

Brain-based Learning: A Synthesis of Research



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Abstract

The purpose of this study was to synthesize research as it relates to brain-based learning and its relevance to the agricultural education profession. Through a comprehensive literature review, brain-based studies were analyzed to create a historical timeline of the discipline, investigate teaching principles, articulate relevance, and identify potential future implications for agricultural education. The holistic approach to learning in agricultural education programs presents a ripe environment for action research with brain-based learning practices. Professional development with agricultural educators may be needed to further encourage and support comprehensive studies that investigate the precepts of brain-based learning.

Introduction

Breathing, digesting, moving. The brain functions as the central component of the mind-body connection. Everyday musculature and mental functions occur without thought and without effort. A classroom may be viewed through a similar lens: students move, communicate, learn, and function in an enclosed system as a cohesive unit. Where such a comparison may diverge is in the analysis of the traditional perceived center of the classroom: the teacher.

Historically, the lecture course was necessitated as a precursor to the development of the printing press and the affordability of text materials (Yamane, 2006). With such limited availability, the professor became a dictator of books for students to copy down information, and was critical for learning to occur in medieval universities. Today, no such dynamic exists; however, teachers continue to conduct class as though they are the single point source from which all learning emanates, and those teachers fail to take full advantage

of the strengths, experiences, and abilities of the students. Brain-based learning encourages agricultural educators, and other subject matter educators, to capitalize on the associations the brain must make to create synaptic connections and anchor learning through contextual experience. While one may argue that all learning requires the brain as a basis for learning, brain-based learning, as a specific teaching and learning strategy, should be more carefully distinguished from conventional teaching and learning strategies.

Chipongian (n. d.) distinguished brain-based learning from conventional learning by making the argument that “there is a difference between ‘brain-compatible’ education, and ‘brain-antagonistic’ teaching practices and methods which can actually prevent learning” (p. 1). Even still, Chipongian concluded that “current neuroscience research does not yet fully and accurately explain why such real-life examples are effective. But, teaching, and a need for understanding how ‘the organ of learning’ works, is now linked as never before” (p. 1). As a result, educators should focus on devising “practical teaching methods that will complement the brain’s natural development” (Gura, 2005, p. 1156) by allowing people to learn through puzzling observations and hypothetico-deductive reasoning because this is believed to be the way that the brain spontaneously processes information (Lawson, 2006).

For decades, agricultural teachers have been encouraged to use a variety of teaching methods in their classrooms to enrich the learning environment in an effort to assist all students with varying learning styles to better learn and retain the subject matter. According to Newcomb, McCracken, Warmbrod, and Whittington, (2004) subject matter that is going to be taught will be learned more quickly if it has meaning, such as using real-world settings that are clear and evident to the learner.

Evers et al. (1998) posited that education should assist people in being able to solve problems, think

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critically, and be lifelong learners. In order for this to occur, teachers need to promote the use of higher order thinking skills. One way that agricultural educators can promote higher order thinking skills is through brain-based learning techniques.

The purpose of this study was to synthesize brain-based research and its relationship to agricultural education. The objectives were to review the research history of brain-based learning and its development; identify the teaching principles derived from brain-based research; determine the relevance of brain-based learning to agricultural education; and envisage the future of brain-based learning as it pertains to agricultural education.

The researchers who worked on this project were selected to participate in a professional growth experience known as OMEGA. This experience, sponsored in part by the National FFA Organization, began in September 2006 and concluded in June 2007. Group members were challenged with a wide range of year-long activities, one of which was to study a phenomenon impacting the agricultural education profession. To that end, these researchers were charged with reviewing the literature and synthesizing the research on the brain-based learning theory in relation to agricultural education. As such, the researchers conducted an extensive search of studies and scholarly writings (i.e., electronic databases such as Academic Search Premier, ERIC Documentation Service, and Google Scholar) pertaining to brain-based learning. Thirty-two studies and works of recognized brain-based theorists were identified, creating a portrait of brain-based learning and its relevance to agricultural education teaching practices and principles.

