NOTE TO USERS

DISSERTATION

BRAIN RESEARCH AND CLASSROOM PRACTICE: BRIDGING THE GAP BETWEEN THEORISTS AND PRACTITIONERS

Submitted by

Jean L. Radin

School of Education

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY JEAN L. RADIN ENTITLED BRAIN RESEARCH AND CLASSROOM PRACTICE: BRIDGING THE GAP BETWEEN THEORISTS AND PRACTITIONERS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Robert W. Richburg

Pat L. Sample

Barbara K. Wallner

James H. Cannning
Adviser

Co-Adviser

Director

ABSTRACT OF DISSERTATION

BRAIN RESEARCH AND CLASSROOM PRACTICE:

BRIDGING THE GAP BETWEEN THEORISTS AND PRACTITIONERS

The purpose of this qualitative study is to discover recommendations for best brain-compatible instructional characteristics from the current literature, and to investigate to what extent these characteristics are incorporated into teacher preparation programs and classroom practice by exemplary secondary teachers.

This study was conducted in two phases. Phase I involved interviews with ten educational theorists in the area of brain research to confirm, disconfirm or add to the principles of brain-compatible instructional characteristics that emerged from the review of literature. Three broad questions were asked of the theorists. Phase II involved interviews with six exemplary secondary teachers to determine to what extent they are aware of and integrating brain-compatible characteristics into their classroom practice. Nine questions that were aligned with the characteristics of brain-compatible teaching were asked of the teachers.

Six characteristics of brain-compatible teaching were identified from the review of literature and confirmed by the educational theorists. The six characteristics are: an enriched environment, the role of emotions, the lowering of stress and threat, the role of physical systems, challenging, relevant work and problem solving, and the role of experience. Two main themes emerged from the teacher interviews: characteristics of teaching process and teacher characteristics. Teacher preparation programs and

professional development were also examined. The study includes a Model of Brain-Compatible Teaching modified following each phase of the research. A description of a brain-compatible teacher is offered.

Findings indicate that, although the exemplary teachers could be labeled as "brain-compatible", a gap exists in their ability to articulate their successful techniques. Only one teacher had any kind of exposure to brain research as it connects to pedagogy. An enriched environment, consisting of the elements of emotion, lowered stress and threat, physical systems, experience, teacher characteristics, and relevant, inquiry-based work was identified as the key component in both exemplary classrooms and in teacher preparation programs.

This study provides a basis for future research that should determine ways to bridge the gap between theory and practice of brain-compatible teaching and learning. It provides direction for teacher preparation, classroom practice and professional development that connects brain research with educational theory and pedagogy.

Jean L. Radin
School of Education
Colorado State University
Fort Collins, Colorado
Spring 2005

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CHAPTER ONE

Introduction

Brain research continues to be at the leading edge of true educational change.
Vincent Ferrandino
Executive Director
National Association of Elementary School Principals

The brain has been aptly termed a "three-pound universe" (Hooper & Teresi, 1986). When one thinks of all the functions a brain performs; thinking, analyzing, storing memories, learning, coordinating multiple body systems, indeed even ensuring our basic survival, it does resemble a small universe. New findings from neuroscience are increasing our knowledge of this marvelous organ every year. Positron Emission Tomography (PET) scans, functional Magnetic Resonance Imaging (fMRI), electroencephalograms (EEG), Computerized Axial Tomography (CAT) scans, and other imaging techniques are bringing to light brain functions that were previously only perceived through explicit behaviors. We are now able to analyze the brain while its owner is living, instead of relying on the dissection of dead individuals' brains.

Behavior-based views, like those of B.F. Skinner, have greatly influenced how most educators teach. Instead of focusing on the cognitive mechanisms and processes of thought and learning, educators have chosen to attend to the visible, measurable manifestations of thought. Since the internal processes of the brain have been until recently unknowable, teaching has focused on the knowable external factors that can be manipulated: the environment and behaviors (Sylwester, 1995). Hence the behavior

modification and punishment/reward system was established in many classrooms and schools (Jensen, 1998, Caine & Caine, 1997).

Many teachers have a vast repertoire of teaching techniques but they don't all correlate with how the brain learns best. According to Schenck (2003), "More effective teaching is developed from old and new discoveries, if we as teachers are willing to grow and learn" (p. 9). Brain research is offering up new avenues of thought regarding teaching and learning. No longer are good teachers merely conveying information, facts and principles; they are in tune with how the brain functions and teach using brain-based instruction to increase student achievement and possibly their own job satisfaction. Learning the best way to learn has become as important as learning the subject matter (Sprenger, 1999).

The development and identification of brain-based teachers takes on new importance as education moves further into the Information Age. Educators need to build an adequate foundation grounded upon the principles of educational psychology, biology, neuroscience, and pedagogy to bridge the gap from the outdated Industrial Era model of schooling to the current Information Era model. It is no longer acceptable to remain with the traditional controlling, lecture-based, fact-gathering approaches to teaching, filling our students' "empty" brains with unrelated, nonrelevant information. However, it is difficult for teachers to relinquish control, power, and structure of their lessons and change their perceptions of teaching and learning (Caine & Caine, 1997).

Problem Statement and Context

Brain-based instructional reform is a tremendous challenge facing both public schools and institutions of higher learning. Ever since President George H. Bush declared the 1990s the Decade of the Brain, educators have struggled to interpret what current brain research may mean for teaching and learning. Proponents of brain-based reform are convinced that recent findings in neuroscience are applicable to the classroom, citing numerous studies and theoretical writings to advance their cause. Others are more cautious, carefully weighing both sides of the issue, trying to discern how one might apply research findings to educational settings. Critics of brain-based reforms state that it is still too early to jump on the brain-based bandwagon, and educators should stick to the tried and true methods of teaching and learning that have been proven successful over time. Others are indifferent toward neuroscientific research.

Berninger and Richards (2002), two professors on the cutting edge of current brain research, admonish educators to remember that "neural science does not yield teaching methods or procedures to impose on students in the classroom without taking into account a good deal of educational and psychological research on learning and teaching over the past century" (p. 6). Berninger and Richards state that further bi-directional research is needed, that is, research involving teacher-researcher partnerships.

To date, several brain-based research studies have explored such varied topics as: the brain-based classroom setting (Brown, Burch & Zellner, 2002), the impact of brain research on elementary instruction (Smith, 1999), the connection to literacy (Hoge, 2002), implications for educational practice (Foster-Deffenbaugh, 1998) and applications to

special education and learning-disabled children (Winters, 2001). Very few studies have examined the application of brain-based research and exemplary teachers.

University schools of education are challenged to prepare future teachers using "best practices". However, most schools of education do not offer courses in neurology or biology, but rather, in educational psychology (Sylwester, 2003). The educational psychology courses usually provide indirect information about how children learn (Jensen, 1998). Segall (2001) challenges teacher preparation programs with the following question:

> And how would the experience of learning to teach, and the experiences those learning to teach might provide their own students in the future, be different if teacher education moved toward a theoretical dialogue on practice that offers opportunities to rethink the nature of educational theory and practice? (p. 239.)

Smilkstein (2003) is concerned that some colleges of education do not educate future teachers about how the brain learns and how to teach to the way the brain naturally learns. Smilkstein also expresses concern that many education college faculty are not aware of brain-based learning. This lack of knowledge is compared to a cardiologist who "studies veins, arteries, and blood chemistry, but never learns how the heart works!" (Smilkstein, 2003, p. 21.)

Sylwester (1995) and Caine and Caine (1997) are concerned that persons preparing to become teachers may not have access to recent cognitive science findings. They echo Jensen's comments about the lack of neurological content in teacher preparation courses, and urge change.

Practicing teachers are often unaware of the research regarding how the brain learns best. Many teachers have intuitively taught in ways that "seemed right", incorporating group projects, multiple intelligences, and challenge into their lessons (Kovalik & Olsen,

1998a). There is a wealth of instructional strategies available to choose from which guide instruction, but busy teachers do not have the time and energy to study and research these strategies and methodologies to make informed choices. Marzano, Pickering and Pollock (2001) acknowledge that there are still many questions to answer to "help move teaching from an art to a science" (p. 9).

Purpose Statement

The purpose of this qualitative study is to discover recommendations for best brain-based instructional practices from the current literature, and to investigate to what extent these brain-based characteristics are incorporated into teacher preparation programs and classroom practice by public school exemplary teachers at the secondary level.

Research Questions

1. What are the most important brain-based teaching and learning characteristics to emerge from a review of current literature?
2. How will a panel of nationally known experts in the field of brain research view the emergent characteristics?
3. To what extent are exemplary secondary public school teachers aware of and integrating these brain-based instructional characteristics into classroom practice?

Definition of Terms

Brain-based instruction or brain-compatible instruction: Instruction based upon the function and structure of the brain. It is respectful of the brain's natural learning systems. (Greenleaf, 2003, p. 14).

Critical periods: Optimal or most beneficial times for the development of bodily skills and abilities. (Caine & Caine, 1997, p. 10).

Downshifting: The tendency under stress or threat to shift to a defensive mode and become less flexible and open to new information and ideas.

Enriched environment – An environment that has many positive elements to facilitate learning that includes visual climate, temperature, plants, aromas, music, problem-solving and social opportunities, and movement (Jensen, 2000).

Learning: The capacity of neurons to reach out to other neurons, enabling the brain to acquire a memory.

Limbic system: The amygdala, hippocampus, medial thalamus, nucleus accumbens, and basal forebrain, which all connect to the anterior cingulated gyrus, This system is where emotions are generated and connected to the prefrontal cortex. (Ratey, 2002, p. 227).

Memory: How and where the brain stores information.

Neural Darwinism: Neurons and neural circuits compete with other neuronal circuits for survival. The ones best adapted to the environment survive. (Edelman, in Ratey, 2002, p. 31).

Neural pruning : Programmed elimination of neural development mistakes.

Neuroscience: The study of the human nervous system, the brain, the biological basis of consciousness, perception, memory, and learning.

Plasticity: The functional organization and reorganization of the brain and its structures that occur through learning. (Smilkstein, 2003, p. 78).

Relaxed alertness: An optimal state of mind consisting of low threat and high challenge (Caine & Caine, 1997, p. 32).

Windows of opportunity: Critical periods when the brain demands certain types of input to create or consolidate neural networks.

Delimitations

This study will be confined to interviewing, via electronic mail, telephone, or personal face-to-face interviews, a panel of 8 to 10 experts in the field of brain-compatible instruction. Responses will be based on the important themes of brain-based instruction that emerge from the literature. The experts will be invited to express their views about the brain-based themes. In addition, interviews will be conducted with a selected number of identified exemplary public school teachers in a northern Colorado school district.

Significance of the Study

Examining the integration of brain-based research into teacher education and teacher practice will be beneficial in a variety of ways. This research will add to the body of knowledge related to the effectiveness of teacher educator programs. A main component of virtually every teacher education program is coursework in pedagogy. However, the essential content regarding teaching and learning varies tremendously from university to university, even from instructor to instructor. The profession has not determined a core body of knowledge that all preservice teachers need to know. A resolution passed by the American Federation of Teachers in July 2000 notes, "it is vital that we identify what science tells us about how people learn in order to improve the teacher education curriculum" (American Federation of Teachers, 2000, p.3). They further recommend that colleges adopt a rigorous core curriculum in pedagogy based on the best research into how students learn. The essential findings validated by the panel of brain experts will help undergird the core curriculum.

As states currently require public school students to demonstrate proficiency on high stakes competency tests, the preparation of today's teachers becomes ever more important. Section 1119 of the No Child Left Behind Act, 2001 mandates a "highly qualified" teacher in every classroom. Recent findings indicate that teacher quality is the single most important school variable affecting student achievement (Darling-Hammond, 1997). Further research into the effectiveness of teacher preparation programs is advocated by several studies (Bratlein & McGuire, 2002, Education Commission of the States, 2003, John, Norton & Burns, 1999).

This research has potential significance in three main areas: educational practice, teacher preparation effectiveness, and future research. According to a recent workshop held in Denver, 1996 called "Bridging the Gap Between Neuroscience and Education", the brain matters in many contexts. It matters for educators, so they can "find ways to enrich the school experience for all children – the gifted, the creative, the learning disabled, the dyslexic, the "average" student, and all the children whose capabilities are not captured by IQ or other conventional measures" (Education Commission of the States & The Charles A. Dana Foundation, 1996).

This study will provide answers in context to questions regarding the extent of awareness and practice of brain-compatible instruction in public schools. By conducting on-site interviews with practicing professionals who have been identified as excellent teachers, this qualitative study will seek to discover possible gaps in pedagogical knowledge. The knowledge of gaps gained from this study will be used as feedback for university teacher preparation programs and continuing education and/or professional development of today's educators.

Researcher's Perspective

As a former public school secondary teacher for over twenty years, I have always been interested in teaching and learning. During my initial years of teaching, I was very focused on my academic content. As I became more comfortable within my profession, I began to spend more time observing and interacting with the students, in essence teaching the "whole child". I consciously strived to build a learning community in each of my classes, and began to integrate more hands-on activities, artwork, music, movement, projects, and drama into my foreign language teaching. I noticed how students engaged

and achieved more when these kinds of activities were included in the lessons, and wondered why these strategies were successful.

It wasn't until I began my recent graduate work that I became fascinated by a new topic: the workings of the brain, brain research, and how this relatively new body of research can be applied to teaching and learning. Added to the mix have been opportunities for me to teach in a university teacher licensure program. It has been an interesting journey. Now the paths of pedagogy, student interaction, teaching future teachers and brain research have all merged into a new body of knowledge to study: brain-compatible education. For me it is comparable to finally putting the cart behind the horse. I intuitively knew, as most competent teachers do, which activities and methods worked best in the classroom, but I didn't know why. The following quote from Kovalik and Olsen (1998b) summarizes how I feel: "...while current brain research findings may amaze us, at a deep level they do not surprise us. They agree with our best intuitions and experiences, both as learners and teachers" (p. 32). I have since become passionate about learning more about the brain and disseminating what I know to my colleagues and students, while ever increasing my own knowledge base.

I hope to contribute my "grain of sand" to the academic sand dune through this study. I am interested in discovering the extent of awareness and application of brain-compatible instructional principles or characteristics used by today's public school teachers. A qualitative design will fit my personal strengths, which include working with others, sharing stories, and building relationships. .

CHAPTER TWO

Overview of Literature Review

The purpose of the study was to explore the characteristics of brain-based instruction and to determine if these characteristics are integrated into teacher preparation programs and classroom instruction by identified exemplary teachers. The purpose of Chapter Two is to provide a review of the literature that examines both brain-based learning strategies and teacher preparation programs. This review of research focuses on three areas. First, this review looks at brain growth and anatomy, focusing on the connections between brain plasticity and learning. Next, the review examines the roles of emotions, movement, stress and threat, enriched environments, and problem solving in learning. Finally, a picture of what a brain-compatible teacher would look like is presented. A discussion of brain-based research focusing on brain anatomy, teacher traits, animal and human research and applications to teacher preparation is offered as a rationale for conducting this study.

