Language Learning and Its Impact on the Brain: Connecting Language Learning with the Mind Through Content-Based Instruction

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Abstract: *Cognitive sciences are discovering many things that educators have always intuitively known about language learning. However, the important point is actively using this new information to improve both student learning and current teaching practices. The implications of neuroscience for educational reform regarding second language (L2) learning can clearly be seen in the following categories: brain structures and the corpus callosum; neuronal development and the parts of the brain dedicated to language; the Brain Plasticity Theory and Language Mapping; memory and the Information Processing Model; and of course, developing and utilizing a brain-compatible language curriculum that is meaningfully integrated into the basic content areas covered in all grade levels PreK–12. This article describes a recent study designed to address relationships between the corpus callosum and bilingual capacity, and provides recommendations to language teachers regarding brain-based learning through content-based language teaching.*

Key words: *brain compatible, brain structures, content-based language learning, corpus callosum, neuroscience*

Language: *Relevant to all languages*

Introduction

The 1990s marked the "Decade of the Brain," when researchers actively began to study and disseminate new information that could help us to understand how the brain functions. Since then, thousands of new discoveries continue to be reported on a daily basis, especially given the advancement of technology that allows researchers to look inside the brain, examine its physical structure, and monitor the constant activity taking place. Studying how the brain functions through the course of thinking and understanding can provide valuable insight into the learning process. Many researchers predict that the brain research findings highlighted

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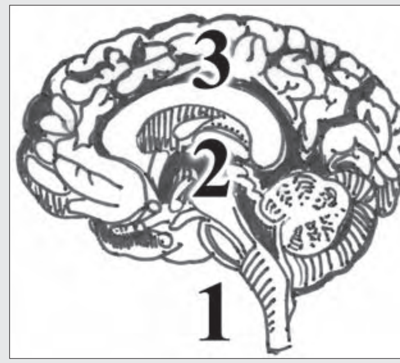
today will eventually give rise to comprehensive changes in education, specifically guiding instructional practices followed in the classrooms of the future. Therefore, educationally speaking, the important next steps must be to apply new findings to the development of practical strategies and lesson plans that facilitate student learning in general, and more specifically, facilitate second language acquisition (SLA) for all students.

> The human brain, a 3-pound mass of interwoven nerve cells that controls our activity, is one of the most magnificent—and mysterious—wonders of creation. The seat of human intelligence, interpreter of senses, and controller of movement, this incredible organ continues to intrigue scientists and layman alike. (Presidential Proclamation 6158, 1990)

FIGURE 1

Information Routing Through The Brain



Sensory information enters the brain by way of the thalamus (1), travels through the Limbic System (2), arriving to the cerebral cortex where is it stored in different localizations or modularities (3).

Brain Structures and the Corpus Callosum

What is known about how the brain receives and processes information is quite complex. During the course of any given moment in time, sensory input travels through the brain by way of the thalamus on its way to the cerebral cortex. This sensory input is filtered by the brain stem and limbic system. It is affected, and sometimes altered, by its passage through the lower, limbic systems of the brain, totally in control of our physical and emotional needs. The limbic brain is made up of clumps of specialized cells rather than the modularities found in the cortex. The thalamus is especially important to second language (L2) learners, as is the amygdala, which controls the emotional response to learning the new language. Information that survives the passage described above, arrives at the frontal cerebral cortex, where information processing and learning begin to take place (see Figure 1). It is at this point that the brain attempts to understand and make sense of the information registered via the senses. Information deemed meaningful and/or relevant is then stored in different localizations or modularities found in the cerebral cortex.

The various parts of the brain communicate by way of neurochemicals. During the past 20 years, the chemical nature of nerve cell communication has been clarified significantly. Many neurochemicals, which serve as neurotransmitters, derive from dietary protein that must be included in daily consumption. Over 100 such compounds have been described (Armstrong, Kennedy, & Coggins, 2002). An insufficiency or too much of any chemical can cause behavioral imbalance, which in turn effects sensory input as well as information transfer to the cerebral cortex.