Upon completion of the synthesis of research, several findings emerged relating to the historical timeline of brain-based research, the teaching principles derived from brain-based research, the relevance of brain-based learning to agricultural education, and the future of brain-based learning as it pertains to agricultural education.

Historical Highlights

The connection between the brain and learning was established long before methods existed for testing the relationship. About 400 B.C., Hippocrates theorized the brain was involved with all sensation and was the seat of intelligence. Similarly, in 387 B.C., Plato taught that the brain was the place of mental process. In 280 B.C., Erasistratus of Chios noted divisions of the brain; and in 177 A.D., Galen gave his lecture, *On the Brain*, concluding that the brain was the source of an animal's soul (Chudler, 2007). These early philosophies framed the world's perceptions of the brain for centuries.

The term neurology was first used in 1681 by Thomas Willis. The field was advanced shortly thereafter with Humphrey Ridley's 1695 publication of *The Anatomy of the Brain* and John Locke's

1696 *Essay Concerning Human Understanding* (Chudler, 2007). Locke drew attention to the essential role that input from the senses plays in learning, and in this way connected neuroscience to study of the learning process (Magoun, 1969).

As the field of neurology grew, developments in psychology also brought new thoughts on learning. During the mid-1900s, John Watson and B. F. Skinner advanced the ideas of operant conditioning and "shaping" with the use of reward and punishment. This behavior reinforcement dominated thinking on learning, in part, because there were no means of knowing what truly occurred in the brain (Jensen, 1998).

Technological developments during the 20th century offered new opportunities for studying the brain. Early technology included the X-ray machine, invented in 1895; the EEG, developed for research in 1929; ultrasound technology, first used to examine the brain in 1956; and x-ray computed tomography (CT scan), developed in 1972 (Chudler, 2007). Devices more relevant for today's brain-based research include magnetic resonance imaging (MRI) machines and position emission tomography (PET) scanners, both of which originated in 1974 (Chudler). These new developments suddenly allowed researchers to study the brain while the subject was still alive. These "brain scanners" paved the way for a new interdisciplinary approach to questions about the brain called neuroscience (Jensen, 1998; Sousa, 2001).

As the brain scanners were being developed, researchers experimented on rats and investigated brain development through autopsies. They discovered that the brain grows through experience, and that enriched environmental stimulation fosters brain development (Bennett et al., 1964; Diamond et al., 1967). This early work was confirmed in later studies (Riout-Pedotti and Friedman, 2000), and the concept of brain enrichment remains a key theoretical component of brain-based learning today (Jensen, 1998; 2006)

During the 1970s, MacLean promoted his theory of the triune brain. He argued that "in the course of evolution we seem to have acquired a mind of three minds" (1978, p. 308). According to the theory, the brain is divided into three components: the Reptilian, Mammalian, and Neo-Cortex. The reptilian part of the brain attends to needs for physical survival and controls "flight or fight" responses. The mammalian part of the brain, encompassing the hippocampus and the amygdale, evokes emotion and stores memory. The neo-cortex is used for higher order thinking skills – synthesizing, logical and operational thinking, speech, and planning for the future (Caine and Caine, 1991; MacLean, 1978; Roberts, 2002).

In 1973, Bliss and Lømo reported their foundational discovery of long-term potentiation (LTP), which has since remained a popular subject of neuroscientific research. LTP is an increase in the chemical strength of a synapse that lasts from minutes to several days. Because changes in synaptic strength

are thought to underlie memory formation, LTP plays a critical role in behavioral learning. Cells change how they respond to messages based on how they responded at an earlier time. This means that each cell has a "memory" and every time it is stimulated by something familiar, it responds less actively. If it is stimulated by something new, it tends to become more efficient in carrying messages to other cells (Bliss and Lømo, 1973; Lømo, 2003; "Long-term potentiation," 2007).

The idea that the human brain is constantly changing can be traced back to research by Greenough and Volkmar (1973). Their research with rats reared in different milieus (complex, social, or isolated) demonstrated that complex environments resulted in increased branching of neuron dendrites. This malleability of the brain, or its susceptibility to change by the environment, is highest at the earliest ages and diminishes over time (Greenough and Volkmar, 1973; Jensen, 2006; Kolb and Whishaw, 1998).