Understanding the Brain

Brain Maturation in Children and Adolescents

For decades, scientists have maintained that the brain is hard-wired from the time the physical connections in infancy and childhood were completed (Ratey, 2002). This meant that once neural connections were fixed; neurons could certainly die, but they could not regenerate or strengthen. Recent studies in neural plasticity have amended this concept. We now know that genes and environment interact to constantly change the brain, from conception to adulthood. Genes control the "broad outlines" of the brain's

development, while the interaction and brain and its environment sharpens the brain's functions (Ratey, 2002).

Human brain development begins soon after fertilization. By the eighth week of pregnancy, the brain has developed its three parts (Diamond & Hopson, 1998). Brain organization is determined by the migration of brain cells, or neurons, to specific sites on the developing brain. Where the neurons migrate to and how they connect with each other organizes the brain's architecture. As recently as the 1980s scientists believed that the adult brain was predetermined by the location and function of fetal brain cells. The key to a normal functioning brain is *proper* migration. Problems that may interfere with proper migration include: hormones, growth factors, cell adhesion molecules and substances in the mother's blood (Ratey, 2002). Beginning around seven months, neural pruning takes place, pruning that consists of programmed elimination of developmental mistakes. Approximately 50 percent of the neurons in the cerebral cortex are eliminated before birth, and up to 40 percent of the synaptic connections by the age of 21 months (Diamond & Hopson, 1998). Pruning continues into early adolescence.

As the child matures, he or she goes through periods of development that depend on extensive neural connecting and pruning called *critical periods* (Diamond & Hopson, 1998). Epstein (2001) states that there are small brain growth stages within in the first year of life, but the first big spurt occurs between three and ten months. From ten months to two years constitutes a period of relatively slow brain growth. In this stage the child practices its repertoire of actions and controls.

The next critical period is from two to four years, which includes the main maturation of senses, especially vision. Again, a slow period occurs between four to six years.

Around six years of age, a child undergoes another period of rapid brain growth where mental and sensorimotor functions become associated. Another slow period occurs between ages eight and ten years. Starting around ten years, the next rapid stage of brain growth happens which initiates the onset of abstract reasoning. Following a slow period between twelve to fourteen years, a significant stage of growth occurs from fourteen to sixteen years. During this time the brain improves in two areas of cognitive function: making connections between previously unconnected concrete reasonings, or it can start to create networks of associated abstract reasonings (Epstein, 2001). Studies indicate that during this time period male brains typically undergo more changes than female brains, and often males begin to excel in mathematics at this stage. Researchers Hudspeth and Pribram (1990) found indications of another critical period of brain growth between eighteen and twenty years. Fischer and Rose (1998) refer to these periods as growth cycles and connect behavior with brain changes. The critical periods or cycles appear to present a wave-like image.

Researchers are discovering that the adolescent brain is a work in progress. Jay Giedd (Frontline, 2002), a neuroscientist at the National Institute of Mental Health, postulates that there is a peak buildup of gray matter, or thinking part of the brain, at puberty. In the frontal part of the brain, the part in involved in judgment, organization, planning and strategizing, appears to thicken substantially around ages 11-12 and then is gradually thinned or pruned. Giedd asserts that this is a critical time for building capacities and skills in many different areas.

Using MRI scans, Gogtay, Giedd, Lusk et al. (2004) report that human cortical gray matter development proceeds in a parietal-to-frontal (back-to-front) direction. Higher-

order association areas mature only after lower-order sensorimotor regions. They state that the order of maturation proceeds in this order: 1) motor and sensory areas, 2) spatial orientation, speech and language development, and attention, 3) executive functions and motor coordination. This team of researchers conducted a longitudinal study of 13 children, aged 4-21 for whom anatomic brain MRI scans were obtained every two years. Their findings may have implications for educators who deal with autistic or schizophrenic students, as well as students with other neurodevelopmental disorders, and even "normal" adolescents.

Brain Anatomy

In order to understand the brain, comparisons are often made to a computer. Gerald Edelman (1992), Nobel Prize laureate in chemistry, disputes this comparison, claiming that this comparison biases our thinking towards a filing system. This model also discounts the role that emotions play in regulating brain activity, plus the parallel, nonlinear processing that occurs in the brain. Edelman (1992) suggests instead that one consider the brain as the complex, layered environment of a jungle. A jungle model assumes no external developer, no predetermined goals. Unlike a computer, a jungle environment selects from among the built-in options available instead of modifying or instructing the competing components

The three-pound jungle-like brain is composed of two kinds of cells: glial cells and neurons. Glia support and nourish the neurons by controlling the metabolism and function of the neurons, and by coating axons with myelin, a fatty substance that improves conduction (Ratey, 2002). Glia also regulate the immune system and remove dead cells. The neuron is the functional and anatomical unit of the brain's nervous system

(Gatz, 1970). Neurons consist of a cell body, spiny growths called dendrites and long fibers called axons. The human brain contains about 100 billion neurons, and each one can connect with 5,000 to 20,000 other neurons. Neurons are vital for performing the brain's work, as they are responsible for processing information and for converting electrical and chemical signals back and forth between other neurons. Neurons are continuously firing, generating and integrating information (Jensen, 1998, Sprenger, 1999). However, cells are lost every day due to decay, disuse, and attrition. Learning occurs when groups of neurons fire, connect, and pass on information.

The bulk of the neurons are in a thin outer layer called the cortex, or "bark". Our large cortex has many regions specialized for particular functions, such as word and object association, reasoning, and memories. According to Ratey (2002), the cortex is what distinguishes us from lesser animals and makes us human.

The brain is divided into four general lobes: occipital, frontal, parietal and temporal. The occipital lobe, located in the middle back of the brain, is primarily responsible for vision. The frontal lobe, located in the forehead area, is involved with judgment, planning, creativity, problem solving, as well as some motor control functions, portions of working memory, personality and expressing our consciousness. Functions of the parietal lobe, located on the top back area of the brain, include processing sensory information detected by touch, temperature, pain and position of the limbs, also language. (Schenck, 2003). The temporal lobes, located on either side of the brain, are involved with processing word meanings and emotions.

Nerve tissues called the corpus callosum join the right and left hemispheres of the brain, shuttling information back and forth between the two parts. Each side of the brain

processes differently, and many earlier assumptions about left/right brain dominance are now out of date (Jensen, 1998, 2000, Schenk, 2003). The areas beneath the corpus callosum make up the limbic system: the thalamus, hypothalamus, hippocampus and amygdala. The limbic system is responsible for many emotional responses, attention, and memory storage.

The brain stem, often referred to as the reptilian brain since it resembles the complete brain of a reptile, is where basic body functions are monitored and controlled (Sousa, 2001). Digestion, heartbeat, respiration and body temperature are regulated in the brain stem.

Other important brain structures include the sensory cortex, which monitors the skin receptors, and the motor cortex, which is needed for movement. Both of these structures are located across the top middle of the brain, and resemble narrow bands. Another area of the brain associated with motor movement, balance and posture is the cerebellum, which is located in the back lower part of the brain. Recent research indicates that the cerebellum or "little brain" has a role to play in connecting motor learning and long-term memory (Jensen, 1998).

Learning and Connections

Learning is a process of building neural networks (Wolfe, 2001). When a neuron is stimulated by incoming sensory stimuli, nerve impulses travel down the axon to the synapse, where neurotransmitter chemicals are released. These chemicals travel across the synapse terminal to the next neural dendrite. A series of electrochemical reactions causes the second neuron to fire or produce a signal, which in turn may cause more receptor sites on other neurons to fire as well. During the process of firing, dendritic

branching occurs when the environment is enriched (Jensen, 1998). If the pattern is repeated through practice or rehearsal, the neuron group tends to fire together and form a network (Sousa, 2001). Long term potentiation (LTP) refers to the process of synaptic awareness and sensitivity where different combinations of chemicals can generate changes in the number of receptor sites. Memory is formed here, in small components called *engrams* (Sousa, 2001). Engrams combine to form neural networks, and hence learning and memory systems are constructed.

Contrary to popular belief, it is not the size of the brain that dictates intelligence, it is the number of connections between brain cells that is key. Each of the 100 billion neurons has the capacity to connect with thousands of other neurons, causing what Diamond and Hopson (1998) label "neural forests." Ratey (2002) states that there are "more possible ways to connect the brain's neurons than there are atoms in the universe" (p. 20).

Interactions with the environment stimulate dendritic growth (Caine & Caine, 1991, Jensen, 1998, Diamond, 1967). Humans learn through experimentation, exploration and thought. Stimulation, repetition, novelty and challenge all promote brain growth. Brain plasticity, or the ability to change the structure of the brain, is the result of genetics, experience and the environment. If connections are not used or practiced, or the brain is not stimulated, neural pruning occurs. The implications for education are enormous, as educators seek ways to teach in a brain-compatible manner.

Other chemicals in the brain such as serotonin, dopamine, and noradrenaline can affect learning, memory and behavior (Jensen, 1998). Behavior manifestations of these brain chemicals can include stress, attention, and drowsiness.

The Role of Emotions

"No one is born with a cognitive interest in anything" (Leamnson, 2000, p. 38). Keeping this in mind, educators are challenged to design instruction that engages student interest and emotion. The brain resists having meaningless, non-contextual information and facts imposed on it. Fear and pleasure are the two emotions for which researchers have found specific brain sites.

We now know that the different modules of the brain are in communication with one another. Emotion regulators in the brain include the brain stem, the limbic system and the cerebral cortex (Sylwester, 1994, LeDoux, 1996). The brain stem, which monitors involuntary activity, keeps the brain at a general level of attention by filtering incoming sensory information. The limbic system, associated with emotion and memory processing, is linked to several other modules, including the frontal lobes in the cerebral cortex. Sylwester (1994) notes that the limbic system "is powerful enough to override both rational thought and innate brain stem response patterns. In short, we tend to follow our feelings" (p. 63). The frontal lobes are the part of the brain that organizes, monitors and prioritizes what the brain will pay attention to. They also are important in the regulation of the body's emotional states and judgments, even to the extent that they can override undesired and automatic behaviors (Sylwester, 1994).

Understandings are emerging about the role of messenger molecules in the body known as peptides. Peptides are distributed throughout the brain and body, and exert a tremendous influence on human behavior (Jensen, 1998, Sylwester, 1994). They travel throughout our body and brain in the neural networks, circulatory system and air

passages, providing a link between mind and body. Carried in the messenger molecules are feelings, including worry, anticipation, frustration, cynicism and optimism (Jensen, 1998). Kovalik and Olsen (1998a) refer to feelings and emotions as the "gatekeepers" to learning, and assert that learning is a "bodymind" activity. Jensen (1998) concurs, adding that "emotions affect student behavior because they create distinct, mind-body states" (p. 75). Damasio (1994) adds that the body and brain form an "indissociable organism" which he compares to a brain-body partnership (p. 88).

The implications of current research on emotions in classrooms are still being debated, but general themes have emerged. Leamnson (2000) asserts that the difficult part of teaching is inspiring students to have a level of emotional involvement with the content. As a first step in learning, Leamnson (2000) connects students' engagement and pleasure in learning with teacher effectiveness, citing pleasure as a biological process. He provides a neural explanation for learning being enhanced or speeded up as a result of emotional engagement. Sylwester asserts that "emotion drives attention, which drives learning and memory" (Sylwester in Brandt, 1997, p. 17). Jensen advocates embracing emotions in the learning process, not avoiding them. He cautions that the emotions triggered must not be extreme, but appropriately "middle ground" (Jensen, 1998, p. 78). Schenck (2003) advocates connecting sense-making with personal meaning-making in order for students to recall information. Wolfe (2001) encourages educators to understand the biological basis of emotion to "provide emotionally healthy and exciting school environments that promote optimal learning" (p. 111). Sylwester (1995) concurs, and voices concerns about schools claims to educate the "whole student", when in reality, schools focus primarily on developing measurable, rational qualities. Goleman (1995)

cautions against ignoring the role of emotions in learning, citing students' emotional quotient as a stronger predictor of happiness and success in life than a person's intelligence quotient. Emotions in learning are an important factor in determining the goals students set for themselves, the things they choose to attend to, and even their depth of processing (Byrnes, 2001).

Teachers play a crucial role in nourishing the emotional health of their classrooms, not only the lessons to be taught. Given (2002) and Smilkstein (2003) advocate creating an environment of acceptance, encouragement and support in the classroom where the teacher serves as a mentor or guide. Making the classroom an emotionally safe place to be in turn creates a desire or maybe even a passion for learning. This concept of an emotionally safe environment is linked to other emergent principles of brain-based instruction; namely an enriched environment, issues of stress, and relevance of problem solving in instruction.

Recommendations from the literature regarding integrating emotions into teaching include:

1. Make learning joyful by incorporating games, music, drama, storytelling and simulations (Sylwester, 1995, Sylwester, 1994, Given, 2002, Jensen, 1998, Schenck, 2003, Wolfe, 2001, Sousa, 2001, Rieber, Smith & Noah, 1998).
2. Celebrate achievements with acknowledgements and fun (Jensen, 1998)
3. Incorporate physical rituals into classroom routine (Jensen, 1998, Roberts, 2002).
4. Help students make personal connections to their work through journals, discussions, sharing, stories and reflection. Provide opportunities for

metacognitive and self-regulatory activities (Given, 2002, Sylwester, 1994, Smilkstein, 2001, Jensen, 1998, Schenck, 2003, Sylwester, 1995, Sousa, 2001).

5. Promote a positive classroom climate by modeling enthusiasm and passion and by guiding and mentoring students in supportive ways (Given, 2002, Kovalik & Olsen, 1998b, Smilkstein, 2001, Greenleaf, 1999, Jensen, 1998, Schenck, 2003, Erlauer, 2003).

The Role of Stress and Threat

Directly related to the role of emotions in learning is the role of stress and threat. Biologically, when fearful sensory input enters the brain, the autonomic system and stress hormones are activated. The thalamus relays immediate input to the amygdala, the emotional center of the brain. Depending upon whether the amygdala perceives the incoming stimuli as threatening or not, signals are sent to the cortex to deal with the threat rationally, or the amygdala bypasses the cortex to deal with the threat in a "knee jerk" reaction (Ratey, 2002). During this process the release of adrenaline, vasopressin and cortisol are released throughout the body, causing changes in the way we think, feel and act.

A typical biochemical response to a perceived threat, whether physical, environmental, academic, or emotional, is the "fight, freeze, or flee" response (Jensen, 1998). The brain may downshift to lower order thinking. This response manifests itself in various ways as the brain tries to ensure the body's survival. Physiological changes include increased metabolism of fat and glucose, dilation of pupils, constriction of heart arteries, relaxation of the bronchial tube, modification of blood chemistry, and slowed digestion (Erlauer, 2003). Threats that are not alleviated can lead to a situation termed

chronic stress. Behavioral manifestations may include withdrawal, violence, aggressive behaviors, or the reverse: increased attention and engagement (Jensen, 1998). Eustress, the condition of heightened challenge and stress, can "invite an up-shift response into higher order thinking skills in the neo-cortex" (Roberts, 2002, p. 283).