Studies have demonstrated that the human brain can and does grow new cells in the hippocampus (Eriksson, Perfilieva, Björk-Eriksson, Alborn, Nordborg, Peterson et al., 1998) and that the brain is capable of building an infinite number of neuronal connections that strengthen the modularities found within the brain. Cortical pyramidal cells grow by adding dendrites, which when given

FIGURE 2

Brain Growth in Relation to the Alternating Stages of Body Growth

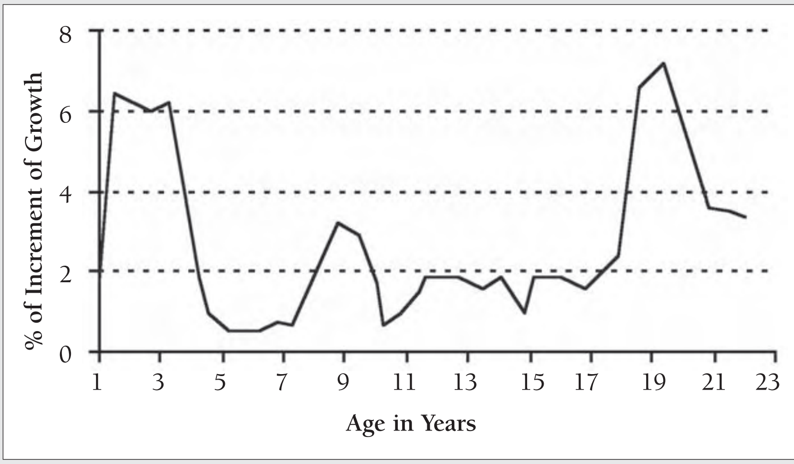


Chart modified from Hudspeth and Pribram (1990), showing growth stages in the frontal cortex, originally cited in Armstrong, Kennedy & Coggins (2002).

appropriate stimulation, will branch and rebranch. Enriched experiences enhance neural growth and thus enhance learning, indicating that brains construct themselves through life experiences. The more stimulation received, the greater the learning (Diamond, 2001). As Diamond has explained, environmental enrichment changes our neuronal network patterns or "maps of meaning." Time, stimulation, repetition, novelty, and motivation are essential to laying the foundations for later learning, which in turn results in either an impoverished or enriched neuronal composition (Jensen, 1998). By reflecting on this process, we can easily see how learning is directly affected by our students' emotional and physical well being. Krashen's (1982) *affective filter hypothesis* is clearly in line with this notion, stating that the acquirer must be motivated, self-confident (have a good self-image), and possess a low level of anxiety in order to receive the comprehensible input necessary for language acquisition to occur.

Physical development also plays a significant role in dendritic growth and the development of an enriched neuronal composition. The brain continues to grow new cells and change throughout a person's life. The line graph in Figure 2 illustrates growth of neuronal connections in the frontal cortex in relation to the alternating stages of brain growth parenthetically not shown on the graph. From birth to about three years in age, babies expand their knowledge of the world around them through their senses, storing information related to sights, sounds, smells, tastes, and touch in their attempt to understand their immediate environment. These sensory experiences produce millions of connections. In order to become more efficient, the brain begins its first "pruning" stage, losing excess connections not being fully utilized at about the age of four. At this point, brain growth steadily decreases until about the age of five or six due to a competing period of extensive body growth. Around the age of seven, a strong growth period occurs in the brain before it engages in its second phase of pruning that occurs close to age 10 to 11, when the process of focusing on dendritic growth begins again. Age 14 to 15, the beginning of adolescence, marks the third phase of pruning, as the brain is focusing on emotional development, and in many cases continued body

FIGURE 3

The Corpus Callosum

The two hemispheres are connected through axonal links at the central *corpus callosum.*

growth. During the period of 16 to 20 years of age, strong connections are developed in the frontal lobes responsible for problem solving and higher-level thinking skills. These major connections continue to grow through adulthood, with new connections continuing to be established, however not as easily as they were during the periods of strong dendritic growth experienced in early youth. This pattern indicates that the brain progresses through formative stages of development during the PreK–12 years. Understanding these developmental stages of the brain and tailoring instruction in a manner that maximizes students' abilities can make learning more relevant and lasting for students (Franklin, 2005).

Although the brain in not fully functional until ages 23 to 29, it is postulated that some variation in growth may influence learning (Hudspeth & Pribram, 1990; Thatcher, 1991). The size and combination of modularities found within the brain ultimately gives an individual his or her unique mental potential. Both nature and nurture are essential components of this equation. Varied experiences then continue to mold each individual's brain throughout life. The permutations and combinations of modularity type and size are infinite, as are the number of experiences one could have.

