learns" (p. 48).

If a student is involved actively in a learning task, it is much less likely that he or she will become "stuck," or will lateralize learning to only one hemisphere. Thus, active learning, as part of constructivist learning theory, is supported by the biology of the brain. Constructivists see learning as active rather than passive. Students construct knowledge and interpret incoming information, which is then processed by the brain to be translated into learning. The concept of lateralization also supports adult learning theories that suggest that adults need to be actively involved in the learning process.

Jensen (2000) explained that the proper environment is important for learning to occur. Color, hydration, visual stimuli, psychological stimuli, seasons, temperatures, plants, music, noise, and aromas can all influence learning. Today's classrooms are often not meeting optimal learning conditions. However, it would appear that with distance learning, the student is better able to control his or her environment. If the student is relaxed in a familiar environment, learning may be enhanced. The instructor should inform students about how to make their environments optimal for learning while using their computers at home or work.

Learning engages the entire physiology, so physical development, personal comfort, and emotional state will affect the brain. For this reason, it is important for instructors to incorporate facets of health, such as stress management, diet, and exercise, into the learning process.

Survival Mode

The brain is primarily concerned with survival, not instruction. It is the brain's prime directive to save a person's life. "The brain will concentrate on instruction that is only perceived as meaningful and only if the brain's primary survival needs have been satisfied" (Jensen, 2000, p. 14). Our brains respond to threat situations with stereotypical responses. A strong emotion, such as fear, will initiate the fight-or-flight physiological and mental response, which shuts down the higher centers of the brain (i.e., the high-level cognition centers of the cerebrum). The lower centers (i.e., the limbic system) of the brain take over to protect the individual from injury. These reflexive responses have been passed down to contemporary humans through centuries of evolution, through which the brain became the complex structure it is today. This response is reflexive; it is not controlled by conscious thought, but is in place to preserve life (Forrester & Jantzie, n.d.).

Instructors need to ensure that they do not invoke these lower centers, or learning will not occur. Stimulation is necessary for learning, but too much information can lead to overload. If a stimulus is too strong, the brain will shut down and go into survival mode. Testing can cause some students to go into "survival mode." In this situation, students will not be able to succeed, even if they have learned the material covered in the test. Thus, instructors should use multiple methods of assessment such as papers, presentations, e-portfolios, case studies, and problem-based learning tools.

Emotions

According to Jensen (2000), emotions are drivers for learning. "All learning involves our body, emotions, attitudes, and physical well being. Brain-based learning advocates that we address these multiple variables more often and more comprehensively" (p. 200). For example, those who were old enough to remember September 11, 2001, will recall exactly what they were doing on that day. This is an emotionally charged memory that most individuals will never forget. Emotion also has a strong influence on learning, and instructors should incorporate emotion into learning to make it more memorable. However, emotional stimuli must be carefully planned and balanced, in order to prevent students from shifting into "survival mode" (Fishback, 1999). If students are forced into survival mode, learning will not occur.

The amygdala is responsible for our emotions, and is concerned with survival and emotional interpretation of situations. It is responsible for bringing emotional content into memory, and plays a major role in learning. As instructors use brain-based techniques, it is important that they integrate emotions into the learning process. Reflection by the students can help this process. It is important to recognize and acknowledge the feelings and emotions that students may have. The instructor should provide personal, meaningful projects, and greater individual choice while eliminating threats, high stress, and artificial deadlines. Instructors should ensure that the resources students might need are available. It is the emotion behind the students' goals that provides the energy to accomplish them (Jensen, 2000).

In addition to establishing an emotional connection to course content, it is important to maintain a positive and supportive climate. The unconscious responses of an instructor, and the student's attitude will help determine how much learning occurs. The instructor needs to model correct behavior, and develop a nonthreatening, supportive climate. Low to moderate stress and general relaxation are best. Instructors should avoid threat-based policies and embarrassment of students (Jensen, 2000). Adult students need a climate that is collaborative, respectful, mutual, and informal in order to learn effectively. This type of environment is nonthreatening, and provides positive emotional support that helps the learning process.

Forrester and Jantzie (n.d.) reported that the limbic system plays an important part in the process of storing information as long-term memories. Activities that provide an emotionally supportive environment may have a positive effect upon the processing of information into long-term storage, and on the subsequent retrieval of those memories. The instructor should utilize group activities, cooperative learning, role-playing, and simulations, as these techniques tend to provide emotional support and an emotional context for learning. Adult students need dialogue and social interaction, as well as opportunities to collaborate with other students. These activities help provide a positive, supportive environment.