On the list of possible student threats and stressors are such issues as home life, personal relationships, harassment, bullying and abuse, and health concerns. School-related stressors are often perceived as non-caring teachers, teasing and sarcasm, homework deadlines, peer pressure, school violence, the potential for humiliation or embarrassment, and feelings of inferiority (Jensen, 1998, Erlauer, 2003). The key word is *perception*, as adolescents are often unable to correctly identify facial expressions associated with fear or threat (Yurgelun-Todd, 2002). The consequences of unrelieved chronic stress include impairment of memory and reasoning skills, increased susceptibility to illness, elevated blood pressure, even shrinkage of the hippocampus (Lupien, 1998). When students are expected to learn in a threatening or stressful setting, learning may be inhibited and narrowed (Jensen, 1998). The results can be a state of helplessness, wherein students become less aware of their surroundings and contexts, and turn inwards to protect themselves from further threat (Caine & Caine, 1991).

In order to address the stress/threat balance, teachers should emphasize relationship building, both peer-peer and teacher-student (Roberts, 2002, Erlauer, 2003, Jensen, 1998). Stress management techniques such as deep breathing, time management, relationship skills and exercise are also recommended (Jensen, 1998). Setting clear expectations through the use of rituals, rules or agreements, and rubrics do much to alleviate students' stress (Erlauer, 2003)

Recommendations from the literature regarding the role of threat and stress in the classroom include:

1. Strive for an atmosphere of *relaxed alertness*, that is, a climate high in challenge and low in threat (Smilkstein, 2001, Jensen, 1998).
2. Build relationships and a sense of community in the classroom and school-wide (Kovalik & Olsen, 1998b, Jensen, 1998, Roberts, 2002, Erlauer, 2003, Smilkstein, 2003)
3. Empower students to set their own realistic goals. (Sylwester, 1994, Kovalik & Olsen, 1998a, Jensen, 1998, Slavkin, 2002, Smilkstein, 2003)
4. Employ stress management techniques in class and teach students how to use them. (Sylwester, 1994, Jensen, 1998, Erlauer, 2003)
5. Establish behavior guidelines for the class that incorporate intrinsic rewards. Teachers should model behaviors and values expected from the students at all times (Kovalik & Olsen, 1998b, Erlauer, 2003).

The Role of Movement

Over half of the brain's neurons are located in the cerebellum, a part of the brain that deals with movement and novelty (Greenleaf, 1999). Other components of the physical learning system are the motor cortex, a strip across the top of the head, and the vestibular system in the inner ear. The inner ear stimulates the reticular activating system, an area of the brain that regulates incoming sensory data and is important for paying attention. All of these brain parts convey messages to the neocortex, the thinking area of the brain (Given, 2000). Thus, the interactions of these areas convert thought into action, indicating that movement plays a role in learning. According to Jensen (1998),

"movement and learning have constant interplay" (p. 84). Sousa (2001) concurs, stating "movement is inescapably linked to learning" (p. 230). Gardner (1999) writes, "I believe in action and activity. The brain learns best and retains most when the organism is actively involved in exploring physical sites and materials and asking questions to which it actually craves answers" (p. 82).

Greenleaf (2003) describes the role of movement in learning into three bottom-to-top experiential systems. The bottom system, or gross motor system, is comprised of the toe, foot and leg. The middle section, the fine motor system, includes the finger, hand, and arm. The neck and head make up the top system, the aural motor system. Greenleaf (2003) states that the integration of learning with movement in one or more these bodily areas is "as or more neurally intricate than any other form of learning" (p. 17).

Linking motor skills to learning has different connotations. It does not mean learning new content area and a new motor skill simultaneously. The brain functions best when it can attend to one skill at a time, and in context (Ratey, 2002). The movement, whether gross or fine motor, produces best results when it accompanies learning in an integrated way. Leamnson (2000) suggests pairing physical activities with problem-solving tasks to connect the acting (motor cortex) and thinking (frontal cortex). These kinds of integrated activities increase memory and learning and contribute to brain plasticity.

Other benefits of incorporating movement into the classroom include: improved circulation which often leads to increased performance, better spatial learning, and an increase in energy levels which improves storage and retrieval of information (Jensen, 2000). Research has also shown that more gifted students and low achievers prefer to learn new information through tactile and kinesthetic engagement (Milgram, Dunn &

Price, 1993, Dunn, 1990). Longitudinal studies by Palmer (1980) have documented the beneficial effects of early motor stimulation on early neural growth. Students who participated in Palmer's "Chance to Learn Project" in Minneapolis exhibited positive effects on the Metropolitan Readiness Test, Test of Visual Perception, and the Otis Group Intelligence Test.

While students perceive sedentary learning as essentially boring, educators now know that sedentary learning goes beyond boring to actually hindering learning. Fatigue, lack of concentration, pressure on the spine from prolonged sitting, restlessness and discipline problems can all result from a lack of movement in the classroom (Jensen, 2000). The admonition to "sit down and be quiet" is not compatible with the brain's desire for interaction, involvement, proximity and procedures (Greenleaf, 2003). If students are not allowed to engage physically with their learning, they will find ways to move that may not be acceptable in the classroom.

Recommendations from the literature regarding the use of movement in the classroom include:

1. Incorporate movement with spatial learning by teaching from different areas of the room, or by having students sit or stand in specific locations for specific learning. This can provide more vivid memory triggers (Jensen, 1998, Greenleaf, 2003).
2. Provide opportunities for frequent movement throughout the school day or class period. These can include active lessons, standing, and stretching exercises (Jensen, 1998, Schenck, 2003, Greenleaf, 2003, Sousa, 2001).
3. Link learning with gross or fine motor movements: clapping, snapping fingers,

stomping feet, crossing legs, pointing, standing, sitting, and demonstrating concepts kinesthetically (Greenleaf, 1999, Greenleaf, 2003, Jensen, 1998, Schenck, 2003, Sousa, 2001).

4. Incorporate active competitive or non-competitive games and activities that reinforce classroom concepts. Examples include charades, races, clapping games, simulations and role plays, among others (Given, 2002, Sylwester, 1994, Jensen, 1998, Schenck, 2003).

The Role of an Enriched Environment

Using Edelman's (1992) metaphor of the brain as a jungle, researchers have explored the value of an enriched environment to promote student achievement. In order to promote dendritic growth, the brain requires stimulation, novelty and problem solving opportunities. Many typical classroom strategies insist on veridical answers and singular approaches instead of encouraging creative insights, multifaceted answers and alternative thinking (Jensen, 1998, Sylwester, 1995). An environment that has mostly predictable or repetitive stimuli fosters boredom in the brain, making it turn inward for new and novel stimuli (Sousa, 2001). Hence, student achievement is not advanced and often discipline problems arise due to lack of stimulation. Slavkin (2002) states: "Failure to produce stimulating learning environments and take advantage of students' interests and knowledge are likely to result in passive memorization, weak pedagogical practices, and limited learning" (p. 22). Creating an enriched environment through new learning experiences and challenges is vital to brain growth.

Diamond's (1988) work with rat cortices in the 1960s is considered to be a seminal study of the importance of environments. Rats from the same litter were randomly

assigned to either an "impoverished" environment consisting of a toyless cage with no other rats, or an "enriched" environment consisting of a toy-filled cage with many other rats. The enriched environment included other stimuli including: colored panels around the cage, music, natural lighting, a comfortable temperature, and occasional rearrangement of the toys to foster problem solving. After 80 days the rats' brains were dissected and Diamond found that the rats from the enriched environment had thicker visual cortexes by 6.2 percent than those from the impoverished environment, including more dendritic branching, larger cell bodies and more growth spines (Diamond, 1988). This study has led to recent studies on enriched environments in school settings.

Dekal (2001) used the Delphi technique to poll a panel of experts consisting of teachers, administrators, schools of education faculty, brain-compatible learning researchers and authors, and students and practitioners of brain-compatible learning. The two tasks of interest were: 1) to identify the top five problems which impede implementation of enriched learning environments, and 2) to identify the top five strategies to overcome barriers to the implementation of enriched learning environments. Dekal's conclusions show that enriched learning environments positively affect student achievement and learning, and that the physical components of learning environments that affect learning are varied and are dependent upon the skill and knowledge of the teacher. Identified strategies to overcome barriers to implementation of enriched environments included education of all stakeholders, including pre-service teachers, providing quality staff development programs, and designing and building new schools to support learning. The study emphasized the "lack of knowledge on the part of

educational stakeholders regarding the effects of brain-based environmental variables on student achievement and the need for teacher training in this area" (Dekal, 2001, p. 154).

Another study conducted by Brown, Burch and Zellner (2002) investigated the connection between quality teaching and learning and quality physical environment. The three researchers were a practicing architect interested in school design, a professor from a school of education, and a doctoral student. The team examined three elementary schools for the connection that exists among the physical environments, brain-based learning tenets, and the impact on learning. The findings show a connection between indirect and/or direct application of brain-based learning, including an enriched environment, on teacher satisfaction and student achievement.

Ramey and Ramey (2003) offer more evidence for incorporating enriched environments in schools through their key study conducted in the early 1970s. In Ramey and Ramey's study, called the Abecedarian Project, low-income, high-risk children were divided into two groups. The control group received no special enrichment or interventions, while the treatment group was enrolled in a specially created early childhood center from age six months to kindergarten entry. The preschool program was a full-day program, five days per week, 50 weeks per year. The curriculum consisted of activities in the area of cognition, gross and fine motor development, social and personal development, and language. Each child's program was highly individualized. Each group's families were provided with adequate nutrition and social services including free or reduced cost medical care for five years. Ramey and Ramey followed these two groups for 12 years, and found a significant difference in the way the childrens' brains had developed. By using brain-imaging techniques and intelligence tests, Ramey and

Ramey concluded that the children in the enriched environment had significantly higher IQ scores and that their brains used energy more efficiently. The children exposed to the enriched environment scored 20 points higher on post-treatment IQ tests than the control group. Also, the group receiving the pre-school treatment were three times more likely to attend a four-year college than the control group.

These studies indicate the importance of an enriched environment to support student learning. The tangible components of an enriched environment can consist of the following: clean, well-lighted classrooms that are pleasant smelling, well laid out for multiple uses, aesthetically pleasing, uncluttered, exhibit student work, set at a comfortable temperature, and contain multiple resources for topics currently under study (Kovalik & Olsen, 1998b, Hoge, 2002). Important as these components are, the intangible components are perhaps even more important but harder to create. The intangibles include a safe, non-threatening environment, social collaboration, active engagement in hands-on and minds-on learning, integration of multiple intelligences, opportunities for inquiry and problem solving, and real-life relevant activities (Jensen, 1998, Given, 2002).

Recommendations from the literature regarding the establishment of enriched environments include:

1. Provide a comfortable environment with adequate lighting, ventilation and space for learning and materials (Kovalik & Olsen, 1998b, Jensen, 1998, Hoge, 2002).
2. Provide opportunities for social interaction during instruction: sharing, stories, discussion (Given, 2002, Sylwester, 1994, Smilkstein, 2001, Jensen, 1998).
3. Provide adequate challenge and opportunities for problem solving (Given, 2002,

Kovalik & Olsen, 1998b, Jensen, 1998, Schenck, 2003, Wolfe, 2001, Erlauer, 2003, Sousa, 2001, Smilkstein, 2003).

The Roles of Challenge, Problem Solving and Authentic Work

Sousa (2001) notes, "Now that we have a more scientifically based understanding about today's novel brain, we must rethink what we do in schools and classrooms" (p. 28). A big part of the rethinking requires a look at what educators ask students to do in the classroom. The brain is an open, parallel-processing system that continually interacts with the physical and social worlds outside. Caine and Caine (1991) state that learners are "biologically driven to make sense of their world" (p. 50). This is one of the biggest challenges facing the brain: trying to connect sense and meaning, and trying to search for patterns (Hart, 1999).

Connecting sense with personal meaning-making can happen when teachers begin their instruction by establishing connections to prior knowledge and current experience (Sousa, 2001, Smilkstein, 2003). Meaningful curriculum content is crucial. Kovalik and Olsen (1998a) caution that the traditional curriculum offered in most of today's schools is "out of sync with the body-mind definition of learning" (p. 36). They suggest that there is little in today's traditional curriculum that students, particularly teenagers, find useful or relevant. Textbooks containing irrelevant factoids do not empower learners. Instead, personalization of information, learner empowerment and choice make neural connections stronger (Brandt, 1997, Diamond & Hopson, 1998). It is from this personal foundation, which includes the variables of cultural practices and beliefs, that new learning can grow. Erlauer (2003) advocates using diverse examples, metaphors and pictures to increase the relevance of the material for every student, claiming that

individual brains are like unique fingerprints. The existing neural network is able to grow new dendrites, synapses and networks by connecting new knowledge to prior knowledge, thus changing the relationship with the material, and ultimately reorganizing the brain (Slavkin, 2002). Smilkstein (2003) states that this is the first step in the brain's natural learning process: a process that is learner-centered. Bartoszeck (1996) cautions teachers against overburdening students with large quantities of factual information without allowing them to integrate the new material with their prior knowledge and then place it in a wider context. The process of connection, integration and expansion is labeled *elaboration* by Schenck (2003), a process wherein understanding is expanded through linkage with personal experience and relevant applications. In doing so, memory (learning) becomes "more strongly tagged with personal meaning, which makes the concept easier to store and later retrieve from long term memory" (Schenck, 2003, p. 85).

Problem solving in instruction is very brain-compatible because multiple neural pathways can be accessed and developed during the process (Erlauer, 2003, Jensen, 1998). Denney states that, "problem solving is to the brain what aerobic exercise is to the body" (cited in Jensen, 1994, p.144). Caution must be exercised to ensure that the problems to be solved are not mere hypothetical problems with canned, convergent outcomes (Wolfe, 2001). When instruction or discussion is paired with hands-on activities, group work, demonstrations or experiments, different areas of the brain are engaged and neural connections are grown. Basically the brain is engaged in discovering multiple answers to a problem, instead of finding the one correct answer. The result is that reasoning, critical thinking and other higher-level thinking skills are engaged, regardless of whether a solution or answer is found. Jensen (1998) notes that

neural growth occurs because of the process, not because of the solution. Research shows that only five percent of all 11-year-olds have developed formal reasoning skills, 25 percent of 14-year-olds have developed formal reasoning skills, and only 50 percent of the general population is able to reason formally (Epstein, 1986).

Harth (1995) points out the necessity for learner feedback, both internal and external, during and after instruction. Feedback can reduce uncertainty and increase coping abilities. Also, because the brain is a self-referencing organ, it builds on what it has learned or processed at previous levels. By providing specific, timely feedback, higher level thinking is encouraged.