Interest in the malleable brain led to new research on accelerated learning. In 1977, Walters compared the effects of accelerated learning among ninth grade vocational agriculture students. A control group was taught using traditional methods of lecture and a traditional amount of class time, while an experimental group met less than half of the traditional time, but was actively engaged in class participation. Post-tests in agribusiness achievement supported the efficiency of the experimental methods, finding no significant difference between scores of the two groups.

Brain research in the 1970s and 1980s brought with it hemispheric specialization and sparked popular interest in our "two-sided brain." The left hemisphere is generally believed to be the language center of the brain, engaging in information processing, while the right hemisphere is believed to be responsible for generalized concepts (Hardiman, 2003).

The science community's newfound emphasis on the brain prompted the 1990s to be themed "the decade of the brain" (Sousa, 2001). This declaration received widespread attention in the form of a presidential proclamation by U.S. President George Bush (Bush, 1990; Roberts, 2002). The decade included increased media attention toward brain research, including a Newsweek cover story entitled "Your Child's Brain" (Begley and Hager, 1996), and a Time Magazine special report on "How a child's brain develops" (1997). The publicity for brain research in the 1990s provided increased emphasis on questions about how the brain learns.

Research during the 1990s laid a stronger foundation for brain-based learning principles. LeDoux (1994) drew connections between emotions, memory, and the brain. Eden and colleagues (1996) reported that children learning to read

require activation of both the auditory and visual areas of their brains to create meaning. Schacter (1996) found that the brain stores real-life experiences differently than it does a fabricated story. These findings and others have slowly prompted changes in teaching methods.

During the "decade of the brain," Caine and Caine worked with schools to apply brain-based learning principles and to "change educators' mental models of teaching and learning" (1997, p. 240). After four years of work with two schools, they reported moderate success in helping teachers move from an information delivery approach to a more learner-centered approach. Based on efforts to progress the two schools toward higher-level learning, Caine and Caine surmised that "results can be influenced but not guaranteed" (p. 244).

As 21st century brain research further develops, additional findings with relevance for teaching and learning continue to amass. In many cases, technology is being used to explore the neurochemical differences among learning disabled adolescents (Richards et al., 2000). Meanwhile, experts on brain-based learning are promoting the use of action research by teachers in the field (Sousa, 2001).

Teaching Principles Connected to Brain-Based Learning

People learn information in a certain pattern within a specific context (Weiss, 2000). As such, when educators introduce new content, the focus should attempt to create a pattern and relate it to content students already know. Roberts (2002) concluded that "patterning refers to meaningful organization and categorization of information" (p. 282). A question of concern is how do educators provide meaningful learning experiences for their students in the classroom?

Thompson et al. (2003) suggested that meaningful learning occurs when faculty transition from a teacher-centered environment to a learner-centered environment. The authors stated that to become learner-centered, educators must develop students' understanding of course content by enriching the classroom environment to include physical, emotional, and social aspects, while adjusting the focal point of the classroom from teaching to learning. One method of creating such meaningful learning experiences for students is brain-based learning.

Brain-based learning has been referred to as accelerated learning, which Birkholz (2004) defined as "an educational delivery method and philosophy utilizing brain research to design optimal learning opportunities" (p. 1). The International Alliance for Learning (2003) identified 10 elements of accelerated learning: 1) knowledge about the human brain, 2) emotional state, 3) the learning environment, 4) the role of music and the arts, 5) personal motivation, 6) multiple intelligences and learning styles, 7) imagina-

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tion/metaphors, 8) suggestion, 9) team learning and cooperation, and 10) improvement and results.

Brain-based learning research consists of shifting from linear, hierarchical teaching toward complex, thematic, integrated activities (Caine and Caine, 1997; Howard, 2000) by focusing on flexible thinking instead of rote memorization (Langer, 1997). Caine and Caine (1991) stated that “brain research establishes and confirms that multiple complex and concrete experiences are essential for meaningful learning and teaching” (p. 5). Based on their research and experience, Caine et al. (2005) argued that great teaching involves three fundamental elements:

1. Relaxed alertness: Creating the optimal emotional climate for learning;
2. Orchestrated immersion in complex experience: Creating optimal opportunities for learning; and
3. Active processing of experience: Creating optimal ways to consolidate learning (p. 4-6).