The two hemispheres of the brain are connected through axonal links at the central *corpus callosum*[1], a broad, thick band, running from front to back and consisting of millions of nerve fibers, in essence, connecting the two cerebral hemispheres of the brain down the middle (see Figure 3). Since the corpus callosum is the major commissure, or bundle of axons connecting the two cerebral hemispheres, there is a direct correspondence left to right and front to back in connections through the corpus callosum. Information received in the brain is transferred from left-to-right, therefore the right hemisphere controls the left side of the body and vice versa. Generally speaking, the left and right hemispheres of the brain process information in different manners. Although the exact function and interplay between the two hemispheres is not yet totally understood, in most people, the left hemisphere is more specialized for linear, logical thought and communication, while the right hemisphere deals with spatial relationships and is more active when we are relaxed, and in a dream state. As the brain develops, the corpus callosum is responsible for transferring information across each hemisphere, reinforcing connections related to tasks that one is genetically predisposed to, or connections related to areas that are adapting and strengthening.

For example, when the left eye sees a word, the right hemisphere will pass the information about the word over to the left hemisphere for processing by the language centers. Therefore, even though we tend to process information using our dominant side, the learning and thinking process occurs only when both sides of the brain participate in a balanced manner. When not actively engaged in learning, the corpus callosum acts as a bridge between both hemispheres, enabling the accomplishment of tasks of varying difficulty levels.

Again, it is important to note that the research cited above has not conclusively determined that all communication between regions in the different halves of the brain are transferred only via the corpus callosum. In spite of the linguistic processing dominance of the left-hemisphere (in most people), behavior, including cognition and communication, are the result of unconscious and seamless coordination of activity between both hemispheres via the cerebral commissures. Although investigations into the organization of multiple languages indicate that in some instances, functional aspects of two different languages may be mediated by overlapping cortical regions, in cases where two languages are processed by separate cortical regions, one would clearly suspect that the commissures would undergo some adaptive modification in response to the organization of both languages. In cases where different languages do not make use of overlapping or convergent cortical regions, it has been postulated that commissural modification, though less extensive, still happens because of increased processing requirements of linguistic switching (Coggins, Kennedy, & Armstrong 2004; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Price, Green, & Von Studnitz, 1999).

Parts of the Brain Dedicated to Language

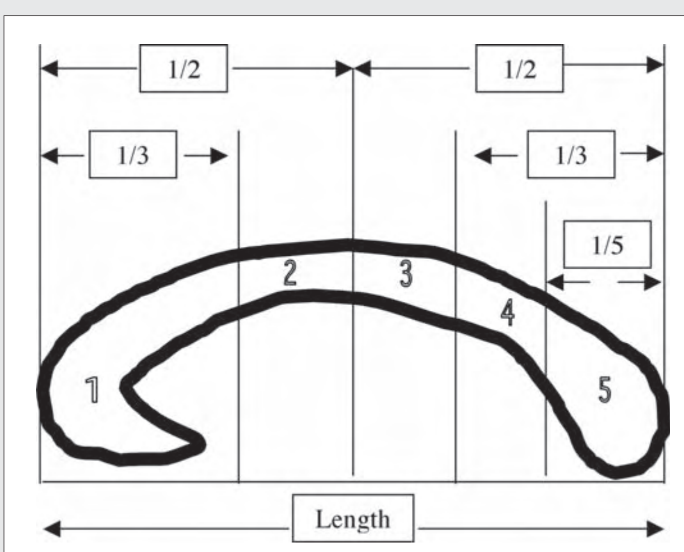
An interesting study of 12 healthy, bilingual volunteers at Memorial Sloan-Kettering Cancer Center in New York, revealed that the location where the capacity to speak an L2 is stored is found in different areas of the brain depending on when in life a person becomes bilingual (Kim, Relkin, Lee, & Hirsch 1997). This suggests that children who learn an L2 store that capacity, together with their native language, in one sector of the brain, while adult language learners store each new language learned in a separate area. This finding helps to explain why children who learn two languages develop the ability to speak both with native pronunciation and proficiency when provided adequate time, supporting the argument that foreign language instruction should be included in the elementary and middle school curriculum.

In response to second language acquisition (SLA) and use, the human brain undergoes cortical adaptation to accommodate multiple languages either by recruiting existing regions used for the native language (L1), or by creating new cortical networks in distinct adjacent areas of the cortex to handle certain functional aspects of L2. However, regardless of how the cortex organizes the circuitry required to handle multiple languages, all nonreflexive behavior, including cognition and communication, is normally the result of unconscious and seamless coordination of activity between both hemispheres via the cerebral commissures. Although language is lateralized to the left hemisphere in over 90% of the normal population, language (subsumed under cognition and communication) normally involves information processing between both hemispheres. Different centers in the brain cooperate to understand and produce speech. Broca's area, in the left frontal lobe, controls the production of speech sounds. It is located close to the area specialized in the formation of words by the mouth, lip, tongue, and larynx. Wernicke's area, located in the left temporal lobe, allows for the formulation of meaning gathered from words and sentences to be connected into speech. Other regions in the brain assist Broca's and Wernicke's roles. For example, one part of the temporal lobe supplies nouns, and yet another joins the two together into logical sentences. Another example of the interconnected nature of the areas of the brain in relation to literacy skills is to examine the brain of a dyslexic reader, which would highlight the lack of distinct modularities communicating with one another—linking vision to sound to meaning.