The body, emotions, brain, and mind are an integrated system (Hill, 2001). Emotions are entwined in neural connections, and emotion and cognition cannot be separated. Emotion is crucial to the storage and retrieval of information. This section has investigated the biology of learning, and has presented the scientific basis underlying current learning theory. The brain can only fully understand information if the information is meaningful. If it is meaningful, the individual will respond to events in ways that have been influenced by culture as well as personal experiences. All of these factors need to be considered in order to understand how an individual perceives and interprets incoming information. The next section will examine how learning is represented in higher order thinking skills, such as memory, metacognition, and meaning making, and will then describe the stages of brain-based learning.

Brain-Based Learning

Memory, Understanding, Thinking, and Metacognition

Memory is due to complex, multipath neuronal growth. The brain is a multimodal processor that assembles patterns, makes meaning, sorts daily life and experiences, and then processes this information. In order for information to get to the hippocampus of the midbrain, which is where long-term memory is believed to be stored, the learner needs to use the information actively to strengthen the new neural circuit. Memories are distributed throughout the cortex and are usually embedded in context. “Our brain sorts and stores information based on whether it is heavily embedded in context or in content” (Jensen, p. 222). Today’s educational system often expects students to retrieve content that has been removed from context. Instructors often tell students to study from chapter 5 for a test: this is an inefficient way to teach. Using real-life simulations and contextualized situations helps students “memorize” information.

There are two different types of memory: explicit memory and implicit memory. These are further broken down into categories that are more specific. Semantic and episodic memories are considered explicit memory, or memory that was learned by effort. Implicit memory is memory that is automatically learned. It deals with nonconscious (nonmental) cognitive processing of experiences. According to Caine and Caine (n.d.), many of the insights and patterns that we grasp are the result of ongoing nonconscious processing. “Psychologists have also known for a long time that understanding is largely a consequence of deep processing. Thus, complex learning depends on a person’s capacity to take charge of the processing of experience which is a matter of becoming aware of what is actually happening” (Caine & Caine, n.d., n.p.).

According to Jenkins (2000), thinking occurs when the brain accesses “prior representations for understanding” (p. 185), or when the brain tries to create a new model if one does not exist. Thinking occurs when the mind, body, and feelings are all involved. Intuition also has a role in the thinking process. Intuition is triggered by nonconscious learning that was perceived during an individual’s lifetime. This is implicit memory and has no symbolic language associated with it. The basal ganglia, orbitofrontal cortex, and amygdala all contribute to intuition, since the experiences stored in these structures cannot be adequately expressed through language.

According to Hill (2001), "Consciousness refers to the ability to be self-aware and make meaning of our experiences. Consciousness can also be thought of as a sense of identity, especially the complex attitudes, beliefs, and sensitivities held by an individual" (p. 77). Sohlberg (n.d.) reported that "Nonconscious is a term that has sometimes been preferred by researchers to signify processes which are not conscious because they are by nature such that they are not available to awareness" (n.p.). In contrast, *the unconscious* is a Freudian term, by which "people usually mean mental contents that are not easily available to consciousness" (n.p.). According to Bollet and Fallon (2002), the unconscious mind is more intelligent than the conscious mind for several reasons. One reason is that the former has a greater capacity for memory. "The unconscious can hold billions and billions of bits of information, while the conscious mind can only hold 5-9 bits" (p. 41). The unconscious mind is able to perform more tasks because of this capacity. The conscious mind is more linear and sequenced (patterns), whereas the unconscious mind is emotional and nonlinear, and deals with inferences and possibilities.

> *It is by bringing to conscious awareness our assumptions, beliefs, habits, and practices that we begin to take charge of them and of our own learning and performance…. As we grow older we have the capacity to develop awareness and to engage in metacognitive observation. The more we can observe in our thinking, the more we can self-regulate and take charge of our own learning.* (Caine, & Caine, n.d., n.p.)

Adult students should be encouraged to use their metacognitive skills to facilitate learning (Hill, 2001). Adults have many experiences and memories that act as a foundation for future learning. Adults have brains that have developed physically, with neuronal growth, in response to their experience, culture, ethnicity, personality, and political philosophy. Metacognition, or the ability to think about one's own thinking, evolves as the brain matures. Metacognition includes models of thinking, automation of conscious thought, accessing automatic processes, practice effects, and self-awareness. It also includes being aware of one's own thoughts, feelings, and actions, and their effects on others. Adult learning theories such as andragogy, transformational learning, experiential learning, and self-directed learning have elements in common, in that they encourage adults to develop metacognition.