Teachers should create a learning environment high in challenge, relevance and problem solving where students can build their own understanding of the content, organize it, and think it through using their own cognitive models, while constantly providing useful learner feedback.

Recommendations from the literature regarding the implementation of challenge, problem solving and relevant work:

1. Provide students with choices in their learning (Given, 2002, Kovalik & Olsen, 1998b, Jensen, 1998, Erlauer, 2003).
2. Incorporate a variety of teaching and learning styles during instruction (Given, 2002, Greenleaf, 1999, Jensen, 1998, Schenck, 2003, Erlauer, 2003, Wolfe & Brandt, 1998, Sousa, 2001).
3. Provide opportunities for experiential learning through field trips, hands-on activities, simulations, models, guest speakers and experiments. Students should be active participants in their own learning. Information should be presented and

represented in multiple ways to stimulate multiple neural networks and multiple areas of the brain simultaneously (Given, 2002, Sylwester, 1994, Kovalik & Olsen, 1998a, Smilkstein, 2001, Greenleaf, 1999, Jensen, 1998, Schenck, 2003, Wolfe, 2001, Roberts, 2002, Wolfe & Brandt, 1998, Sousa, 2001).

4. Students should do the work of learning, not the teacher (Kovalik & Olsen, 1998a, Smilkstein, 2001, Greenleaf, 1999, Erlauer, 2003).
5. Link the information to be learned with current events, stories, myths, legends and metaphors (Smilkstein, 2001, Greenleaf, 1999, Wolfe, 2001, Sousa, 2001, Erlauer, 2003, Zull, 2002).
6. Supply specific, timely, learner controlled feedback during and after instruction (Harth, 1995, Smilkstein, 2001, Jensen, 1998).

Understanding Brain-Based Learning: The Brain-Based Teacher

"The really difficult part of teaching is not organizing and presenting the content but rather in doing something that inspires students to focus on that content – to become engaged, to have some level of emotional involvement with it. This is not at all an easy thing for a teacher to accomplish. It cannot be done by force or threat" (Leamnson, 2000, p. 39). In keeping with this quote, Caine and Caine (1997) and Smilkstein (2003) provide two frameworks for investigating the portrait of a brain-based teacher.

Caine and Caine's Instructional and Perceptual Models

Through a five-year-long study conducted in two California schools, Caine and Caine (1997) sought to explore how teachers' perceptions of education influenced their teaching. The goal of this study was to challenge educators to "go beyond a

predominantly behavioral view of learning and teaching, which has dominated education for several decades" (Caine & Caine, 1997, p. 27). The Caines hoped to change teacher beliefs about learning and teaching, while helping the teachers redesign their classrooms, school, and their instruction. Initially, the volunteer groups at each school met weekly and explored their teaching in relation to brain/mind principles developed by the Caines. Over time the teachers were gradually introduced to brain-based theories and instruction strategies and began to incorporate these strategies into their teaching. It was not an easy task, as most of the teachers held strong beliefs about learning and teaching, many of which were quite traditional. The Caines make a distinction among surface knowledge, technical or scholastic knowledge, and dynamical knowledge. Surface knowledge is low-level knowledge comprised of rote-memorized facts and skills. Technical or scholastic knowledge is defined as intellectual understanding that lacks the ability to solve problems or deal with complex situations. It is not deep or generative understanding. Dynamical knowledge is the type of knowledge that "connects to the real world, that can be used naturally and spontaneously, and is demonstrated in authentic situations" (Caine & Caine, 1997, p. 32). This was the objective of the Caines' study; to promote dynamical knowledge in the teachers they worked with and ultimately in the schools' students through alignment with the Caines' theory of brain-based teaching. Their research included both systematic data collection and naturalistic compilations of observations and conversations.

As the study progressed, three types of teachers and teaching styles emerged. The three categories were labeled Instructional Approaches 1, 2, and 3 respectively.

Instructional Approach 1 was very teacher-centered and teacher-managed, focusing on discipline as a way to get students to learn. Teachers using Instructional Approach 2 focused on "tying technical and scholastic knowledge to critical concepts" (Caine & Caine, 1997, p. 38). Instructional Approach 3 involved teachers who made learning engaging and meaningful, who invited students to work in pairs and groups often to solve challenging problems, and who were concerned with dynamical knowledge.

The Caines also discovered that the differences in instructional strategies and ideas about learning were related to three perceptual orientations about teaching and learning. They chose to label the three perceptual orientations Perceptual Orientations 1, 2, and 3 respectively. On a continuum, Perceptual Orientation 1 teachers were bureaucratic, highly structured and directive, whereas Perceptual Orientation 3 teachers, at the opposite end of the continuum, were characterized as "at home with the kind of flow needed to challenge and engage student minds to the fullest" (Caine & Caine, 1997, p. 38). Other characteristics comparing Perceptual Orientation 1 (PO 1) and Perceptual Orientation 3 (PO 3) teachers are summarized as follows: PO 1 teachers derive their power and focus from extrinsic sources such as state guidelines, study guides and grading, whereas PO 3 teachers derive their power and focus from intrinsic sources such as classroom relationships and the power of their own cognition. In addition, PO 1 teachers tend to rely on coercion in various forms to maintain control, while PO 3 teachers rely on the strength of interconnectedness within the classroom and self-organization skills. Perceptual Orientation 2 (PO 2) teachers are in a transitional stage between PO 1 and PO 3. These PO 2 teachers begin to empower students in the areas of interaction and experience, but discipline, meaning and purpose

of experiences remain teacher-controlled. Their theory closely parallels a description of three curriculum orientations noted by Miller (1993) as: transmission (PO 1), transaction (PO 2), and transformation (PO 3).

The unexpected results of Caine and Caine's study led to a description of what they consider to be a brain-based teacher. Indicators of this description include: objectives of instruction, use of time, sources for curriculum and instruction, approaches to discipline and approaches to assessment. According to Caine and Caine (1997), a brain-based teacher engages in "teaching that takes place on the edge of possibility", stating that their "espoused models and mental models become congruent, their actions become more authentic, and their teaching becomes sophisticated enough to generate the learning that we desire in students" (p. 90). The Caines concluded that the PO 3 teacher embodies the characteristics of a brain-based teacher for several reasons:

1. They are able to use all three instructional approaches, but they are flexible, choosing an approach based upon context.
2. They find meaning and connections in real-life situations and can apply them in a relevant manner to the classroom. Many of their instructional ideas come from non-traditional sources.
3. They believe that their classrooms are "complex adaptive systems rather than mechanical systems (Caine & Caine, 1997, p. 64). Dynamic patterning governs the use of time and content.
4. Student interests, ideas, suggestions and needs are central to the curriculum. Empowering others is important.

5. They constantly engage in self-reflection while teaching. They are mindful of themselves and their students.
6. They perceive power as coming from themselves, not from an outside source. They are authentic and embrace change.
7. Understanding the relationships between information and experience, learning and context, and students and teacher govern their organization and procedures.

Caveats exist, however, in trying to neatly summarize or describe a brain-based teacher. Ideally, the Caines describe this type of teacher as one who is a PO 3 teacher, and can effectively use all three Instructional Approaches. However, the process of becoming a PO 3 teacher is strictly voluntary. No one can forcibly create a brain-based teacher, since so much of the process involves self-direction and self-reflection. "Teachers... need time and opportunities to rethink pedagogy, so that they can reflect on their own present assumptions and learn about alternatives" (Caine & Caine, 1997, p. 189).

Smilkstein's Model

Based on the theory that human beings have an innate, natural learning process directly related to the physiological processes of the brain, Smilkstein (2003) offers another model of a brain-based teacher. Using a student-centered curriculum as the focal point, Smilkstein (2003) stresses the importance of student learning over "attention-getting activities that are more or less peripheral to a curriculum" (p. 3). These attention-getting activities include physical activities, music, visual imagery and dramatics.

The natural learning process, as described by Smilkstein, encompasses such elements as making one's own discoveries, learning from mistakes, and active, creative learning geared to finding multiple answers. The research involved more than 5,000 participants from Kindergarten through graduate school, over a period of several years. Smilkstein observed learners of all educational levels and disciplines as they struggled to learn academic content. Specifically, Smilkstein began the research in a community college basic skills English class, a class full of frustrated students who believed that they couldn't learn. The author challenged the students to think of something they had learned well outside of school, then to write down: 1) how they had learned it, 2) how they had progressed in their learning, and 3) how they became good at it. Amazingly enough, the sequences of learning stages Smilkstein reported for every group involved in the years of research were similar. Each group reported an initial Stage 1 of interest, motivation or need, followed by Stage 2 practice, trial and error and experimentation. Stage 3 was comprised of continued practice, increased level of difficulty and beginning to take risks. At Stage 4 the learners were refining, applying and looking for feedback. The final Stages 5 and 6 encompassed further refinement, making connections, not giving up, and ultimately mastering the learning and teaching others. This research aligns with laboratory brain research that shows that the brain physiologically learns in the same sequence to construct knowledge and make connections. Neural growth follows this pattern of branching, connecting with other neurons and finally constructing complex neural networks. Smilkstein has labeled this process the "Natural Learning Process."

Smilkstein asserts that educators "cannot grow students' neural structures for them; they can only help their students grow their own structures by providing students with

opportunities for this growth, this learning" (2001, p. 30). Several principles guide the implementation and success of the natural human learning process and describe a brain-based teacher. These principles include:

1. Educators should have an awareness of brain physiology and how the brain learns. This knowledge will help the educator and the learner believe that everyone needs to and is able to learn.
2. Learning happens most effectively when students do the work of learning. Making mistakes, practice, and adequate processing time are crucial for growing new neural networks.
3. Educators must meet students where they are, realizing that students must have the prerequisite neural structures with which to connect and construct new higher-level structures.
4. Learners must make personal connections with something they already know or can do in order to construct neural networks in a sequential manner.

According to Smilkstein, a brain-based teacher offers curricula that are learner-centered and activity-based. Elements of brain-based pedagogy include: active learning, independent work, feedback, self-evaluation, communication skills, respectful interaction, community building, collaboration based on learning communities, and holding students to high standards. Knowing that all brains learn in the same way, by growing and connecting neural structures, educators can utilize the brain's natural learning process to reach all learners. Smilkstein (2003) asserts that the natural learning process is a viable methodology for "developing and delivering a whole curricula that

will work with all students" (p.125), even taking into account diverse learning styles and intelligences.

Comparing the Two Models

. One of the biggest obstacles to using brain-based methodologies is overcoming the traditional view of the teacher as leader/director/disseminator of all knowledge. Both the Caines and Smilkstein offer a portrait of a brain-compatible teacher as one who is student-centered. This type of teacher is willing to take risks to empower students to do the work of learning. Both authors espouse the value of an organic, adaptive, jungle-like classroom environment where learning is happening at many levels, although Smilkstein's model is more sequenced. The roles of authentic work and problem solving are crucial to both models, as are the roles of building positive relationships and collaborative learning. The goal is dynamical knowledge which links students' past experiences with new learnings, connects with real world situations and ultimately leads to transfer of knowledge to other authentic situations. It is indeed teaching that takes place "on the edge of possibility" (Caine & Caine, 1997, p. 90) which challenges teachers to rethink the old paradigms of teaching and learning.

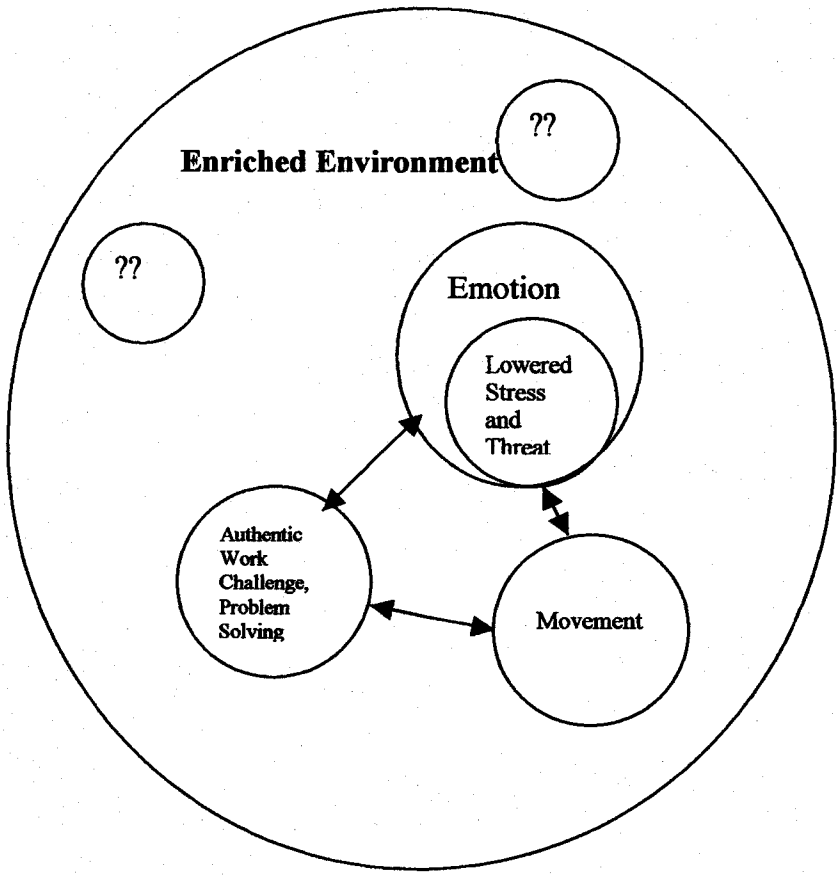
The Brain-Compatible Teaching Model

Figure 1 provides a visual model of the principles of brain-based teaching that emerged from this review of literature. An enriched environment is viewed as the most important stage with the components of emotion, movement, stress/threat, and challenge/authentic work playing roles on that stage. Other components of brain-based instruction are illustrated but were not found to be as crucial. This emergent model will be utilized in

the research portion of this study to determine the awareness and integration of brain-based principles by practicing teachers.

Figure 1

Model 1: Principles of Brain-Based Instruction from Literature Review



CHAPTER THREE

Methods

The purpose of this basic interpretive qualitative study was to explore the characteristics of brain-based instruction and to determine if these characteristics were incorporated into teacher preparation programs and classroom instruction by identified exemplary teachers. Chapter 3 will describe the design and procedures used in the study. First, a brief overview of the qualitative paradigm of research is presented and the reasons why it was selected as the methodology for this study. Next the research design for this study is described, followed by a section detailing the participants and sites. Then, data collection procedures are described, including an interview protocol. The next section describes the data analysis procedures. Finally, plans to assure verification and trustworthiness of the analysis are discussed.