In 1991, Caine and Caine summarized the theoretical foundations of brain-based learning into a set of 12 Brain / Mind Learning Principles. These principles are highlighted in Figure 1 and further operationalized in Figure 2.

Relevance of Brain-Based Learning to Agricultural Education

Brain-based learning affects agricultural education in many ways. The goal of most agricultural educators is for students to learn and retain subject matter and apply that knowledge as they progress further in college and/or careers. Teachers can accomplish this by better understanding how students learn and realizing each student may learn differently. When a student learns new material, the neurons in the brain connect together; thus, allowing the student to think through the activity, react to it, and function in varying situations (Kitchel and Torres, 2005).

Clearly then, agricultural educators can benefit from using brain-based learning techniques in their classrooms. Often in classroom and laboratory settings, agricultural teachers use patterning, meaning, emotion, and personal experiences to enhance student learning (Kitchel and Torres, 2005). These learning techniques are indicative of how brain-based learning is different from general learning.

Patterning refers to how teachers help students categorize subject matter content in their own minds and then make it meaningful, so they may retain it longer (Roberts, 2002). According to Weiss (2000), people pattern information in many different ways to learn. When new information is introduced in the classroom, teachers should attempt to pattern it back

to a context that is familiar to students. For example, if students learn they should always wear their safety glasses when working in the agricultural laboratory, and when working around hazardous materials, then they develop a pattern of always being aware of their environment.

Agricultural educators can also enhance student learning by making meaning out of what they are teaching. If the subject matter has meaning to the student, the retrieval process is improved and learning is permanent (Kitchel and Torres, 1995). Teachers need to be sure to use meaningful examples while teaching subject matter. A good example of this is how students prepare for FFA career development events. Perhaps when a student prepares a speech on the importance of keeping records in livestock management, the student