It is also worth mentioning that the corpus callosum has been studied extensively in relation to disease and injury, resulting in many interesting findings related to language. Post mortem, *in vivo,* and presurgical studies in humans have shown that language is susceptible to various impairments due to lesions of certain structures of the brain, but not surprisingly, the relationship between corpus callosum variability and language has not been a wide-ranging topic of neurological research. However, extensive research has examined the extent to which the corpus callosum links the modularities on either side of the cerebral cortex. One theorist, Gazzanaga (2000), has implied that the corpus callosum provides clues to high conceptual level individuals. The Gazzanaga team noted that each hemisphere has specialized functions, but the corpus callosum allows these developments to be integrated into a constant functional system. Research conducted at the University of Idaho, utilizing measurement calculations developed by Sandra Witelson (1990), has suggested that the anterior and posterior pieces of the corpus callosum are larger in gifted children when compared with "normal" controls (Armstrong et al., 2002). This may be attributed to either more axonal strands found in the larger sections of the corpus callosum connecting the two hemispheres or greater myelination (Coggins, 2002). Questions also arose during this research regarding relationships that could exist due to language experiences, resulting in the first known study to address the relationship between corpus callosum and bilingual capacity. It was hypothesized that the corpus callosum of bilingual individuals would differ from the corpora callosum of monolingual individuals in the midsagittal plane (Coggins et al., 2004). A small group of right-handed volunteers, consisting of 15 foreign language teachers and 15 science teachers (teaching at either the secondary or university level), participated in magnetic resonance imaging (MRI) to produce images of their corpora callosa. Of the 30 initial participants, only 19 images were acceptable for use in the study (11 of the participants moved slightly during the imaging procedure resulting in a blurred image that could not be used in the study). All 12 of the bilingual teachers whose images were used reported studying their L2 for more than seven years, with seven teach-

FIGURE 4

Regional Subdivision of the Midsagittal Corpus Callosum



Region 1: Anterior Third; Region 2: Anterior Midbody; Region 3: Posterior Midbody; Region 4: Ithsmus; Region 5: Splenium. Adapted from Witelson (1989) and originally cited in Coggins, Kennedy, & Armstrong (2004).

ers beginning their L2 study early in life, during their elementary education. None of the bilingual participants reported being raised in a bilingual environment since early childhood. All teachers reported to possess Advanced to Superior levels of proficiency in the L2 according to the established ACTFL Proficiency Guidelines (1985). The seven monolingual teachers who participated reported no previous study of an L2 and all are presently teaching in science content areas. This distinction bears important relevance to the hypothesis that the corpus callosum of the bilingual individuals would have a different formation than the corpus callosum of the participating monolingual individuals in this study.

Using a modification of Witelson (1989), the midsagittal corpus callosum images were partitioned plane into five subregions (see Figure 4). Results of the analysis showed that the anterior midbody to total corpus callosum midsagittal area ratio was significantly larger in the bilingual individuals compared to the monolingual individuals at the 0.05 alpha level. Although this significance should be interpreted cautiously due to the small sample size available, the results can be interpreted as an adaptive response to bilingual capacity. With respect to L2 education, the results of this study could suggest that bilingual learning and use can have a profound effect on brain structures in general, and on the corpus callosum in particular, since callosal adaptation might facilitate increased interhemispheric transfer by way of increased myelination, or by way of an increased number of fibers that provide greater cortical connectivity.

Implications of Neuroscience for Educational Reform

Theories have been developed to investigate the optimal age to undertake the study of an L2. Research has shown that the Brain Plasticity Theory (Baker, 1993; Chugani, 1996; Nash, 1997), the Biological Predisposition Theory (Lemke, 1990; Genesee, 1996), the Imprinting Theory (Asher & Garcia, 1984; Celestino, 1993; Hart, 1983) and the Native Language Magnet Theory (Kuhl, 1994) commonly share the theme that the younger the individual is when he or she is exposed to a new language, the greater the probability of acquiring native pronunciation as well as proficiency in that language. Lending further support to this thought, researchers often refer to a newborn's mind as unprogrammed circuits of a computer that have almost infinite potential, additionally comparing the mind to Pentium chips found in a computer before the factory has preloaded the software (Begley, 1996). Begley reported that the circuits in the auditory cortex of the brain are wired by the age of one year, concluding further that the learning window for total language learning is from birth to 10 years of age. This implies that the critical periods for language learning close with each child's passing birthday.