To promote higher-level learning, metacognitive skills, or critical thinking, the online environment needs to create challenging activities that foster students' metacognitive abilities, and help them acquire meaningful knowledge. Students need the time to collaborate, interact, and reflect during the learning process (Ally, 2004). The use of self-check questions that provide feedback is a strategy that allows students to check how they are doing. By doing this self-check, students can use their own metacognitive skills to adjust the learning process if necessary.

Making Meaning or Meaningful Content

Caine and Caine (1994) asserted that the search for meaning is innate. It cannot be stopped; however, one can channel or focus it (Deveci, 2004). According to Jensen (2000), the brain is designed to seek meaning. There is a significant difference between the meaning that is gained when one memorizes material, and the meaning one achieves by developing an authentic grasp of a subject. In addition, what is meaningful to one person might be of no interest to another. According to Jensen (2000), three factors generate meaning: (a) relevance or connection with existing neural sites, (b) emotions that trigger the brain's chemistry, and (c) the context that triggers pattern making. If information is personal, emotional, and makes sense, it is meaningful. Learning and memory are context driven.

Meaning involves one's values and purpose, and it is generated when one asks questions such as "Who am I?" and "Why am I here?" The search for meaning is "survival oriented and basic to the human brain/mind. While the ways in which we make sense of our experiences change over time, the central drive to do so is life long" (Caine & Caine, n.d., n.p.). Learning should be meaningful for the student. According to Deveci (2004), "In contextual learning, students learn better when they think about what they are doing, and why they are doing it" (n.p.). The brain seeks meaningful patterns, and interprets new experiences through what is familiar. Learning should be made meaningful for students (Hill, 2001) so that they can apply and personalize new information.

Adult students need to feel that learning focuses on issues that directly concern them. They want to know what they are going to learn, how the learning will be conducted, and why it is important. Instructors should design activities for students that are interactive. The new information will assist the student in constructing new knowledge. Motivation for this process can come from a sense of personal need (Deveci, 2004). When a learner receives opportunities to develop motivation through problem-based learning or case-based learning activities, personal ownership results. Active learning is fundamental to achieving a sense of ownership. Having students draw on their previous knowledge, with the instructor acting as a facilitator in a contextual learning setting, allows the student to connect content with context, thus bringing meaning to the learning process. When connections are made with old memories and new connections are developed, new learning is fostered. "It is this initial process that constructivism has hung its hat on. In fact so much so that it would seem as though constructivism did not come about until the research was printed. On the contrary, this research simply provides a validated backdrop for which teachers can use to guide their use of this teaching approach" (Brunner, 2000, n.p.).

The Aging Brain

Neuroscience has proven that learning is possible at any age, and that cognitive growth can continue into the nineties. Normal aging and good physical health are important in the maintenance of cognitive abilities. Tests performed on individuals over 65 years of age have demonstrated that the more the brain is used and the healthier the individual, the less significantly cognitive abilities decrease over time (Anderson & Grabowski, 2003, n.p.). In order to maintain cognitive status and promote continued growth, the brain needs to be used. High levels of activity, both physical and mental, have been shown to improve cognitive changes due to age. The brain can be compared to muscle tissue that strengthens with weightlifting or activity; the brain's neuronal structures will continue to sprout and route axons as long as the brain is stimulated. Since we now know that adults can continue to learn into old age, it is important for instructional designers to be aware of the principles of brain-based learning when designing instruction for adults.

The following section of this paper describes two instructional design theories that have been developed based on neuroscience research. These theories were developed to provide instructors with methods of incorporating neuroscientific findings. Interpretation of neuroscience is necessary, and is often difficult for many who do not have training in the field. These theories have taken the findings of neuroscience research and have developed methods to assist instructors as they design learning environments.

Neuroscience and Instructional Design Theories

Instructional design theories serve as guides to professional practice, and provide different methods of facilitating learning. Instructional design theories are often built based on different learning theories. Cognitivist learning theory, although closely aligned with brain-based learning, is concerned with internal, physical changes in the learner, whereas constructivist-learning theory considers how knowledge is transferred into true learning. This author believes that the learning theory most compatible with brain-based learning is constructivism. Constructivists feel that students need to make meaning from active participation in the learning process while building personal interpretations of the world based on experiences and interactions. Constructivism also promotes the idea that learning is embedded in the context in which it is used, and that authentic tasks should be performed in meaningful, realistic settings.