Qualitative Research Methodologies

Several features of qualitative research have been outlined by Miles and Huberman (1994). The features include using the field for the research setting, incorporating a holistic world view, attempting to understand the multiple realities of the participants, preserving the forms of the original data collected, interpreting the manner in which the participants realize their worlds, remembering that the researcher is the instrument, and analyzing the data using words rather than numbers. In qualitative research, certain assumptions undergird this paradigm. They include: a subjective and multiple reality, researcher interaction with the participants, bias and values in the data, personal and

informal researcher language, and an inductive, emergent, context-laden research process (Creswell, 1998).

I am comfortable with the assumptions and research processes associated with qualitative research. With regard to the research question, the research was exploratory, seeking to discover what a brain-based teacher looks like and to what extent the identified participants are aware of and utilizing brain-based instructional principles. The extensive literature review has revealed a gap between theory and practice; the research regarding brain-based instruction is readily available, but it is not often integrated into teacher preparation programs or classroom practice. By employing qualitative methodologies, this interpretive and descriptive study sought to examine to what extent exemplary practicing teachers were aware of brain-based approaches to instruction and utilizing them, and ultimately to provide a portrait of a brain-based teacher.

Research Design

This qualitative study had two phases. Since qualitative research is "multimethod in focus, involving an interpretive, naturalistic approach to its subject matter" (Denzin & Lincoln, 1994, p.2), this study investigated two areas of interest regarding brain-based instruction. Phase I involved interviews with nationally renowned experts in the field of brain-based instruction, and Phase 2 involved interviews with practicing teachers. This design provided a "complex, holistic picture...that takes the reader into the multiple dimensions of a problem or issue and displays it in all of its complexity" (Creswell, 1998, p. 15). Strategies and procedures from participants' perceptions are used by qualitative researchers to help them consider experiences (Bogdan & Biklen, 1998).

The basic interpretive approach was utilized for this study for the following reasons: I posed "how" or "why" questions, I had little control over events, and the focus was on a contemporary issue with real-life contexts (Yin, 2003). Merriam (2002) notes that this type of study has the strength to deal with the following types evidence: documents, interviews, and observations, which I utilized.

Participants and Site

For Phase I of the study, a cover letter was mailed to brain experts scheduled to attend the *Learning and the Brain* conference held in mid-November 2004 in Cambridge, MA, inviting them to participate in a short interview. These people were identified in the review of literature as leading experts in the field of educational brain research. The interviews took place on site at the conference. Additionally, cover letters detailing the study were also sent to identified experts who could have attended the *Learning and the Brain* conference, but who were not listed in the program schedule. It was my hope that some of the other renowned experts would attend the conference and be willing to participate in an interview while in Cambridge. If not, they were invited to participate in interviews via telephone, email or through video conferences. Consent forms were provided at the time of the interviews.

For Phase II of the study, a cover letter was mailed to exemplary secondary or middle school public school teachers in a Rocky Mountain state school district. The letter described the study and invited participation outside of school hours for the identified exemplary teachers. Criterion sampling dictates that the participants be public secondary or middle school teachers who have met specified criteria to be identified as exemplary. The District Foundation of the local school district provided strict criteria for selecting

nominees and awardees of educational excellence. After receiving responses from potential participants, a cover letter inviting participation in the study was mailed to the teachers. Again, a consent form was provided at the time of the interviews. I expected to interview seven or eight teachers. The interviews took place after school hours in their classrooms or offices and lasted an hour on average.

The Human Subjects Committee was consulted and their approval obtained before data were collected from participants, in compliance with Colorado State University research guidelines. Informed consent was obtained from participants to ensure that confidentiality was observed, that participants were aware of any potential psychological risks, and that participants understood the purpose of the research (Appendix F).

Data Collection

My data collection began by contacting twelve nationally renowned experts in the area of brain-based education via letters and email (see Appendix A). I was able to meet with several of them at the *Learning and the Brain* conference in Cambridge, MA in November 2004. The others were contacted via telephone and email interviews (Appendix B). I conducted interviews with the experts regarding the brain-based instructional themes that emerged from the literature. The following questions were posed:

1. How would you describe brain-based teaching?
2. Are there certain principles or characteristics about brain-based teaching that you feel are most important?
3. How would you describe a brain-compatible teacher?

The protocol for these interviews is included in Appendix C. The brain-based instructional principles that emerged from the review of literature were also available at

the time of each interview for discussion and verification. Individual interviews were audiotaped using a digital recorder. Informed Consent Forms were provided (Appendix D).

The second phase of my qualitative study consisted of mailing cover letters to seventeen identified exemplary teachers as detailed in the previous section (Appendix E). I expected that seven to eight teachers would volunteer for the study. They contacted me via telephone or email to volunteer for the study.

The Informed Consent Form (Appendix F) describes the project, procedures, risks, benefits, and confidentiality used for this study. I conducted audiotaped interviews with six teachers. The interview questions are included in Appendix G, and included such semi-structured questions as:

1. Can you describe the environment in your classroom?
2. Where do the ideas for your teaching come from?
3. What kinds of activities or experiences do you use in your teaching?
4. How do you get the highest achievement out of your students?
5. What does order in your classroom mean? How do you maintain order?
6. What is your approach to grading and evaluation? Please be specific.
7. Why do people think you are exemplary?
8. What are you learning about now?
9. What kinds of brain-based instruction or professional development have you had?

Creswell (1998) advocates asking open-ended questions and refraining from "assuming the role of the expert researcher with the best questions" (p. 19).

The interviews took place at the teachers' respective schools for their convenience.

Data Analysis

Phase I

Twelve nationally renowned authorities in the field of educational brain research were contacted, and interviews were conducted with ten of them. Four of the interviews took place in a hotel conference room in Cambridge, MA and six were conducted via telephone or email. After the interviews were conducted, the text of each interview was transcribed. Responses and quotes were identified that either confirmed or disconfirmed the five principles of brain-based instruction that emerged from the review of literature. In addition, other important themes emerged.

Phase 2

Interviews were also conducted with six practicing public school classroom teachers. After the interviews were conducted, the text of each interview was transcribed. Using the technique of constant comparative analysis, common themes were found within each question, and subcategories were created. Constant comparative analysis is an analysis strategy often utilized in grounded theory where initial categories of information are formed, called *open coding* (Creswell, 1998). Next the data are assembled in new ways, named *axial coding*. Finally, *selective coding* is employed to tell the story and integrate the categories in the axial coding model. The first open code from this study was "Characteristics of Teaching Process", with axial codes labeled: 1) emotional climate of classroom, 2) physical setup of classroom, 3) caring for students, 4) encouraging students and 5) relevant, inquiry-based work. The second open code was "Characteristics of Teachers" and included the two axial codes of: 1) lifelong learners, and 2) lack of articulation.

Other data sources, such as documents and observational notes helped to substantiate the findings. I sought what Eisner (1991) states as a "confluence of evidence" (p.110) to triangulate the data. I also utilized the model that emerged from the review of literature, which depicts the five principles of brain-based instruction. The model was amended after each phase of the study to mirror the participants' input.

By utilizing the transcribed data from six interviews, along with observational notes, possible artifacts or documents, and the framework of the literature-based brain-compatible instructional principles, I was able to piece together a picture of current perceptions and classroom practices of brain-based education and describe what a brain-based teacher might look like.

Verification

Trustworthiness, or the accuracy of the data analysis and its fit with reality, is a primary concern of qualitative research (Lincoln & Guba, 1985). Creswell (1994) refers to this as *internal validity*. Stake (1995) suggests triangulation of information through data sources, investigator, theory, and methods.

In order to determine the accuracy of the data, I utilized the process of member checks (Creswell, 1998). This involves checking the findings and interpretations with the participants to see if the data accurately represents the reality they have presented. Each participant was mailed a copy of the transcribed interview for review and revision. Minimal revisions were made and satisfaction was inferred. I also clarified my bias as a researcher at the beginning of analysis. This helped the reader to understand any biases or assumptions that impact or influence the study.

Another important aspect of verification is indicating external reliability. In order to assess external reliability, I assembled an audit trail (Miles & Huberman, 1994). An audit trail provides detailed documentation of the research processes so that the study can be assessed for accuracy by an informed colleague. The object is to examine "whether or not the findings, interpretations, and conclusions are supported by the data" (Creswell, 1998, p. 203). An audit trail also allows the study to be replicated by others. My advisor and I met at regularly scheduled intervals to assess my progress and discuss my findings and interpretations to verify that they were supported by the data. A thorough description of the audit trail is included in Appendix H.

CHAPTER FOUR

Findings

The purpose of this study was to explore the characteristics of brain-based instruction and to determine if these characteristics are incorporated into teacher preparation programs and classroom instruction by identified exemplary teachers. Data collection was divided into two phases. Phase I involved interviewing ten recognized authorities in the field of brain research to confirm or disconfirm the brain-based instructional principles that emerged from the review of literature. Phase II involved interviews with six exemplary secondary teachers in a Rocky Mountain state to gain an understanding of their perception and integration of brain-based principles into their classroom instruction. Ultimately, a portrait of a brain-compatible teacher was offered.

Phase I

I had the opportunity to attend the semi-annual *Learning and the Brain* conference in Cambridge, MA in the fall of 2004. While in Cambridge, I conducted individual interviews with four leading brain experts in the fields of neuroscience, cognitive science, and education. Another expert was interviewed on the telephone, and the remaining five agreed to conduct email interviews. I found differences in the responses gathered from the individual interviews and the telephone interview versus the email interviews. The experts I interviewed personally had to "think on their feet", and often digressed in interesting ways from the questions. However, the insights they offered into their work and personal lives expanded upon the themes of brain-compatible teaching and learning.

They also told more stories and gave more personal examples than the emailed experts, which made the data rich. On the other hand, the email interview texts were very succinct and concise. Since I emailed the questions to this group of experts, they had ample time to construct their responses, often citing books and articles for me to read. One of the experts even sent me part of a book chapter she is working on, along with a detailed email response.

Of the ten experts I contacted, seven of them were college professors, two were educational consultants with learning companies, and one was a high school science teacher (See Table l). These individuals were chosen because their work was cited in my review of literature.

In reviewing the backgrounds, credentials, and professional interests of the "brain experts", it seems more appropriate to call them *educational theorists*. Their levels of education, expertise and interests vary widely, from neuroscience and biology to psychology to educational applications of brain research. Several individuals concentrate their professional work more on scientific work with the brain and less with teaching and learning. Others are very involved with pre-service teacher training and working in public schools. A few are consultants in the area of professional development. In order to provide a more balanced picture of what a brain expert is, and to respect the varied work of these individuals, the term *educational theorists* seems a good fit.

Table 1

Educational level and professions of educational theorists

Expert Pseudonym	Level of Education	Current Profession
Theorist A	Ph.D. – Educational Administration	Educational consultant
Theorist B	Ph.D. – Cognitive Science	Professor of Education
Theorist C	Ph.D. – Education, Interdisciplinary Studies	High school science teacher
Theorist D	Ph.D. - Neuroscience	Professor of Anatomy
Theorist E	Ed.D. – Educational Administration	Program and Planning Specialist at a University Educational Laboratory
Theorist F	B.A. - English	Educational consultant
Theorist G	Ph.D. – Educational Psychology	Professor of Education
Theorist H	Ph.D. - Psychology	Professor of Educational Psychology
Theorist I	Ph.D. - Education	Professor of Education
Theorist J	Ph.D. – Cell Biology	Professor Emeritus of Biology

The purpose of interviewing these theorists was to determine if the five main characteristics of brain-based instruction that emerged from the literature were indeed the most important or most relevant ones to keep in mind as I progressed into Phase II with practicing teachers. Each person is identified through an alphabetical pseudonym.

Listed below are the three questions posed to the theorists.

Questions asked of the educational theorists:

1. How would you describe brain-based teaching?
2. Are there certain principles or characteristics about brain-based teaching that you feel are most important?

3. How would you describe a brain-compatible teacher?

I deductively indexed their responses with the five main characteristics of brain-based instruction that I found in the literature. Those five characteristics are:

a. The role of an enriched environment

b. The role of emotions

c. The role of movement

d. The role of stress and threat

e. The role of authentic work, challenge and problem solving

Responses to the first question around describing brain-based teaching revealed that the educational theorists believe that all learning is brain-based. They described brain-based teaching as "an emphasis on learning rather than on teaching" (Theorist A), "to me it really means what are the things I can do or we can do, not to force, not to make, but to cause learners to process?" (Theorist E), "instruction that seeks to distance our profession from that earlier [behaviorist] perspective, and focus on the new insights neuroimaging provides" (Theorist I), and "it is the application of a meaningful group of principles that represent our understanding of how our brain works in the context of education" (Theorist F). These ideas are incorporated into my description of a brain-compatible teacher.

The next section details the theorists' responses to question number two regarding what they view as important characteristics of brain-based teaching. Their responses are aligned with the five brain-based teaching principles found in the review of literature.

The Role of an Enriched Environment

Five educational theorists expressed ideas and comments about what an enriched environment is and its role in teaching and learning.

Theorist D stated, "You have to define what you mean by *enrichment*. That can be many forms." She added that forming a respectful, cohesive learning community in the classroom is very important. She labels such a learning community a "learning family." Theorist A agreed that defining an enriched environment is difficult. "It's really hard to determine what an enriched environment is comprised of." She advocates making a distinction between enriched and complex environments, citing the work of William Greenough from the University of Illinois.

Theorist G offered a definition of an enriched environment by describing it as "learners' active and interactive experiencing and processing of an object of learning is the nourishing environment." However, Theorist E cautions educators to be wary of over-enriching the environment. "When you over-enrich the environment, what most of us would call an enriched space is probably cluttered with too many alternatives, that we do not stop and process on them. We just scan." He makes the following recommendations to educators for enrichment:

1. Introduce two concepts at a time, no more. Choose intervals of time to introduce new or different things.
2. Remember that the social aspect of learning is important as it can provide intermittent reflective moments. Group students by interest. Pairs are best as it doubles the processing (50%).
3. Use lecture, but intersperse it with different modes and different opportunities for

thought, such as partner interaction or making summary statements.

Theorist C points out the advantages of using different types of music to enrich the environment. "[Music] is hugely important because that affects both attention and emotions. It can really change the atmosphere, just like in a movie." He uses music for study time, student dialoging or to energize students.

None of the educational theorists specifically addressed physical components of an enriched environment such as: temperature, lighting, color, décor, room and furniture arrangements, or sufficient materials.

The Role of Emotions

The role of emotions in teaching and learning was one of the most interesting and passionate topics that the theorists discussed. Theorist A states that emotions are a key issue in education. "It's a double-edged sword. It's difficult to learn when you're under stress, but if there's no emotion the whole brain shuts down." She advocates making learning fun and engaging, using more visuals, and taking advantage of emotional systems that lead to better memory storage. Theorist E concurs, with the comment that "All long-term memory is emotionally tagged." Emotion to him means relevance, meaning and context. To facilitate these concepts, educators need to be aware of how they orchestrate or frame students' learning activities and contexts to ensure that they are relevant and meaningful. He states, "It's how you orchestrate it, the activity, the context, is really what helps. What I like about that is that learning isn't about getting it in, it's really about can we get it back out and use it?"