More recent research has concluded that the window for acquiring syntax may close as early as age five or six, while the window for allowing for the addition of new words may never close (Nash, 1997). However, Nash found that the ability to learn an L2 undergoes a steady and inexorable decline after the age of six. Many researchers postulate that after this critical period, brain plasticity becomes slowly less effective, in other words, the brain may be less able to make particular changes that organize the location of specific information processing functions resulting from experiential effects ("Language Learning and the Developing Brain", 1996). Others have documented studies that support early language acquisition and believe that there clearly appears to be a "window of opportunity" when the brain is particularly efficient in learning (Chugani, 1996). Information released from the UCLA School of Medicine stated that the learning experiences of a child determine which connections in the brain become developed and which will no longer function ("Language Learning and the Developing Brain", 1996). Additional reports released also document studies that have shown that the brain of a two-year old has twice as many synapses or connections as an adult's brain. Consequently, the failure to learn a skill during this sensitive period holds important significance because the young brain must use these connections or they will be lost. Since the fixing of speech habits occurs at about the age of 10, the consequent age barrier in language acquisition is directly linked to psychological as well as neurophysiological factors (Clyne, 1983; Krashen, 1976).

Examining the methods that enhance L1 learning, and the types of activities and environments that positively affect the learning process, provides teachers with an insight into truly creating a brain-compatible classroom for students that are trying to acquire an L2 after the initial neuronal pruning stages have occurred. Almost all language skills are more easily acquired through natural language acquisition experiences, even for adult learners. The natural approach to language learning outlined by Krashen and Terrell (1983) maintains that beginning language learners should be taught a new language in the same manner that they acquired their first, encouraging observation, listening, and understanding before developing skills in speaking, reading, and writing.

Of particular importance is the variable of time. Studies have shown that it takes thousands of contact hours to achieve the ability to function beyond the tourist level in Spanish and French; four to five times longer for other languages such as Arabic, Japanese, Korean, Mandarin, or Russian (Brown, 1997). In fact, the Foreign Service Institute—the U.S. Federal Government's primary training institution for officers and support personnel of the U.S. foreign affairs community—documented that it took at least 720 hours of intensive study for adults with high aptitude to become proficient at an L2 (Omaggio Hadley, 2001). Research has also reported that the length of time students study an L2 relates directly and positively to higher levels of cognitive, as well as metacognitive, processing skills (Rosenbusch, 1995). It is important to note that in nearly all adults (90%), the language center of the brain resides in the left hemisphere, but interestingly enough, the brain appears to be less specialized in children. According to a recent PBS special on the brain, "scientists have demonstrated that until babies become about one year old, they respond to language with their entire brains, but then, gradually, language shifts to the left hemisphere, driven by the acquisition of language itself" (*The Secret Life of the Brain*, 2002)[2]. Emotion, experiences, and learning of meaningful information strengthens useful connections and results in cortical pyramidal cell branching.

The physiological architecture of the brain changes in response to life experiences, adapting in response to environmental stimuli. It is not surprising to find that studies show young infants are predisposed to attend to the language spoken by others around them, using context to figure out what someone must mean by various sentence structures and words. Language development studies illustrate that children's biological capacities are set into motion by their environments (Bransford, Brown, & Cocking, 1999). Research has also shown that we are born with an ability to distinguish among different language sounds (Kuhl, 1994). Similar sounds are chunked together into one single category, and according to Kuhl, "language magnets" are developed that attract babies' ears to the specific phonemic sounds found in the language(s) they are accustomed to hearing. For example, a baby that listens to Swedish (16 vowel sounds) will have different language magnets than a baby who hears Hangul (10 vowel sounds), English (8 or 9 vowel sounds) or who hears Japanese (5 vowel sounds). According to Kuhl, while the Swedish baby retains all the distinctions, the babies lose the ability to distinguish those vowels because their languages do not contain or utilize them. Kuhl's research postulates that infants' perceptual systems are established by six months of age and are at that time configured to acquire their native languages. She further explains that this wiring, or perceptual map, accounts for the accents that signal our national and regional origins. In contrast, the perceptual map experiences a certain amount of language interference with adult language learners. For example, many times, adult language learners have difficulty readily separating similar sounds in a foreign language. Basic examples include the difficulty experienced by adult native English speakers in regard to distinguishing the difference between a [B] sound and a [V] sound in Spanish, or that adult native Japanese speakers typically have difficulty hearing the difference between the [L] and [R] sound in English. This is explained by the opposite linguistic filters listening to the [B] and [V] or the [L] and [R] sound for English and Japanese speakers.