Constructivist learning theory is based on the assumption that learners construct knowledge as they attempt to make sense of their experiences. What we know depends on the kinds of experiences that we have had and how we organize these into existing knowledge structures. (Boulton, 2002, p. 3)

Existing knowledge structures can be compared to the existing neural network in the brain. Learning occurs as neural connections are developed. As these neural connections develop within the existing knowledge structures in the brain, the student constructs individual meaning from information and activities. Thus, brain-based learning follows the tenets of constructivist learning theory.

There are two instructional design theories that are based on the information provided by current neuroscience research on learning. One theory is Gardner's theory of multiple approaches to learning. According to Gardner, this theory is based on human biology. The other theory is Kovalik's integrated thematic instruction (ITI) theory.

Gardner's Theory of Multiple Intelligences

According to Gardner (1999), traditional psychologists believe that there is one intelligence that is fixed, and that it may be assessed by a simple intelligence quotient (IQ) test. Gardner countered that belief by proposing that individuals have more than one intelligence. He based this assertion on neuroscience research, and developed the theory of multiple intelligences. Sherow (2000) reported:

Gardner defines intelligence as the capacity to solve problems or to fashion products that are valued in one or more cultural settings. He believes that every individual has different abilities in each area and that incorporating all intelligences in the learning process maximizes learning potential. It is important to recognize and utilize aptitudes and interests because they *motivate learning; adults learn faster and better when what is to be learned is relevant and meaningful and can be applied directly to their lives and interests.* (Sherow, 2000, p. 7)

Everyone possesses each of the intelligences, but to different degrees (Osciak & Milheim, 2001). For example, one person might have stronger kinesthetic learning ability than another might. Instructors need to use a variety of instructional methods and media to meet the differing needs and learning styles of students. The element of choice in learning is also important (Caine & Caine, 1990); students should have some choice in their learning activities. By having a choice, the learner can use his or her stronger intelligence to learn the necessary content. Learning styles need to be considered for all students of all ages. In any group of adults, there is a wide range of individual abilities; thus, the individualization of learning experiences is important in many situations.

Gardner's Multiple Approaches to Understanding

Gardner also developed an instructional design theory, the multiple approaches to understanding, in which he looked at "ways to foster understanding in ways that capitalize on differences in learners' intelligences" (Gardner, 1999, p. 70). Every student is bombarded by information, and each incoming stimulus gets sorted and sent to different regions of the brain in order to be interpreted in short-term memory. Once information is sent to short-term memory, "its next goal is to be employed into fitting into the category of understanding. It is through exposure and understanding that something gets committed to memory. If it does not connect through association to a previous memory or have some personal relevance to latch on to, all is lost" (Brunner, 2000, n.p.).

Gardner (1999) proposed that "Education in our time should provide the basis for enhanced understanding of our several worlds: the physical world, the biological world, the world of human beings, the world of human artifacts, the world of self" (p. 72). He saw that students need to demonstrate their understanding of important topics. Memorization, or the ability to paraphrase learning, does not constitute understanding. "Students exhibit understanding to the extent that they can invoke these sets of ideas flexibly and appropriately to carry out specific analyses, interpretations, comparisons, critiques" (Gardner, 1999, p. 81). This theory has a focus on understanding as an important type of learning outcome.

The primary goal of applying Gardner's theory of multiple intelligences should be to take advantage of the differences in students' intelligences and consider their individuality. Earle (n.d.) reported on the values upon which the theory is based, including the following:

(a) the criticality of 'what to teach' and the variability of 'how to teach it'; (b) being able to deploy understanding (performances of understanding); (c) preparing students for valued adult roles; (d) helping students to enhance their various intelligences; (e) tailoring instruction to individual differences in students' intelligences; and (f) an approach to instruction that is not formulaic. (Earle, n.d., n.p.)

Perkins and Unger (1999) developed a similar theory about understanding. Their theory defines understanding as knowledge in thoughtful action. Their theory, like Gardner's, expands the concrete meaning of understanding. These theories place emphasis on students' appreciation of the information they are learning. "The word 'appreciate' connotes that affect is an element of deep understanding. An intersection of cognition and affect is a major thrust of the new paradigm of instructional design theories" (Gardner, 1999, p. 90). In a later article, Gardner (2003) admitted that when he formulated the multiple intelligences theory, it had an "individual-centered" bias. Gardner (2003) stated:

Most students of intelligence, however, are now coming to the realization that intelligence cannot be conceptualized, or measured with accuracy, independent of the particular contexts in which an individual happens to live, work, and play, and of the opportunities and values provided by that milieu (Gardner, 2003, n.p.)