Theorist F addressed the natural craving we have for "positives, including novelty, fun, rewards, and relationships." He asserts that, "Our emotional and body states

influence our attention, memory, learning, meaning, and behavior. These states become more stable over time and will resist changes." Theorist F claims that these stable states have profound implications for the social and behavioral role of education. Theorist G elaborates on this theme by addressing motivation to learn. She suggests that motivation to learn increases when learners have the opportunity to construct their own meanings. Endorphins, or pleasure hormones, are released when the brain is actively producing new knowledge or making network connections. Theorist G adds, "The brain feels pleasure when constructing both new and higher levels of knowledge." To engage learners emotionally with the content, Theorist G advocates that students work cooperatively with each other and learn socially, that they give and receive feedback from peers and teachers, and that students reflect on their own learning through reflective practices such as journaling.

Theorist D addresses the role of emotions in learning from a teacher standpoint. Teachers must be emotionally involved in their teaching, not just the students emotionally involved in their learning. She draws an analogy between the human heart and teaching, that teachers must take care of themselves first, just as the heart supplies itself with blood first, then other organs. By doing so, teachers will be more effective. She described her personal "Four Ps" philosophy that guides her priorities in life. The Four Ps in rank order include: personal priorities such as family and friends, professional priorities dealing with brain research and her students, the importance of perseverance, and maintaining a positive attitude. By keeping her personal life and teaching in perspective, "you have a foundation on which to feel good about others", which ultimately can carry over into the classroom where we assume the role of encourager.

Theorist D related a story about how she gets her students emotionally involved in their initial learning by bringing a human brain to class and pointing out that:

> These cells, that together only weigh three pounds, can conceive of a universe over a billion light years across. Do you ever introspect and appreciate what you carry in the top of your heads? Everything that you learn at this great university, in your four years of education, will be coming through this three-pound mass.

The Role of Movement

After speaking with the theorists, I changed my label of "the role of movement" to "the role of physical systems." The theorists chose to discuss concepts beyond gross and fine motor movements. I will begin with Theorist A, who asserts that there is a strong body-mind connection. Sufficient glucose and oxygen are necessary to get good brain function. She feels that physical movement can be important component of brain-compatible teaching, perhaps even overemphasized. She, along with others, made references to the Brain Gym program, questioning its research and effectiveness. Theorist A states that, "I really don't think we have any good, solid research on incorporating movement [into learning]." She fails to see all the connections people are making.

Theorist E broadens the role of movement to include physical systems. Movement does not have to mean motion, it can include spatial orientation in the classroom. Examples provided by him include: having students write diagonally on paper, cross or uncross their legs while learning a concept, remembering their seating position in class while learning material, the value of changing seating arrangements, and having students learn tactilely.

Theorist C expands on Theorist E's definition of physical systems to include homeostasis. He claims:

> You're teaching, first of all, to the entire person. If you think you're teaching only to the brain, you have a basic misunderstanding here of what's going on. Because the way it's wired into the rest of the body and how the brain is responding and using homeostasis to monitor and control what's going on, that needs to be kept highly in mind. The moment they start noticing it's too cold, too hot, their seat, it doesn't matter what else you're doing they've lost focus.

Theorist C mentions how emotion, attention and motivation all weave together to help form the working memory, and that it is all really a homeostasis issue.

The Role of Stress and Threat

Directly related to the roles of emotion and physical systems is the role of stress and threat in the classroom. The theorists validated this principle by stating, "I think classes need to be safe, physically and psychologically. The fight or flight response is identical" (Theorist A), and "We try to limit pain even if it means compromising our own integrity" (Theorist F). Theorist F pointed out that the longer one is angry or depressed, the more comfortable he or she becomes with that state. It develops into a new state of homeostasis, a stressful one where the student constantly feels threatened, and ultimately unable to learn effectively.

Theorist C related a story of how he used to "terrorize" kids on the first days of school when he was a beginning teacher. Now he reflects back on that time and regretfully wonders now "what kind of damage this did."

Theorist E thoroughly addressed this principle by noting:

> The level of capacity of learners to participate in their own learning is going to be influenced if not dictated, whichever one, by the level of safety in the room. Emotional safety is what holds kids back. Teachers need to be unequivocal in articulating what is not negotiable in the classroom, then students don't have to enact their stress response, defenses, and other things that get in the way of learning. [Students] have to feel safe to try, to explore, to go on that journey.

He expands on the idea of reducing stress and threat by using appropriate questioning techniques. This person also mentions why it is all right to elicit wrong answers so that students must process them, correct them and learn from them.

The Roles of Challenge, Problem Solving and Authentic Work

The educational theorists confirmed this important principle of brain-compatible teaching by looking at this issue through different lenses. Theorist F states that the brain seeks and creates understanding. "The more important the meaning, the greater the more attention we must pay to influencing the content of the meaning." It is vital to provide authentic, challenging work for students that is meaningful to them and relevant.

Theorist A also stresses the importance of the brain making meaning through a meaningful curriculum. She says her favorite quote is, "Our species has not survived by storing meaningless information." She points to the importance of incorporating hands-on activities in instruction, using metaphor, analogy and simile, and making connections to prior knowledge to build new networks of knowledge.

Theorist A cites research done by Jacobs, Schall and Scheibel (1993) which discovered that dendritic growth is a reflection of the learner's educational and (a)vocational experiences. Through experience, exploration, trial and error, practice, creative and critical thought, the dendritic networks are encouraged to grow, "physiologically constructing the new knowledge", states Theorist A. She favors the quote, "The more we grow, the more we know."

Theorist E is passionate about framing learning for students so that it either invites or causes one to learn. He says, "Problem solving can clearly have an impact on that [students doing the work and linking it in ways that create longer-term memory system

capacity], or it can die a natural death like it does in so many classrooms." He is adamant that students do the work, and hence the learning, claiming that too many teachers work too hard doing all the work of learning.

Theorist D sums up the principle of challenge and problem solving by reminding me that it is an important component of maintaining balance in life, along with diet, exercise and novelty, for after all, "You've only got 100 years! And in this case you know your brain, your genetics, where you're coming from, so you feel good about yourself and you have a foundation on which to feel good about others."

The Role of Experience

This sixth characteristic or principle of brain-compatible teaching emerged as I continued my interviews with the educational theorists. Not unexpectedly, the role of experience in learning surfaced as a component of brain-compatible teaching. Theorist A addresses the experience role by stating, "Probably the most important thing we have learned is that the brain is the only organ in the body that sculpts itself through experience. The teacher's part in this is that the teacher literally sculpts the kids' brains." She emphasizes the work of Bruce Perry and others regarding early childhood development and abuse. Perry studied abuse that ran the gamut from physical to neglect to emotional abuse. Theorist A urges educators to keep in mind that what happens to us on a daily basis is critical to shaping the brain.

Theorist G also mentioned the theme of brain sculpting. Connecting with the concept of dendritic growth, Theorist G recognizes that learners build cognitive schemas from the ground up for each new object of learning. The building blocks of schemas are prior

knowledge, active experiences and processing. Thus, she says, the "brain is sculpting itself."

Theorist F reminds us that our subjective perceptions of sensory input can be altered, thus altering our experiences. "Perception influences our experience and it's our experience that drives changes in the brain", he asserts. We now know that our experience can drive physical changes in many areas of the brain including the sensory cortex, frontal and temporal lobes, the amygdale and the hippocampus.

Theorist H speaks to the need to be cognizant of the individual differences in human talent. She suggests that educators should "devote more energy to finding and nurturing those unique abilities that individual children have that are most likely to lead to marketable and leisure-time skills for them as adults."

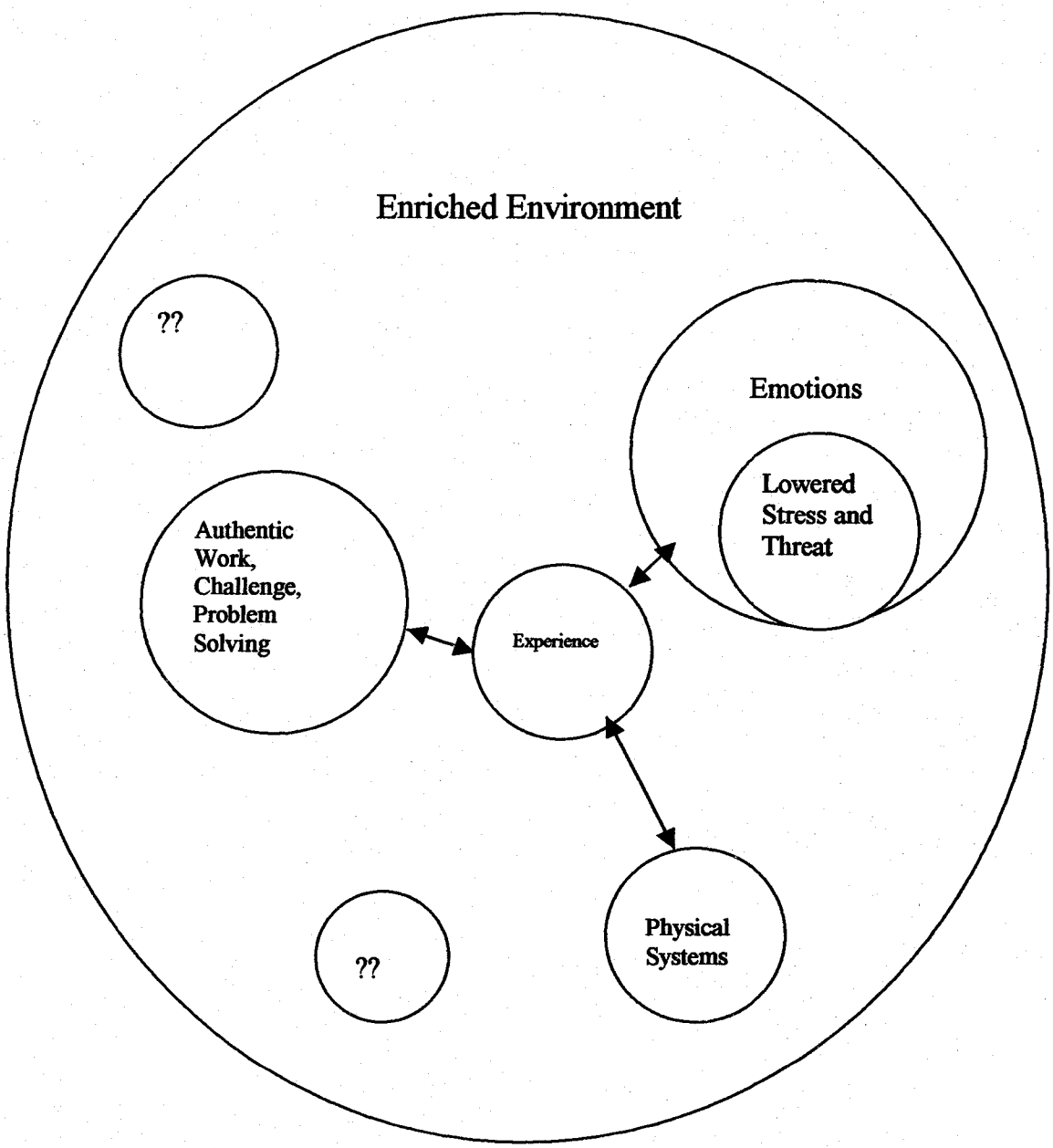
And finally, Theorist B takes this theme of individualization one step further, and gives us hope for the future when he states, "When you look at what's going on with the brain, it's just clear that there's enormous plasticity even in middle age, even in old age."

Summary of Phase I Findings

Originally I discovered five main characteristics of brain-compatible teaching through the review of literature. The questions asked of the educational theorists were quite broad, but were targeted to elicit responses that would align with the five principles. If no response was offered that referred to one of the principles, I used extenders to probe a little deeper. After deductively analyzing the content from my theorist interviews, I altered the Model of Brain-Compatible Teaching. The role of experience was added, and the role of movement was changed to *physical systems* and diminished. The role of experience emerged inductively as the theorists had a lot to say about this characteristic.

Of course there are still unexplored "question mark" components to the model, but I will use the updated model as a guide to deductively analyze data from the classroom teachers, which is Phase II of this study.

Figure 2. Model 2: Characteristics of Brain-Compatible Teaching from Theorists



Phase II

Phase II of the study involved interviewing secondary teachers in a Rocky Mountain state who were identified as exemplary teachers. Each person had either been nominated for or awarded an Excellence in Education award within the past three years from the local school district. The local public school district is comprised of over 24,000 students, 1,735 teachers, and includes 30 elementary schools, eight junior high schools, four high schools, three charter schools and 19 alternative schools and programs. Each nominee or awardee was evaluated using strict selection criteria that included letters of recommendation from administrators, peers and students, participation in professional organizations, and community involvement. The following table shows the participants' demographics. Pseudonyms were used to protect their confidentiality.

Table 2

Demographics of the Exemplary Teachers

Name	Grade level taught	Subject(s)	Years teaching	Educational level
Ed	elementary	6th grade	39	M.A. + 90 hours Elementary Ed.
Kathy	Junior High School	social studies	14	M.A. - anthropology
Heather	Junior High School	science	8	B.S. + graduate hours
Robin	Junior High School	mathematics	16	M.Ed. + 60 grad hrs.
Jan	Senior High School	physical education, health	21	B.S. + graduate hours
Todd	Senior High School	physics, chemistry	17	M.S. - chemistry

In analyzing the data from my interviews, I identified two main themes. The first main theme, "Characteristics of the teaching process" includes five sub-themes. The second main theme, "Characteristics of teachers" includes two sub-themes. Each theme is described through paraphrasing and direct quotes from the participants. A summary of the brain-based teaching and learning characteristics, my research questions and the associated themes are provided in Table 3.

Table 3

Brain-based characteristics and emergent interview themes

Brain-based characteristics/principles from literature review and educational theorists
• Enriched environment • Emotions • Physical systems • Lowered stress and threat • Authentic work, challenge, problem solving • Experience
Research Question #3: To what extent are exemplary secondary public school teachers integrating these brain-based instructional characteristics into classroom practice?
Emergent Themes • Characteristics of teaching process 1. Emotional climate of classroom 2. Physical setup of classroom 3. Caring for students

4. Encouraging students

5. Relevant, inquiry-based work

- Characteristics of teachers

1. Lifelong learners

2. Lack of articulation

Characteristics of Teaching Process

The following five emergent themes are all centered around the teaching process itself and concern establishing an enriched environment. Each of the following sub-themes deals with a specific component of an enriched environment.

Emotional Climate

The first theme to emerge from the teacher interviews was the theme of providing a positive learning environment. One of the key features of this environment identified by the teachers is the emotional climate of their classrooms. Robin, Jan and Ed were concerned that the students make connections with each other.