However, it is misleading to characterize the acquisition process as simply easier for children in comparison to adults. Paradoxical views have long surrounded the development of language in young bilinguals, with some viewing early language learning as extremely difficult, characterized by language delay and language confusion, while others viewing language learning as relatively trouble-free (Pettito & Kovelman, 2003). The fact remains that the most difficult task for children and adults alike may be the attempt to acquire second language proficiency in academic environments. Older students typically excel in their initial rate of L2 learning since input is more comprehensible for them due to their extensive background knowledge and advanced learning skills they have already acquired and are prepared to apply—they are faster acquirers as well as faster learners, and because of this they have a greater ability to consciously learn grammar rules, and due to their past experiences, more easily make connections with vocabulary between L1 and L2. However, it has been shown that younger students excel in long-term L2 achievement, especially in pronunciation. The basic points to remember are:

- Language processing involves many *senses*, including *vision*, both in early infancy and in adulthood.
- *Time* and *age* are critical factors that affect the processes associated with language acquisition.
- *Enriched environments* promote neuronal development.
- We use our *emotions* to tell us what is important to learn and what to remember.
- The brain stores information based on *functionality* and *meaningfulness*.
- Emotions drive *attention*.
- Attention drives learning and memory.
- *Repetition* is necessary but it requires *novelty* with regard to instructional design (which should incorporate all five language processes—observation, listening, speaking, reading, and writing—and utilize a variety of methods and approaches).

Acquiring new vocabulary involves actively storing information gathered by explicit memories that have been processed combined with implicit learning, including skills and conditional responses. Access to long-term memory is an immediate goal in language acquisition. Given the average retention rate after a 24-hour period, we must help our students move information into long-term storage by providing them with higher level activities promoting application, analysis, synthesis, and evaluation. As a result of participating in small-group activities that promote practice by doing, and verbally working through meaningful problems, students are able to retain 90% of newly acquired knowledge. Information processing emphasizes cognitive structures built by the learner through actively processing, storing, and retrieving meaningful information that can be interpreted from the beginning within context supplied by existing knowledge. Class time must be structured in a manner that takes *ultradian rhythms*, the attentional highs and lows commonly experienced in cycles of 20 minutes or less, into consideration. Allow time for students to mentally rehearse and summarize concepts before moving on to the next topic and to initiate closure at strategic times throughout each class session, in either small-group discussions or simply taking time to verbalize thoughts aloud or in writing.

In order to stimulate active involvement and evoke memory hooks that engage the learner, it is recommended that teachers provide their students with multiple opportunities to use vocabulary in meaningful and creative ways that stimulate the mind, which directly affects the growth of enriched neuronal connections (Jensen, 1998). Words should be heard and spoken before seen in written form to assure correct pronunciation as well as to facilitate memory recognition and word retrieval. Avoid providing lengthy word lists until after the students are familiar with the vocabulary words. Visual imagery elicits memory retrieval, reinforcing the concept that we need to introduce vocabulary through the senses using visual methods, such as through TPR, pictorial teaching through a mnemonic device, or strategies found in the Gouin series as described by Curtain and Pesola (2004).

The Multiple Intelligences theory (Gardner, 1999) suggests that there are eight or possibly nine, intellectual variables associated with human performance. This theory is supported by the contention that the frontal cerebral cortex is made of thousands of modular units responsible for our conscious thinking, remembering, and behaving (Gazzanaga, 1989). This theory suggests that some individuals could possess different language competencies due to their experiences in each of the areas, as identified by Gardner, which allow them to readily make connections with the vocabulary. Since vocabulary must be heard between 40 to 80 times, depending on the complexity of the word, before it is stored in long-term memory, language teachers must create learning experiences for their students that are centered around many different activities. The multiple intelligences theory provides a guide for language educators to create meaningful experiences using language in a variety of areas, and more importantly, developing areas that may not have extensive experience.[3] The finding of plasticity, and the growing understanding that brain activities are directly linked by networks of neurons that simultaneously perform a variety of operations, suggests that education must broaden its scope to integrate language learning across the entire school experience. The tendency for the brain to consider the entire experience and to search for meaningful patterns calls for thematic, content-based interdisciplinary language instruction at all levels.