Gardner (2003) further stated that intelligence is the result of an interaction between biology and "opportunities for learning in a particular cultural context" (n.p.). He considered the total person not only in terms of intelligence, but also as an integrated individual with motivation, personality, emotions, and will. Instructors need to respect the individual differences of every student. According to the neuroscience research discussed earlier in this chapter, everyone's brain is unique, and individuals learn in their own unique ways. Multiple intelligence theory suggests that there are observable, innate human intelligences that are based on biology. These natural intelligences are important for survival and the continuation of the species; however, the context of the individual must also be considered when discussing these intelligences.

Brain-based learning, a comprehensive approach to education, supports the notion that individual differences need to be considered in any educational setting. Although Jensen (2000) did not introduce the term *multiple intelligences,* he discussed how each person's brain is unique and individual. Everyone's intelligence is deeply entrenched in his or her context. Jensen stated that "our brain sorts and stores information based on whether it is heavily embedded in context or in content" (p. 222). Jensen described two ways that our brain deals with new information. "Information embedded in context is 'episodic' memory, which means it is stored in relationship to a particular location, circumstance, or episode; and information embedded in content is 'semantic' memory (facts), which is usually derived from reading and studying" (p. 222). Learning in context provides "more spatial and locational 'hooks' and allows learners more time to make personal connections" (p. 224). It is important for instructors to engage multiple memory pathways, and to have a focus on multiple intelligences. Ways to foster multiple intelligences include the use of real-life simulations, thematic instruction, interactive contextual learning, and a focus on multiple intelligences. When such methods are used, students activate multiple memory systems that help with learning retention.

Integrated Thematic Instructional Design Theory

The second instructional design theory that has a basis in neuroscience is the integrated thematic instruction, or ITI model, developed by Susan Kovalik. According to Dorner (n.d.), the "ITI model (Integrated Thematic Instruction) developed by Susan Kovalik carefully develops a brain-compatible learning environment, then structures curriculum to take advantage of the way the brain learns best" (n.p.).

According to Kovalik (n.d.), integrated thematic instruction is a "comprehensive model that translates the biology of learning into practical classroom and school strategies" (p. 375). Kovalik and McGeehan (1999) based their model on the "bodybrain partnership," which, as they explained, is "a coined word to reflect the collaborative activity of both brain and body for learning" (p. 376). Based on the biology of learning, they developed six learning principles: (a) intelligence is a function of experience; (b) emotions are the gatekeepers to learning and performance; (c) all cultures use multiple intelligences to solve problems and to produce products; (d) the brain's search for meaning is a search for patterns; (e) learning is the acquisition of useful mental programs; and (f) one's personality has an impact on learning. These six principles lead to nine body-brain compatible elements for instruction that serve as guides for applying the research when developing curricula and instructional strategies. Each of these principles applies to adult students as well.

The first principle involves the absence of threat, and the need to create a trustworthy environment. Instructors need to make students feel free from anxieties, and need to help students develop positive emotional associations with learning (Kovalik, n.d.). The absence of threat is necessary for the student to do reflective thinking. This principle correlates with the brain-based concept of the brain's survival response (fight or flight) to any threat situation. It is important to prevent this reflexive reaction; if it is invoked, students will "downshift" to the lower centers of the brain, and learning will not occur. Students need:

to explore the new and different and to be open to new ideas requiring confidence that one is in a safe environment, one in which mistakes and difficulty in understanding/doing something are considered just part of learning, not an opportunity for sarcasm and put-downs. (Kovalik, n.d., n.p.)

The second principle is meaningful content. Curriculum must have relevance. Learning should include examples that relate to students' lives, as such examples will assist them in understanding the information. Assignments should allow students to choose meaningful activities to help them apply and individualize information (Ally, 2004). This principle relates to the process in which axons reach out to other neurons and start to form new pathways. Prior knowledge is very important and helps to cement new information. Information that has entered the short-term memory is parked there while the student is actively using it in activities that depend on the rehearsal process (Brunner, 2000). Developing real-life context and importance to the learner is also vital. The brain looks to make associations between incoming information and experience, while also seeking patterns of meaning that depend on experiences. Two ways to develop context and importance are to consider students' prior experiences, and to encourage students to feel that they are part of a community. When an instructor uses these strategies, students' brains perceive the new information as meaningful. Students then develop a sense of well being.

The third principle is providing choices. "Provide options as to how learning will occur, considering multiple intelligences and personality preferences" (Kovalik, n.d., n.p.). Choices allow students to have control over the learning process. It is important to allow choice, as everyone's brain is unique and the correct selections are important to activate the right pathways of learning. Choices may also allow the instructor to challenge students in a supportive environment, which will decrease stress and then enhance learning.