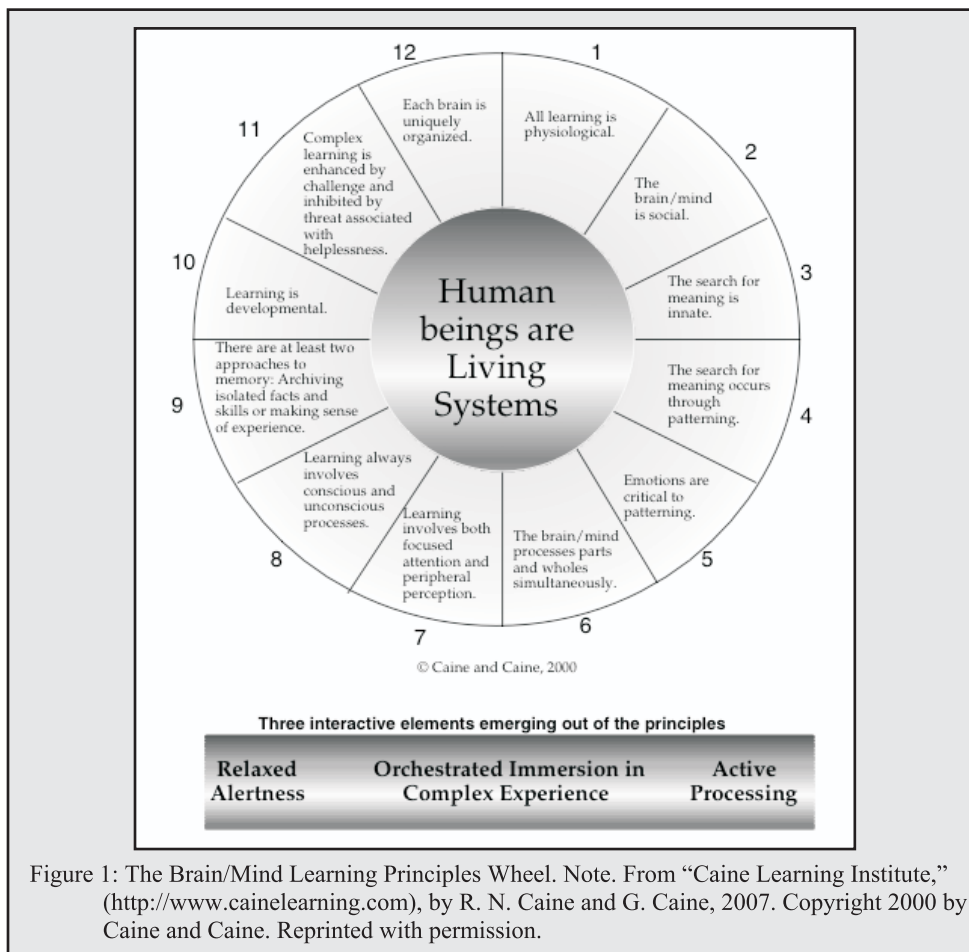


Figure 1: The Brain/Mind Learning Principles Wheel. Note. From “Caine Learning Institute,” (<http://www.cainelearning.com>), by R. N. Caine and G. Caine, 2007. Copyright 2000 by Caine and Caine. Reprinted with permission.