> A lot of my students say they feel like they're coming home when they come in the classroom and I can't think of a finer compliment. [There are] no put downs, I don't have a bunch of rules or regulations, they just need to respect [each other]. I feel very strongly that this little room here is safe. I don't know if I feel like that about the whole school. (Robin)

> I try to create a homey atmosphere and a caring atmosphere. At first they may not sense that, but then they find out that they have an old guy in their corner. I have always felt like the school's a family. There are times that wear thin and it's kind of hard to get through the day, [but] when times became trying between each other, you weathered those storms, got over them, became better people. (Ed)

> [I have] few rules. It's friendly, with open communication. Even though it's high school level I still feel like students don't know each other well, so my first week, a lot of it is activities and different things geared around at least talking to different individuals. I really try to foster different things where it's non-personal issues, but

they're talking to someone different and a lot of times they find, that you could have someone sitting across from you with several hundred piercings and just totally different from you. And you find out some very interesting things about that person. So I think if you can make small connections like that, it just gives a more humanistic value to your classroom. (Jan)

Kathy and Heather feel that being fair and treating everyone the same is important. Their comments about the emotional climate of her classroom:

I treat [the students] how I would want to be treated. Like adults, no patronizing, no assumptions about capabilities. I look for strengths. (Heather)

Caring, loving. I say out loud, "I love you!" (Kathy)

Todd is concerned that the emotional climate is positive. He states:

I smile a lot, I try to be a very positive person, I try to get to know the students so they can come to me with questions about the content, about anything, whether it's the school policies, or problems with another teacher or another student or whatever. I also try to foster a healthy learning environment. Kids can't learn if they're hungry, sleepy, emotionally distressed. And so anything I can do to alleviate those things, I mean there's not much I can do about hunger or sleep, but I can certainly make this as non-threatening as possible. (Todd)

Physical Set-Up of Classroom

Another component of creating an inviting atmosphere is the physical setup of the classroom. Here is what the teachers had to say about the physical layout and components of their classrooms that help promote a positive learning environment:

I try to do a lot of plants and pictures of the students, pick up on their interests, incorporate that into my lesson plans. [There are] a lot of pictures of students' activities, there's a girl competing in her ice skating...here's one horseback riding, I love having pictures of the kids. And as I look at those pictures, it really encourages me, and I think it encourages the students. I research which plants help oxygenate the air because we have bad air. (Robin)

I love the natural light. I also love the high ceilings because then for physics we can do other interesting experiments with high ceilings. These mobiles that you see hanging kind of liven up the room. (Todd)

I have lots of different sayings in the room and things like that that I believe give a

little food for thought. Plants and that kind of thing, just trying to create again the little homey atmosphere instead of a sterile atmosphere, and a colorful atmosphere with the different Disney characters and bulletin boards. It looks to me warm and inviting. We also have class gerbils. (Ed)

Heather and Kathy also addressed the issue of the physical classroom. Heather mentioned that the classroom feels constrained: the size of the room and size of the classes (33) are a problem. Both mentioned that plants and student work displayed make it more like home. Jan had a problem trying to create a welcoming physical environment since most of her classes are held in a large gymnasium. In her health classroom she hangs inspirational posters that deal with nutrition, exercise and other health issues.

Several teachers also addressed their use of physical space. They were concerned that their seating charts and room arrangements would allow for optimal individualization and social learning opportunities. Their comments:

Pretty much everyone has a front row seat. I like the "square donut", without anyone having the back seat or in the back of the room. I have the center table there, when it's not filled with other things, that's where I do most of my instruction. The kids come up and sit there and I sit there [in the center of the room] for most of the day. (Ed)

I have half of the class looking at the other half. So the rows are looking to each other and not straight forward to the teacher. (Jan)

We structure our science classrooms around a laboratory setting and so you see groups of tables rather than rows of desks. (Todd)

[The classroom] is not set up in rectangular rows, see how it's diagonal so they can look at the board but they're not directly looking at each other. It really works well for me. (Robin)

Caring for Students

Besides providing a safe emotional climate and physical components that are inviting and student-centered, these teachers showed they cared about their students through their interactions and the attitude they have toward adolescent learners. They hold high expectations for all of their students.

Kathy cares deeply for her students and still feels connections with kids, having raised teenagers herself. "I can think like a teenager", she states. Heather advocates for all kids, saying, "I aim high, there is no option of "low" until I see that they can't do the "high" level. Junior high kids are much more capable of sophisticated thoughts, ideas and work habits. We're afraid to raise the bar too high, then we have to deal with failure."

Todd also enjoys interacting with adolescents and finds ways to connects kids' interests with the concepts they learn in his physics class.

> You know you start talking about applications and all of a sudden the engineering types kind of perk up and say "Oh yeah, you know I did this", or "I can see that!" [Then] you have a kid with his head on the desk, and you know he's into skate-boarding and so you start talking, "Hey, did you ever wonder on your skateboard why this happens? This is exactly what we're talking about – the friction" or, "What do you notice when you're riding your skateboard on a wet surface versus a dry surface?" And so you involve them with their own experience and all of a sudden you've got them. (Todd)

Jan realizes the importance of meeting kids where they are, not where you expect them to be. She offers alternative assignments and assessments to meet individual needs. She states:

> I try to provide alternatives so it's not that I expect all kids to achieve this level and that's the only way that you're going to exit out of here. I've got to reach them at their level to begin with. For instance, I had a girl last year suffering from depression. [She was trying] to get the diagnosis and trying different medications. One day she was all for it, another day she didn't want anything to do with a physical activity type thing. I was very lenient with that. Another girl this year is troubled with migraines. So you can't be black and white. (Jan)

Ed also holds high expectations for all of his students, but is willing to give second or third chances when appropriate. He can be caring, but he can also be demanding, which shows he cares. A couple of quotes from Ed:

> I don't settle for too much below a "B". I give a second and third chance you know, versus mark 10 wrong and get a "D" or and "F". When I'm working with kids and showing them a math problem or a little work, if there's a little thing I've seen that [is a concern], well, I kind of just talk under my breath to them that some things they need to think about and do that with them.

Reaching out to students who are on the fringe, whether they are special needs or gifted students, is a priority for Robin. She describes a field trip she arranged recently:

> We have quite a high percentage of ELL, English Language Learning group of students. They tend to get isolated no matter how hard we try to integrate them into the classroom. So one year we talked to our highest kids, our Integrated IIIs, and these kids are very gifted. I said "I'm going to try to arrange a field trip, but the only way I'll do it is if you promise to partner up with either an ELL, a resource, or a student with some disabilities, and the whole day is spent in partners. You can choose. But you can't clique off with your usual classes." I thought we were going to have the Integrated IIIs explaining things, but it worked both ways. It was amazing The whole day the interaction was positive, nobody felt put down, nobody felt superior, they were just people out there learning just like everybody else. (Robin)

Even though these teachers are positive and caring, they are not afraid to be tough when the situation calls for it. They view this as a part of their caring, nurturing relationship with their students. Here a few quotes that illustrate this point:

> I hold them accountable and they know that from day one. They know I'm tough, I'll never win Teacher of the Year. (Kathy)

> I think I come off with high expectations. I call them on the first infraction. So I don't let things go until they build up, I'll acknowledge something right away, not in front of the whole class, but on the side. I never would ever try to shame a kid in front of other classmates. (Jan)

> When you threaten them it's already gotten out of hand and you've missed something. That happens. But you try to head off problems before they start. (Todd)

> The kids know I can be pretty gruff with them, but they also know that I'm the one

in the corner for them. Even if they got a good bawling out one day they come back the next day for more. I always tell them that "Remember, besides your diploma in the spring, you have to get a certificate from me that says you survived Barking 101, because you're going to have that all your life." Sometimes they have the tough love. It doesn't mean the huggy hug kind of love, sometimes it's the tough love that you are going to get this done by golly, and that's it. I've told them that the day, if I feel you need it [being barked at], the day I stop and you know you needed it and you didn't get it from me, then that's the only day you need to worry. Because that's the day you know that Mr. X [Ed] gave up on you. (Ed)

Encouraging Students

Assuming the role of an encourager means that teachers must find ways to look for the best in every student, to motivate, and to reduce stress and uncertainty. Here is how these exemplary teachers fulfill the role of encourager:

One boy is going to a tournament tomorrow and I pretended I was kicking a hockey puck to him, and I said, "Whose job is it now? You know, you've got a great support system, good teachers, good paras [paraprofessionals], good students aides, you have peer tutor lists, we have wonderful counselors, administrators, your parents, your sisters, your brothers, your cousins, your neighbors, your friends, but who has to kick that hockey puck? The whole team can be working for you, but if you sit down on the ice..." And they get it then. I try to really reward kindness, generosity, helpfulness, not just straight "As" in math. I try to validate whatever that individuated high potential is, not standardized test definitions of what high potential is. (Robin)

I have a saying that I've had in the room for years that my father always raised us kids by, "Remember a winner never quits and a quitter never wins." Now even if you are, it doesn't matter, you don't have to be the first one across the finish line. You can be the very last one across the finish line, but because you crossed that, you're a winner. But if you stopped along the way because everyone else was already across that line two hours ahead of you, then how do you know if you couldn't have won? (Ed)

Todd faces the challenge of trying to motivate low-achieving students in his high school physics class. One technique he says works well is to sit down with the student and actually having a conversation around the question, "What is it going to take for you to do the work?" By doing this, he and the student can make a plan together.

Kathy encourages her students to take risks by role modeling: "Students are not afraid to take risks because they see me take risks first." Jan strives to put students in a position where they can be successful "so they might be more of a support and then be a leadership role when they're ready." Heather role models motivation to learn by being a high energy person and by "being spastic." She says, "I get excited, that's where it starts."

All of these exemplary teachers exhibit a love for children and a willingness to build learning environments that are emotionally safe and promote academic achievement.

Relevant, Inquiry-Based Work

Providing relevant, inquiry-based class work is another theme that emerged from the teacher interviews. All of the teachers expressed how important it is to get students emotionally engaged in their learning, and one way they do this is to offer content that is meaningful and relevant to the students.

Heather is adamant that science lessons are presented through hands-on, inquiry-based problems that she challenges the students to solve. "Inquiry is the way to teach science, inquiry is science", she claims. Her class usually starts with a warm-up activity or questions. She encourages the students to play around with the material and infer the answers. For straightforward topics she employs full inquiry and for more complicated topics she employs guided inquiry. "What happens if you do this? What do you think is the answer to this?" are two of her favorite questions. She always tries to link science with real life examples, such as musical sound waves and building materials.

The following quotes provide an insight to the variety of creative, relevant topics that these exemplary teachers teach:

My health classes deal a lot with kind of personal, kind of self-help things and wellness issues like stress management, fitness, sexuality. It's all related around the positive. [We do] some role playing. You could speak it all day long, and have them writing a book, but until they're actually speaking it, doing it, they're not going to really grasp it. And in health I think it's the same way. If we're talking about refusal skills, say, if we're talking about sexuality or how do you say no in a dating situation when it might be progressing past the point, you know it's kind of more controversial issues, but like sexuality. But if they don't practice that and I just say, "Oh, you know, you've got to say a clear no statement." You have got to be assertive, and these [are] the steps, and okay, practice this with a partner. (Jan)

After Todd took a graduate research class, he thought of how he could apply his new-found knowledge to his high school curriculum.

So when I came back [from a sabbatical], I said "Okay guys, we're going to put together a research journal like Science Magazine. You guys are going to get into groups and you're going to come up with your own experiments that you devise. Our goal is to make it nice and concise, a two-page research article on anything you want that's dealing with physics." Kids [looked] at different kinds of bathing suit material and how they affect drag in the water. And these guys looked at all the factors that affect electromagnets, number of windings, the coil, the voltage, the current going through. This girl was interested [in] how different colors absorb different amounts of light, why you have a black shirt it absorbs a lot of light. She thought maybe that impacts how fast water freezes, and so if I freeze different colors of water is there a relationship with how it absorbs heat energy versus light energy? I said, "These don't have to be elaborate experiments, they just have to be something that interests you, and that you don't know the answer to, but you can do an experiment for it and figure it out." It's really evolved into something we're proud of, and the students are really proud of. (Todd)

Robin tried a new technique for her most recent math review:

Today we did a silent homework race. So I did a review sheet, and they were allowed to work in groups but they couldn't talk. Where this came from is that being able to explain things [is] a high correlate to problem solving. So today they were allowed to work in groups, but they had to be silent and they had to write their explanations to each other, and it was a race. And it was amazing. I saved the dialogue sheets, they were just awesome! They got done with the homework, whoever got the most problems right got a Jolly Rancher. I actually reported the dialogue sheets to our administration. "Dang it, number ten! Ew! Gr! How do you do four through nine? On that? Don't you remember [the teacher] told us to use ratios on that one? How about proportions? Is this 90 degree rotation or is this a reflection? Does anybody know how to do number 16? Ben, what are you drawing? What is a dilation?" See, this gives me amazing insight. (Robin)

Kathy described a relevant, inquiry-based lesson she does with her 7th-grade social studies class called "African Market." It involves first researching peoples in an African country, drawing situation cards for your group, and then experiencing a simulated market day which involves all bartering, no money, just your group's "wealth cards." The object is not to be rich at the end of the market day, but to have all of your group's needs met. Kathy claims this lesson is good because it's "participatory, authentic and hands-on." It also makes students think about cultural differences.

Ed likes his "Blockbuster" reading series that he starts every year after Christmas. This is how he describes the activity:

> I'll start with a three-day read-a-thon, they bring in their sleeping bags and pillows and snacks, and for three solid days we don't do anything but read. Because of their lifestyle, and they don't have any modeling [at home] when it comes to their reading, you need to provide that opportunity for some kids. Sometimes you've got to bag the schedule and give them enough time to try to get them into it and whet their appetite. This year's group is one that has a lot of reluctant readers in it, and it's because, well, half the class has families that are multi-level, messed-up families. And they're all from dysfunctional families. (Ed)

These teachers are aware of what makes good teaching: "trying not to spoon feed so much and let them discover it more" (Robin), "there are different, variable ways to do the same thing." (Todd), "I think they learn by teaching someone." (Jan), "I don't like step by step." (Heather). They strive to be interdisciplinary, too, to connect their content area with other content areas. Kathy describes herself as a "Renaissance woman." She reports, "I don't think I will ever run out of ideas." These teachers' rich personal and professional backgrounds enable them to pull many concepts together across disciplines in a relevant manner.

Characteristics of Teachers

The second big theme that emerged from my data is centered around the teachers themselves, what they are like and what they are learning about. Of course, this theme is related to the process theme also.