The fourth principle is establishing a schedule that offers ample and flexible time for thorough exploration. Students need enough time to explore, understand, and use information and skills (Kovalik, n.d.). Time is needed by the brain to seek and build patterns that can be saved in long-term memory. Students need time to master a skill or concept. Time is also needed by the adult student to reflect upon and internalize information.

The fifth principle is an enriched environment that provides a learning atmosphere that reflects what is being taught. An enriched environment is a setting that provides multisensory input. The more senses that are involved in the learning experience, the longer the learned information will stay in memory. The brain is a multiprocessor of incoming sensory information that performs many operations simultaneously. A rich sensory environment enhances learning with a variety of stimuli. Examples of activities that might occur in a rich sensory environment include the following: using hands-on items, visiting sites, reading books, watching videos, and employing a variety of good references. The instructor should ensure that the room is body-compatible by avoiding clutter and distraction. Instructors should change displays and bulletin boards often, invite guest speakers, and generally increase overall sensory input. The use of multimedia in the online learning system will be discussed in greater depth later in this chapter.

The sixth principle is collaboration. Students need to work together to investigate and solve problems. "Collaboration increases understanding and improves quality of output. In the classroom, collaboration dramatically increases opportunities for the bodybrain partnership to play an active rather than passive role in learning, thus spurring physiological change in the brain" (Kovalik, n.d., n.p.). For collaboration to occur, interaction must occur. Interaction is vital to creating a sense of community, both in the classroom and online. Interaction develops a sense of community, and can promote deeper and richer learning in the adult learner. A sense of community personalizes the material for the learner and may help to contextualize information. According to Jonassen (2000), learning tasks that are meaningful, real-life tasks or activities are considered contextualized. It is this type of learning environment that puts students into learning communities.

The seventh principle is immediate feedback. It is necessary to provide coaching to promote effective teaching or learning. Immediate feedback is necessary for pattern seeking and program building. Feedback also motivates students and allows students to apply what they have learned to real-life situations (Hill, 2001).

The eighth principle is mastery/application, in which students internalize what they have learned and apply it to real-world situations. It is necessary to ensure a curriculum that allows students to acquire mental programs in order to use what they have learned in real-life situations (Kovalik, n.d.). It is important to avoid imposing perspectives on students, and to permit them to construct their own knowledge. Instructors should not make assumptions about what their students need, and should engage in communication with them. Instructors should answer questions such as "What do the students need to know and why?" and "How will this information be used?" (Imel, 2000). Online strategies should foster this transfer to real-life situations. It is possible to conduct simulations, case studies, and problem-based learning online; these approaches help students develop personal meaning, as well as contextualize the information.

The ninth and final principle is the use of movement to enhance learning. "Movement is crucial to every brain function, including memory, emotion, language, and learning" (Kovalik, n.d., n.p.). The movement principle relates to the process of lateralization, in which students' thinking can become "stuck" on one side of the brain. Cross-lateral, changing activities are important to keep the brain active on both sides, and to allow use of the entire brain.

Comparison of Gardner's and Kovalik's Theories

Gardner and Kovalik's theories serve as models for instructors. Kovalik's theory is in closer alliance with brain-based strategies than Gardner's is, since the former is based on empirical neurophysiological research. Gardner's theory also considers individual differences, diversity, and biology; however, his theory does not appear to be as heavily based on neuroscience research as Kovalik's does. Gardner based his theory on cognitive psychology and considered the brain's functions. Both of these educator-researchers have chosen to interpret the research on human learning; however, the author maintains that Gardner's multiple intelligence theory is a piece of the puzzle of Kovalik's more comprehensive theory.

The author would incorporate information from both of these theorists, especially since the author views Gardner's theory as a part of Kovalik's broader interpretation of neuroscience research. Gardner's theory has been recognized by more theorists in the literature, and provides a good foundation for understanding the individuality of students. However, it only addresses individual differences, and does not address methods of working with all the components of the "whole person" — including health, environment, context, absence of threat, respect, and pattern matching — that have been identified by Kovalik and other neuroscience researchers. It is interesting to note that both Kovalik and Gardner developed their theories in the early 1990s, when neuroscience research was in the early stages of development, and the same information was available to both authors.

It is important not only to consider individual learning differences, but also to remember that each person comes with his or her own "set of directions" and history. The positive effect of incorporating these strategies into the learning process has been proven by neuroscience research, and should be considered by instructors developing teaching strategies.