Content-Based Instruction—Integrating Brain-Compatible Language Curriculum

Integrated language and content instruction offers a means by which students can continue their academic cognitive development while they are developing a fuller proficiency in not only their L1, but in all languages of study. An approach that integrates L2 instruction with the content of other curricular subject areas commonly found in the K–12 experience allows classroom teachers to reinforce "the basics" while ensuring that L2 instruction is meaningful, and therefore motivating for the students to actively acquire new languages. Although teachers are increasingly embedding content into their language teaching, for example using the Cognitive Academic Language Learning Approach (Chamot & O'Malley, 1994; 1996), the balance between language and content often varies depending on the academic setting. In immersion and bilingual settings, the success of content-based programs becomes "critically dependent on students' mastery of the academic content to the same degree and level as students in native-language classrooms" (Genesee, 1998, pp. 103–105). However, the academic content in other language programs typically serves as the medium for language instruction even though greater emphasis is actually placed on the acquisition of language skills, rather than on the academic or cognitive skills associated with the content

(Brinton, Snow, & Wesche, 1989; Snow, Met, & Genesee, 1989). All in all, the end result of content integration into both scenarios is that the language classroom becomes an environment where rich discussions occur, ultimately improving language fluency while reinforcing the content taught in many different academic areas.

It should be noted that past research efforts have also documented academic achievement related to language learning. For example, research has shown that children who have studied a foreign language during their elementary school experience, integrating language study across the curriculum, achieve expected gains and receive even higher scores on standardized tests in reading, English language arts, science, mathematics, social studies and geography, as well as show greater cognitive development in such areas as mental flexibility, creativity at solving complex problems, divergent thinking, and higher order thinking skills, when compared to monolingual children (Armstrong & Rogers, 1997; Bamford & Mizokawa, 1991; Genesee, 1979; Genesee, Holobow, Lambert, & Chartrand, 1989; Kennedy, 1998; McCaig, 1988; Rafferty, 1986; Swain, 1984). In addition, research has shown a difference of more than 250 points in average composite SAT scores (a set of standardized college entrance examinations used in the United States that assess student reasoning based on knowledge and skills developed by the student in past school coursework) between students that had no experiences studying foreign language and those who had five or more years (Cooper, 1987). It has been further reported that while four years of any particular subject increased SAT scores, four years of foreign language education specifically produced the highest verbal scores compared with four years work than any other subject. Other studies have also shown that individuals who are competent in more than one language outscore those who are speakers of only one language on tests of verbal and nonverbal intelligence (Bruck, Lambert, & Tucker, 1974; Hakuta, 1986; Weatherford, 1986). Combining language study with other subject areas not only increases academic performance, but it also allows students to see the connections between what they are studying and the world around them. In other words, content-based language learning provides students with a valid or meaningful reason for using the language they are learning.

GLOBE—A Model for Content-Based Language Teaching

One program that has been shown to successfully integrate academic content into the language classroom is the GLOBE Program[4] (Kelly, Kennedy, Eberhardt, & Austin, 2002; Kennedy, 1999, 2001, 2002, 2003, 2005, 2006; Kennedy & Canney, 2000; Kennedy & Henderson, 2003; Kennedy, Nelson, Odell, & Austin, 2000; Kennedy, Odell, Jenson & Austin, 1998). GLOBE (Global Learning and Observations to Benefit the Environment) is a hands-on, school and Internet-based science and education program that unites students, teachers, and scientists around the world in study and research about the dynamics of the Earth's environment. Since its inception in 1994, over 35,000 teachers representing over 100 countries around the world have attended professional development workshops to become certified GLOBE teachers. Currently over a million GLOBE students in more than 18,000 schools worldwide have taken important environmental measurements for use in their own research, also making their data, over 15 million measurements, available to scientists around the world.

The GLOBE program can bring virtually every classroom in a school together to work on a single project with other students and scientists on an international level. Although GLOBE's primary focus is science (through activities related to atmosphere and climate, hydrology, land cover biology, and soils), it also provides students studying an L2 with authentic opportunities to communicate in the languages they are studying since the science content provides a focal point around which oral language and literacy can develop through activities involving technology, math, geography, culture, art, music, and other discipline areas as well. GLOBE provides a variety of user-friendly data protocols, lesson plans and learning activities as well as technology applications that span across the PreK–12 curriculum. In the face of the dreary economic circumstances of many schools, GLOBE offers amazingly rich teaching resources, most of which are located online, keeping implementation costs to a minimum. The GLOBE Teacher's Guide, consisting of over 1,000 pages, has been translated in all six United Nations languages (Arabic, Chinese, English, French, Russian, and Spanish), and at least part of the GLOBE Teacher's Guide is available in Dutch, German, Greek, Hebrew, Japanese, Portuguese, and Thai, with many other materials becoming available in other languages through GLOBE's international partners.