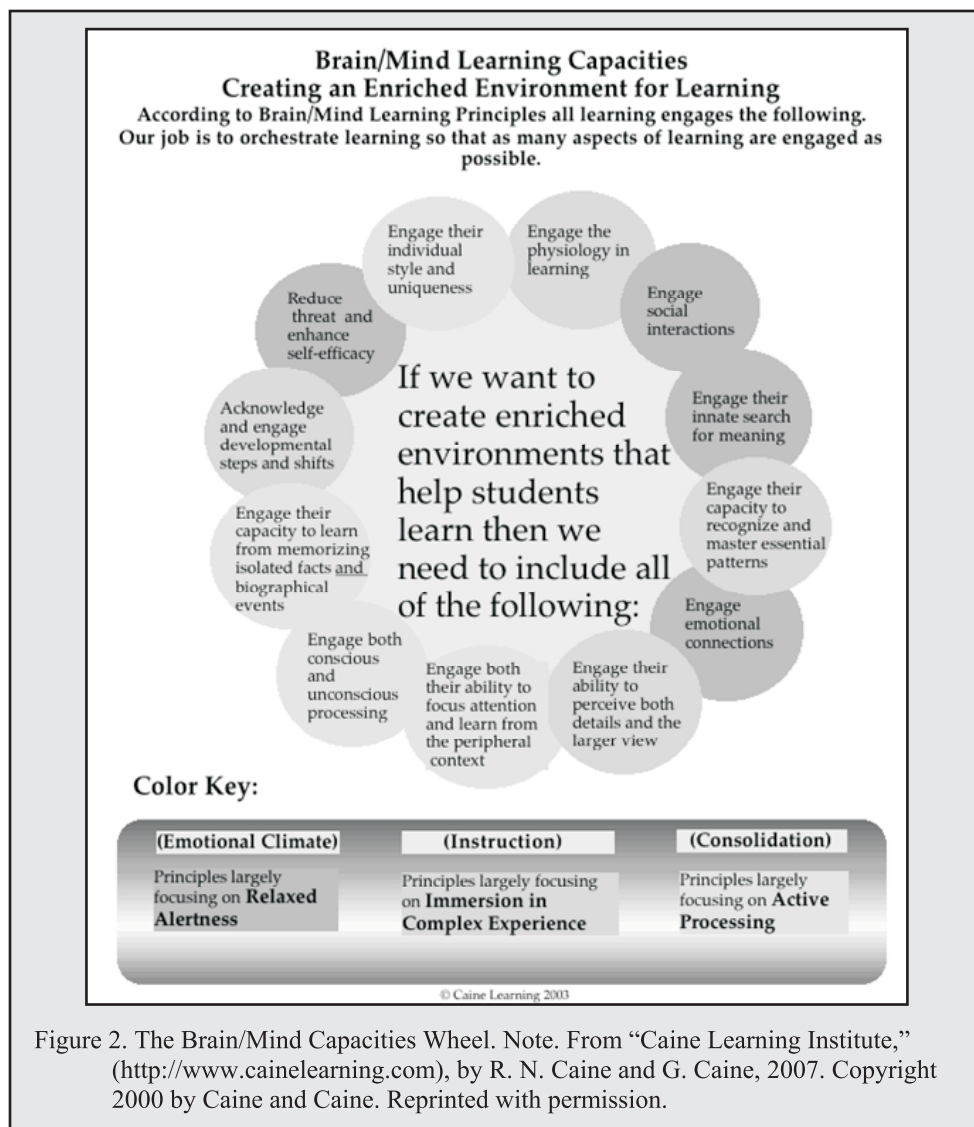


Figure 2. The Brain/Mind Capacities Wheel. Note. From “Caine Learning Institute,” (<http://www.cainelearning.com>), by R. N. Caine and G. Caine, 2007. Copyright 2000 by Caine and Caine. Reprinted with permission.

contain innovative strategies that cause students to become interested and motivated in subject matter (Kitchel and Torres, 2005).

Brain-based learning is evident in all major areas of secondary agricultural education: the classroom and laboratory, FFA events, and SAE activities. Essentially, these areas are impacted by causing students to think critically, solve problems, and provide in-depth and thoughtful answers to all sorts of questions. Agricultural educators must understand how the brain works to synthesize and break down information. Only then can they successfully help students learn in different ways. It is imperative that agricultural educators integrate brain-based and cognitive techniques as they learn more about the details of brain-based learning. It is exhilarating to observe students succeed because of any type of learning technique. However, as investigation into brain research continues, its importance is evident in agricultural education classrooms

may be able to define the various areas in which he or she has managed that are productive. However, if the student can also explain and synthesize the impact that keeping records has on productive management, then a rich and insightful learning activity has taken place.

Emotion is also an important component of brain-based learning and can have a huge impact on teaching and learning (Caulfield et al., 2000). Weiss (2000) noted that brain research shows that emotions and thought processes are deeply interconnected. Using positive emotion in the classroom allows the learner to retain subject matter content. In contrast, if the emotion is negative, the learning process may slow (Caulfield et al., 2000). Educators must learn to balance the amount and type of emotion used in the classroom. One way this may occur is through continuous work on building and maintaining positive relationships with students. By earning students' trust, a mutual positive relationship will occur between the students and teacher. Additionally, the agricultural educator should spend quality time preparing lessons that

because it helps students achieve at the highest level possible.

The Future of Brain-Based Learning in Agricultural Education

As history so often demonstrates, one must look back before looking ahead. The Storrs Agricultural School, established in 1881 in Mansfield, CT, was one of the first agricultural schools during the New Movement for Agriculture in Secondary Schools 1881-1900 (True, 1929). Fifteen-year-olds passing examinations in English, arithmetic, geography, and American history were admitted into the Storrs Agricultural School to “acquire dexterity” on the farm. This two-year program required students to work on the school farm for three hours a day in the fall and five hours in the spring, with “hands on training” in farming, horticulture, and mechanical arts, and the remainder of the day in a classroom (True, 1929). Students were responsible for learning practical skills, along with the understanding of the theories and concepts of agriculture and other academic subjects in the classroom.

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Although today's agricultural education curricula incorporate more than strictly production agriculture concepts, these programs still incorporate the model of classroom instruction and practical experience (Supervised Agricultural Experience), along with leadership development (FFA). By including the three integral components, the instructors employ the core principles of brain-based learning to holistically educate students (Talbert et al., 2007).

In essence, secondary agricultural educators teach using brain-based concepts, albeit sometimes unknowingly. The agricultural education model fits with the major tenets of brain-based learning: orchestrated immersion, relaxed alertness, and active processing (Caine et al., 2005). Through leadership development events (LDE), career development events (CDE), and supervised agricultural experiences (SAE), students experience orchestrated immersion, relaxed alertness, and active processing. LDE, CDE, and SAE are initially introduced in a classroom. Through the classroom setting, new information is introduced to the student. He or she then makes a connection between the newly presented information and previously stored information. Through creation of an orchestrated immersion environment, and by allowing students to make their own connections, a full experience of learning is provided.