The following section of this paper will integrate ideas about specific brain-based strategies with distance learning. There are references to distance learning and online learning in the next section; the author considers the two terms to be synonymous, unless specified otherwise. These strategies are grounded in the brain-based research and instructional design theories discussed in this paper. The section will integrate and summarize the principles presented by neuroscience research, and demonstrate how they can be implemented in an adult distance-learning or online learning environment.

Brain-Based Learning and Distance Learning

Significant features to consider regarding the online learning environment for distance learning, the use of multimedia, and adult learning needs, will be presented. Ideas for developing distance-learning courses are presented that summarize and synthesize key concepts related to brain-based learning and its implications for the online environment.

Distance Learning

Distance learning and the online classroom are becoming more common today. A trend of increasing dependence on technology to assist in learning is becoming more widespread as well (Montgomery & Whiting, 2000). Understanding neuroscience research about learning and cognition can help instructors as they develop online learning environments for adults.

The brain-based learning research substantiates that learning is best facilitated when students are actively engaged in the creation of knowledge. Interaction among students (and between students and the instructor) is vital for true learning. However, technology must be used actively, and not just for transmitting information to students in a passive mode (Montgomery & Whiting, 2000). Students should not be passive recipients of information. Additionally, constructivists argue that students cannot directly learn from either teachers or technology. Students learn from thinking, and they must be actively involved in the learning process. Technologies can support learning only "if they are used as intellectual partners and tools that help learners think" (Montgomery & Whiting, 2000, p. 796).

Implications for Multimedia

Multimedia gives the instructor the ability to bring the real world to the learner with a multisensory approach, using multiple types of media simultaneously and in an integrated manner. Media might include sound, graphics, video, text, animation, or any other form of information representation. Multimedia can help motivate students and give them additional connections to their personal knowledge structures. Multimedia also helps present learning in a multimodal manner, thus allowing students to build their connections, or neural networks, in response to the material being presented. Internet and distance leaning programs can capitalize on multimedia. There is a wealth and variety of information available on the Internet, and instructors should consider this as they design their online classrooms.

Contemporary multimedia platforms allow a greater degree of learner control and more freedom for the learner to undertake self-directed exploration of the material. Such self-directed learning is likely to be more meaningful and more connected to existing knowledge structures within the learner's brain. Therefore, educators should perceive the advantages of learning programs that include multimedia presentations. (Forrester & Jantzie, n.d., n.p.)

Opportunities to self-pace and to get immediate feedback should also be built into the program or course management system. This allows students to form the correct "connections prior to reinforcing connections between new and old information incorporated within existing knowledge structures" (Forrester & Jantzie, n.d., n.p.).

Distance learning and multimedia present new challenges to today's instructors. Instructors who learned in traditional, passive classrooms need to learn new skills and ways of teaching. Today's instructors must also cope with developing new neural networks as they relate new methods of instruction to the old.

Implications for Preparing the Learner

Preexposure and scaffolding are important methods of preparing students for learning. The following are recommendations for instructors to consider as they design online learning environments: (a) use mind maps; (b) present an overview of class material before the session starts; (c) discover students' interests and backgrounds through a discussion board or students' Web pages; (d) have students set their own goals and integrate them with class goals for each unit; (e) develop a course map with hyperlinks and a site map; provide hyperlinks to related information; and (f) be a positive role model.

The instructor also needs to consider the multiple intelligences of students and provide a multimodal environment that allows learner choice. Recommendations for implementing this environment include the following: (a) use a variety of teaching tools and strategies, such as Web quests, real-life projects, role-play and design complex, and multi-sensory immersion environments; and (b) provide online students with control of navigation.

Implications for the Online Environment

Implications for the online environment include ensuring that there is positive emotional commitment by the student, with an absence of threat. Frequent feedback, mutual respect, and strong peer support are vital to maintaining a positive emotional environment. Specific recommendations for the creation of such an environment are as follows: (a) recognize that it is difficult to "unlearn" old beliefs, and allow students time to work through conflicts; (b) be aware that the learning environment may trigger past negative learning experiences for some adults; (c) use a variety of input methods, including online lectures, readings, films, videos, audio, journals, models, and pictures; (d) incorporate health education on topics such as stress management, fluid intake requirements, and movement; (e) build "attention getters" into the educational plan, and engage students in group discussions; (f) use humor and acknowledge emotions; (g) provide interactive feedback using collaborative activities and a discussion board; (h) increase rapport by developing partner learning, discussions, dialogue, and collaborative activities; (i) set up a method that allows students to express concerns in an anonymous, nonthreatening forum, such as a separate discussion board; (j) provide social opportunities for groups to interact informally; and (k) set ground rules that emphasize respect for fellow students.