Through GLOBE, students are provided access to GLOBEMail, an e-mail feature connecting them to their peers around the world for daily communication. Students also have opportunities to participate in Web chats and international student–teacher conferences (GLOBE Learning Expeditions) where they can meet face-to-face to practice their language skills while discussing relevant topics about the world around them.

Many other NASA education programs provide the opportunity for integrated language and content instruction, weaving interdisciplinary lessons in science, mathematics, social studies, language arts, and world cultures into everyday classroom teaching through extensive Web environments that naturally provide a rich context for genuine language usage. For example, current events surrounding the International Space Station provide students with unique, stimulating conversational topics that cross all areas of the curriculum. In addition, many NASA materials have been translated into numerous languages including Arabic, Catalan, Chinese, Czech, Danish, Dutch, French, German, Greek, Hebrew, Italian, Japanese, Korean, Malay, Portuguese, Russian, Spanish, and Thai. In fact, there are over 50 NASA Web sites that currently contain an eclectic collection of classroom resources available in many languages.[5]

Conclusion and Recommendations

Research activities related to the Decade of the Brain in the 1990s persist today through Brain Awareness Week,[6] continuing to communicate the progress and promise of neuroscience research. Implementing educational activities that take brain research, together with an understanding of the developmental process of the brain, into consideration promote active learning and maximize students' abilities to achieve across the curriculum. Brain-based learning through content-based foreign language teaching utilizes multiple teaching strategies, takes into consideration the different learning styles and intelligences represented in the classroom, and of course, follows the guidelines set forth by national as well as local standards in all areas of instruction. Teachers must employ curriculum design focused on high-powered, content-based lessons that truly keep the learners' brains in mind. The challenge ahead for teachers will be to incorporate brain-based activities framed around content-related topics into their classroom teaching, and of course, to promote programs that begin language learning as early as possible in a sequentially organized framework. After all, if the next generation of students are expected to be able to successfully communicate, regardless of the content area in which they choose to pursue after their K–12 experience, they must know "how, when, and why, to say what to whom" (National Standards, 1996, p. 11).

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Notes

1. The term *corpus* refers to the main portion of any anatomical part, structure, or organ. The *corpus callosum* is an arched mass of white matter, found in the depths of the longitudinal fissure of the brain. It is composed of three layers of fibers, the central layer consisting primarily of transverse fibers connecting the cerebral hemispheres. The subsections, from anterior to posterior, are called the rostrum, genu, trunk (truncus), and splenium. An extended definition can be found at http://en.wikipedia.org/wiki/Corpus_callosum.
2. *The Secret Life of the Brain,* a David Grubin Production, is a five-part series that initially aired in the United States on PBS in the winter of 2002. It revealed the processes involved in brain development across a lifetime and provided new information in the brain sciences from the foremost researchers in the field. See http://www.pbs.org/wnet/brain/3d/index.html for visual imagery that can help explain the complicated manner in which the brain functions.
3. For more information regarding the brain research discussed in this article as well as suggested activities associated with each of Gardner's Multiple Intelligences, refer to the following Web site: *Language Study and the Brain* (http://www.teresakennedy.com).
4. GLOBE is an interagency program funded by NASA (National Aeronautics and Space Administration of the U.S. government) and NSF (National Science Foundation), supported by the U.S. Department of State, and implemented through a cooperative agreement between NASA, the University Corporation for Atmospheric Research in Boulder, Colorado, and Colorado State University in Fort Collins, Colorado. GLOBE is NASA's premier international K–12 program, and all teachers and students in the United States can participate. Internationally, countries must sign bilateral agreements with the U.S. State Department and NASA before GLOBE activities can occur. All GLOBE activities are conducted under the guidance of GLOBE-trained teachers. The first step in becoming a GLOBE teacher in your school is to attend a training workshop in your state. Schedules for workshops and registration forms are available on the GLOBE Program homepage. To join GLOBE, go to http://www.globe.gov, click on the link to U.S. Partners on the navigation bar, then click on your state and contact the nearest partner to your school. For more details on The GLOBE Program see http://www.globe.gov.
5. For a complete listing of bilingual materials available from NASA and other science organizations see http://www.teresakennedy.com/NASALanguageMaterials1.htm.
6. *Brain Awareness Week* (BAW) consists of a series of events around the world typically held in March each year to increase public awareness about the brain. Go to http://web.sfn.org/baw/ for more information.

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