The unique experiences in and outside of the classroom have the greatest impact on students' retention of information: field experiences, guest speakers, debates, skill-based tasks, and other sensory-based experiences. By assembling interactive, rich, and authentic instructional experiences, the LDE and SAE enable students' brains to process information. It is through these experiences that agricultural education enables students to have a personal, meaningful challenge.

Centuries of brain research have evolved from speculative theorization in the absence of medical or technological means to rudimentary rodent experimentation and post-mortem human brain exploration. Technological advances in medical equipment and renewed scientific interest garnered the ability to view neurological activity in the living brain, lending support for research into brain-based learning. Such investigations into neurochemical effects on learning and differences between individual learners are still in a relatively infantile stage, with much left to explore. Research of both quantitative and qualitative means are needed to further investigate the empirical nature of brain-based learning in the adolescent and post adolescent experience.

Meaningful learning occurs when new content is introduced in the context of the learner's experience. Rote memorization with the teacher serving as the point source for learning has been replaced with flexible thinking, and integration of complex,

thematic, student-centered teaching methods. Agricultural educators must take advantage of professional development opportunities that focus on the integration of brain-based learning concepts in the curricula.

The triune model of secondary agricultural education – classroom and laboratory, leadership development, and supervised agricultural experiences – preceded modern brain-based learning research by several decades. While brain-based learning research predicates a holistic engagement of students in the learning process, agricultural education has utilized the integral foundation upon which it was established to relate concepts of science, mathematics, language arts, social science, and fine arts through the context of agriculture. Moreover, reinforcement of those concepts and principles has further solidified through student application and participation in project-based experiences. Agricultural educators at both the secondary and collegiate level have been charged with the renewed task of educating students, parents, administrators, and fellow agricultural educators about the need to integrate all three of the components into the total, comprehensive agricultural education program, rather than placing greater emphasis on one or two components. Further, secondary agricultural educators must recognize that supervised agricultural experiences, as a context for teaching, must encompass the students' interest and experience, and not be limited to those traditional experiences within the expertise area of the teacher.

Most would argue that a student's brain is stimulated by the multi-faceted experiences, which are the cornerstone of agricultural education, but currently there is little empirical evidence to support that the agricultural education model of instruction definitively enhances learning. To that end, a gap in the scholarly body of knowledge exists as it pertains to brain-based learning and agricultural education. Further research is needed in a programmatic, comprehensive, longitudinal manner whereby the precepts of brain-based learning are studied in both experimental and qualitative venues to determine the empirical value of brain-based learning, as well as to investigate the individual differences of students taught in this manner. In doing so, as technology progresses, agricultural education may provide a stellar way to holistically promote brain activity and, in turn, learning.

Summary

Speculation and medical posthumous examination surrounding the brain and its functions permeate more than two thousand years of historical narratives. More recently, cognitive neuroscience and educational psychology investigations provide greater insight and expanded views of brain function and learner abilities. While rudimentary research once limited analyses of how people learned to a two-sided hemispheric framework, more recent research reveals a multidimen-

sional spectrum of multiple intelligences working together to anchor experiences for long-term retention. Agricultural educators are known for understanding this more complex approach to teaching and learning, and regularly seek to provide concrete experiences for students to more successfully embed learning through a kinesthetic approach.

Analyses of previous research indicate that secondary agricultural education has long utilized brain-based principles via teaching through the triadic approach to secondary level agricultural courses (Newcomb et al., 2004). To what extent, though, is this approach being continued and reinforced at the collegiate level? Faculty in colleges of agriculture may assume an andragogical approach to teaching, while their clientele may still be dependent on a pedagogical approach for their learning styles. If such a divergence exists, research should first seek to confirm the potential existence of this inhospitable environment, and then to inform and provide professional development to assist faculty in understanding the needs of their students.

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