It is also important to provide an authentic learning environment in which the learner can contextualize the patterns found, building on his or her previous experience. Some specific methods to achieve this include the following: (a) Get the students' attention and personalize the environment by using technology that recognizes the student's name. (b) Provide meaningful challenges by solving real-world problems. (c) Use experiments, and have students investigate using an active learning approach. (d) Present information through context, which allows the learner to identify patterns and connect them with previous experiences. (e) Use problem-based learning, collaborative/cooperative learning, project-based learning, and service learning. (f) Chunk the material; this will help students classify incoming information, and develop a pattern that they can use to build new neural networks. (g) Use students' prior knowledge. (h) Provide a model of a good performance, and then let students analyze their errors, as well as identify general patterns that underlie the concepts being studied.

Implications for the Individual

Everyone's brain is unique. It is important to promote active processing, as well as encourage reflection by the students. There should be a balance between novelty and predictability in the content. Methods of fostering active processing and reflection include the following: (a) Use a note-taking function for the students to write thoughts as they review the online material. (b) Use computer conferences such as listservs, electronic mail, bulletin boards, and MUDs (multi-user dimensions) to foster reflection. (c) Provide ways for students to engage in metacognitive reflection by using think logs, reflective journals, and group discussions within a cooperative learning setting. (d) Ensure that the student can examine the material's relevance to his or her life. (e) Provide some challenge. The brain is always looking for novelty and is responding to stimuli; thus, the environment should be stable and yet novel. (f) Use multifaceted teaching strategies in order to capitalize on the student's preferred method of learning. (g) Put collected data into a personal "scrapbook," or have each student develop an e-portfolio.

Impact of Research on Education

The principal implication of brain-based research for education is that online educators should be responsive to the latest findings on the neuroscience of learning. Scientific, objective research is proving that learning is an active and individual process. For the author, the primary question that arises from this information is this: Why aren't more educators implementing this type of training? Why are professors still "performing" in massive lecture halls? The implications of research in brain-based learning, for teaching and learning are remarkable. Educators need to be introduced to this research in a manner that allows them to understand and interpret the findings. Educators should be prudent when applying the findings of brain-based research, but at the same time, they should move forward with what is already known.

Conclusion

The underlying theme of this chapter — which has encompassed Gardner's multiple approaches to understanding, Kovalik's integrated thematic instruction, and brain-based learning — is one of diversity and individuality, which seem to be in conflict with each other. How can we teach for diversity and yet consider the individuality of each student? This is the challenge for educators, as the new brain-based research has shown the importance of diversity and individuality as characteristics of students.

Knowledge of how the brain learns provides a basis for achieving a better understanding of how adults learn. Neuroscientific research has found evidence of the brain's plasticity and ability to respond throughout life, and it has shown that adults continue to learn throughout the lifespan. Emotion and sensory experiences are integral to learning. Meaning making, morals, consciousness, and associations with others are critical to adult learning.

Two instructional design theories have been discussed that are based on the biology of learning. Kovalik's ITI theory is the most comprehensive theory, in that it incorporates much of the current research on brain-based learning. Researchers continue to discover more about how the brain learns. As new information is discovered, new learning theories will be developed. It is important to understand that research on the brain is dynamic and is rapidly providing new information. Instructional designers, as well as instructors, need to understand that the information available today may change in the near future. Instructors and instructional designers should continue to question what the theories say as new information emerges.

In the last 30 years, researchers have developed new technological tools to discover a completely unknown territory, the brain. Brain-based learning is closely aligned with the constructivist theory of learning, as well as with current information available on adult learning. Brain-based research has provided facts and objective information to support how instructors teach. The way in which the learning process is employed will have the largest impact on students' learning. A paradigm shift to constructivism that supports new instructional design and learning theories is substantiated by the research that has been presented in this paper. Learning is the beginning of discovery. Educators should consider integrating brain research into teaching strategies as learning theories continue to be developed, refined, and implemented.

Brain-based research is validating the assertion that learning is individual and unique. This implies that current practices such as standardized materials and instruction may, in fact, diminish or inhibit learning. However, instruction should not be based solely on neuroscience. Brain-based learning provides new directions for educators who want to achieve more focused, informed teaching. With additional research in brain-based approaches, there may better options for those struggling with learning. Since no two people have had the same experiences that modify neural networks, the potential for cognitive differences among individuals is huge. Brain-based research needs to be interpreted for educators so that they can utilize this information in the classroom. It is vital for the educator of tomorrow's students to understand the importance and implications of brain-based research.

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