Lifelong learners

The teachers I interviewed are role models for their students because they themselves are lifelong learners. When asked where they get their teaching ideas from, they all mentioned "from myself", although at the beginning of their careers they often looked to textbooks and curriculum guides for help. They draw from multiple sources for inspiration, including relatives, master teachers, their students, colleagues and the environment around them. Here are a few examples of my findings:

> Well, at the very beginning of my career they [ideas] came from my aunt that was a second-grade teacher, other they just came out of myself, books, looking at how other people have set up their rooms and then conjuring in mine, and then kind of being able to take an idea and think, well, it calls for this, but if I add this to it, kind of change it in my own mind, and that's just where it comes from. (Ed)

> As a beginning teacher I think they [ideas] come from other teachers, primarily, and the textbook, the resources you're given. But over time I have ideas and say, "I wonder if this would work", and you know it develops into a lab. Students over the years have brought in things. You go to workshops and pick up an idea here, an idea there. (Todd)

> A number of places. Past teachers' ideas, good things and bad things I have done, from my first job at a high school, especially the influence of a colleague there who was very inquiry-based, hands-on activities I make up myself from my work with gifted and talented students. (Heather)

> I remember my first years of teaching. I can remember my first few very vividly because I think when you come out of student teaching and in the teacher ed programs you feel ready to go and take your own classroom, but those first few years are definitely a sink-or-swim. I was put into a department of very outstanding teachers that all worked together. I went to the principal and asked who are the master teachers of the building, or who are known for their unique approaches, and every off hour that I could muster I would go observe. So that really helped me because I

watched, I learned about cooperative learning and some different techniques. (Jan)

When asked, "Where do the ideas from your teaching come from?" Robin answered:

> Everywhere. Everywhere. I can be in the grocery store watching comparative prices and there's my lesson for unit ratios and unit prices and rates. From students, a lot of times I try to find out what their background is, what they're interested in, what they already know, Dr. Richburg, other teachers, I've tried very much to tie into other curriculums when I do scientific notation, the science teachers and I get together. (Robin)

Todd especially had a lot to say about where he gets ideas for the many labs that are a essential part of his physics program. He proudly showed me his notebook of labs and noted:

> This was a lab that I made up. This is a lab from a canned program that we used to teach. This lab is a computer program that a student made me aware of and brought in, so I incorporated that the following year. This was one of those general labs out of the book. This one I made up, [these] I kind of stole from another program. Here's one I read about in a book. This one I developed with some other teachers in a summer workshop. My student teacher's mother-in-law sent him this article and we told the kids about it. (Todd)

These exemplary teachers are busy continuing their professional education by taking classes, serving on the boards of professional organizations and participating in professional development workshops. Todd has just finished his master's degree in chemistry. Heather is taking a master's level class in ecology and an on-line chemistry methods course. Jan works on curriculum issues in health and physical education with the district. Kathy attends workshops on Pre-AP courses in addition to history courses at the local university. Many of the teachers expressed how much they have learned from their student teachers and practicum students. They also continue to learn about teaching methods and strategies. Todd mentioned that he is learning about the AVID tutoring program, Socratic seminar and other questioning strategies. Kathy and Jan both related that they are trying to integrate more technology into their teaching. Robin was excited

about the prospect of obtaining a grant to use white boards in her math classes.

When asked "What are you learning about now?" they dug deeper than the traditional academic answers, although that was important to them, too. They are learning other skills that are personally or professionally meaningful to them:

> I'm learning to be a better parent. (Todd)

> The biggest new learning I've had, is the fact of finding that there's a lot of people out there that do craft fairs, they're trying to pay, they're retired, they're crippled, emphysema, all kinds of things, rheumatoid arthritis, they're getting tremendous bills that Medicare doesn't always cross, so they're trying to do something like this [selling crafts] that will help make their ends meet. Consequently I've met an awfully lot of nice people that would give you the shirt off their back from across the country and I've learned an awful lot about people, some things you don't want to know. (Ed)

Ed mentioned this because he helps fund his students' "Eco-Week" field trip by hosting craft fairs in his home to help subsidize the students' fees.

> I always try to stay open to learning. Not just from academia, or math, or masters, or research, but also from the kids. You can learn a lot from every kid, every student. Daily I learn, always, some kind of down-to-earth lesson like boy I misread that kid. You know because he came up to me later and said, "You know Grandma had a car accident last night", and I thought he was just being flippant. So it's always humbling. That's an ongoing learning thing too. (Robin)

> I love to scrapbook, so I take classes a lot. I'm learning to ride dirt bikes with my boys. Well, they ride the dirt bikes, I ride the four-wheeler. (Jan)

> I just enjoy gardening. I can lose myself for hours in designing a flowerbed and doing it over and over again. (Ed)

It appears that this group of exemplary teachers has a good balance between their careers and personal lives. They work hard and have open minds about learning new things. "There's never been a day when I didn't want to come to work", states Kathy.

Lack of Articulation

Only one of the six teachers interviewed has had any kind of formal training in brain research or brain-compatible teaching techniques. When asked directly, "Have you had any kind of brain-based instruction or professional development?" these are the answers I received:

> I've never had a class that would say anything like that, that was based on that [brain research], that I'm aware of. I mean it might have been a class like that, but called something different. (Ed)
>
> I don't know how to answer that. (Kathy)
>
> A little. I just read a *Brain-based research: How we learn* booklet. (Heather)
>
> I would say very superficially. (Todd)
>
> You know I've heard about it. In fact one of my colleagues went to a seminar or whatever they call it, I think Dr. Amen was his name. She said she was really pumped up. I remember her talking about it. Now as far as myself being in any specific work-shop like that, I've not taken one. Something I would be interested in learning more about, I'm sure. So my instruction is not, definitely not based on brain research because I don't know what it is, really. But I should, huh? (Jan)

Robin was the only one of the six teachers who had experienced any kind of brain-based instruction or professional development. She was quite knowledgeable.

> I think the brain research is really a revelation. When you consider what a high percentage of what we know is in the last five or ten years because of technology. That absolutely fascinates me. If we can really figure out and get in there and see which kids have the thick dendrites and how those connections and permutations are being made, I think that's...after I finished my work with Dr. Richburg in that research, I still continued to take a bunch of those courses. I did an on-line course with the University of California on brain-based learning that had audiovisuals and writings, and examples, lots of different writers in that course, it was really good. I've done a lot of reading. I took a brain-based course post-master's. (Robin)

The other five teachers either had no idea what was meant by the term "brain-based instruction", or they attempted to connect some of their prior knowledge about other

aspects of teaching that they thought might be considered "brain-based." Todd thought that learning styles and the Myers-Briggs personality test were related to the concept. He says:

> I have a sense that it [learning styles, Myers-Briggs test] really work, too. (Todd)

When asked why he thought it works, he replied:

> Otherwise people wouldn't be talking about it. And definitely the direction research is going. I trust my colleague that says "Hey, it's [brain-based research] worth looking into." From my understanding now I'd be hard pressed to distinguish what the buzzword "brain-based research" is from learning styles. They would almost be synonymous to me at this point. (Todd)

Heather reflected on her familiarity with differentiation and multiple intelligences, thinking that these may be pieces of brain-based instruction. She also mentioned her work with gifted and talented students. Kathy and Ed could make no connections to prior knowledge about the subject. Then we discussed professional development opportunities:

> One Wednesday a month we're supposed to have a staff development. We either pull in an expert or find an expert on staff that'll give us clues. (Todd)

> There's a guru person or name for something every five years. Something comes on the table again. I can remember Madeline Hunter, Common Learning, then it was cooperative learning for a while, and now it's differentiated learning, and probably now the brain-based, it's always something that evolves. I think the brain research, I don't think it's been big in our district. It's interesting that different districts around the state or in the country will pick up on different things and that's their big thing or push for a few years. And then it kind of evolves to something else. I think our district jumps on those bandwagons, and then there's not much follow-up afterwards. Like we'll all have this huge workshop or session or two-day whatever, and then it kind of fades off. (Jan)

Summary of Phase II Findings

I felt this statement from Jan was a good ending to Phase II of the study. This phase concludes with the realization that these exemplary teachers are doing wonderful things

in the classroom, but, with the exception of one person, cannot articulate why what they are doing "works". Chapter five will pull together the following strands: the principles garnered from the literature review, the educational theorists' comments, the teachers' statements, and the portraits of brain-compatible teachers offered by Caine and Caine and Smilkstein to analyze where the gaps are, if any.

CHAPTER FIVE

Discussion

The following discussion will be comprised of five sections: summary of the findings, conclusions, recommendations, needs for future research, and a final summary.

Summary of the Findings

The purpose of this study was to explore the characteristics of brain-based instruction and to determine if these characteristics are incorporated into teacher preparation programs and classroom instruction by identified exemplary teachers. This qualitative study was conducted in two phases. Phase I involved interviews with ten authorities in the area of brain research to confirm, disconfirm or add to the five principles of brain-based instructional characteristics that emerged from a review of literature. Phase II involved interviews with six exemplary secondary teachers to determine to what extent they are aware of and integrating the brain-based characteristics into their classroom instruction. I used a semi-structured approach in my interviews that were a mix of structured questions and semi-structured questions. Three broad questions were asked of the educational theorists, and nine questions were asked of the teachers. All questions were aligned with the emergent characteristics of brain-compatible instruction. The following sections summarize my findings.

Phase I

The Brain-Based Instructional Characteristics

First I discovered that the majority of theorists do not use or like the term "brain-based", claiming that all learning is based in the brain. They also hinted at commercial overtones of that "uselessly redundant term." Consequently, to honor their perspectives, I will use the term *brain-compatible*. The five principles that emerged from the review of literature: the roles of an enriched environment, emotions, physical systems, stress and threat, and authentic work, challenge and problem solving, were all validated by the theorists through their insightful comments and personal stories. The overarching concept is one of an enriched environment, and the other components fit into this concept. The principle of *movement* was adjusted to refer to *physical systems*, which includes the ideas of spatial orientation and homeostasis, as suggested by Theorists C and E. The physical systems characteristic was the one with which the theorists were most at odds, citing that more solid research needs to be done in this area.

In addition, the "role of experience" was added as a characteristic of brain-compatible instruction after several theorists made reference to the importance of experience in shaping our brains. The implications of this characteristic will be addressed in the "brain-compatible teacher" section.

Another topic that the theorists chose to address at length is teacher preparation, both for pre-service and practicing teachers. This topic was not specifically included in the questions posed to them, but it emerged inductively. Recommendations for teacher preparation and professional development cited by the theorists will be included in the "conclusions" section.

Phase II

In order to discover if the six exemplary teachers were aware of or integrating the five brain-compatible characteristics identified in Phase I, I framed the nine questions posed to them around these characteristics. Each question was related to two or more of the brain-compatible characteristics. The following is a summary of the emergent themes from this data rich study.

Characteristics of Teaching Process

The theme of teaching process characteristics emerged from the teachers' answers to questions about the classroom environment, grading and evaluation, activities and experiences they use in their teaching, sources of teaching ideas, and maintaining order. All of the exemplary teachers addressed the emotional climate of their classroom by stating that they try to keep it positive, friendly, homey, and caring. Fostering respect and connections among students was very important in establishing a good emotional climate.

Another factor that contributed to a caring climate is the physical layout of the classroom. None of the teachers arranged their classroom in a traditional classroom format of desks in straight rows. Room arrangements revolved around tables, flexible group configurations, and diagonal rows to facilitate both social interaction and the need for individualization. I observed that artwork, posters, student projects, plants, interesting objects and good lighting enhanced the overall climate in each classroom.

Caring was defined by many of the teachers as being a "family" in the classroom. By this they meant that everyone worked together, encouraged each other, and stuck it out through thick and thin. Two of the teachers set up a peer tutor system. Robin states, "I

do a peer tutor list so they can call each other. It's volunteers, they put their number down knowing anybody can call, and they both benefit, the person that explains and the person that is lost on a problem or sick, or at home." Teachers were willing to meet students where they were, both emotionally and academically. They worked on building connections between the academic material and students' interests.

The role of encourager seemed to come easily to these teachers. They looked for the best in every child. They viewed each student as having potential, and did not define the students by their grades or achievement. "I hate grades," states Robin. "I hate that it becomes the identity of the kid. So many times kids don't keep going because that grade defines who they are." Todd adds, "I grade the homework on effort rather than correctness." All kept expectations high, while putting children in positions where they can taste success.

These teachers were very respectful in their approaches to discipline. Threat and shame were not used to coerce good behavior. "I set the tone the first day", says Kathy. She earns students' respect through challenging work, showing her grasp of the content, and by caring. Ed added that he has instituted "cloud talks", which are inspirational talks during "teachable moments". He uses his cloud talks to help kids deal with real-life problems and to teach life lessons.

The theme of relevant, inquiry-based work surfaced from the teachers' answers to the questions dealing with inspiration for teaching ideas, activities and experiences utilized in the classroom, approaches to grading and evaluation, and motivation to get high achievement from their students. The teachers were eager to share their teaching ideas and exemplary lessons with me. The words most often used to describe their teaching

were: *inquiry-based, problem solving, experiments, authentic, hands-on*, and *discover.* Play and fun were also components of their students' classroom experiences.

The teachers were all willing to meet the students where they were. After establishing a knowledge base, these teachers encouraged students to explore and discover topics that were of personal interest through role plays, research projects, simulations, experiments, and field trips. Students were empowered to construct their own meanings from the content. Framing the material to be learned was crucial. "I think first of all you have to let them believe that they have potential, it's significant, relevant, and matters", (Robin). Kathy adds, "so much of what I do is psychological."

No one mentioned starting their lesson planning solely from the textbook or curriculum guides. Instead these teachers tapped into their students' interests and prior knowledge, expanding on it, just as dendrites grow from stubs, searching to connect with other dendrites.

Characteristics of Teachers

The theme of lifelong learners as a teacher characteristic emerged through the teachers' responses to questions dealing with the sources of their teaching ideas, activities and experiences used in class, and the direct question, "What are you learning about now?"

The interviewees related that they have been constantly learning about new things throughout their careers, although many admitted to getting their initial lesson ideas from textbooks. Since they have felt more comfortable in the classroom, their teaching ideas come from "themselves". They view real-life experiences and social interaction as rich sources of inspiration for teaching and personal growth. Life lessons learned became

integrated into classroom instruction. Ed relates, "I use what I consider folksy little things and homespun ways to create the atmosphere in my classroom." Kathy keeps 3x5 index cards handy at all times for "when inspiration strikes." Many were involved with professional organizations, taking graduate classes, mentoring student teachers and obtaining grants for improving classroom instruction.

However, professional growth was not the only facet of their constant learning. Mention was made of learning to be a better parent, of realizing the struggles of people's daily lives, of avocational, enjoyable pursuits such as scrapbooking, gardening and riding four-wheelers. Finding balance in their lives seemed important, too.

When asked the direct question, "Have you had any kind of brain-based instruction or professional development?" it became clear from this study that this has not been a topic that has been addressed in either teacher preparation courses or professional development. Only one of the exemplary teachers had any familiarity with brain research. Although the teachers were using many of the brain-compatible techniques in their classrooms, they were not able to articulate why these techniques were successful. Except for Robin, the teachers were functioning intuitively and had learned through trial and error what strategies were "working." All expressed frustration during their beginning years of teaching, citing the need to rely on the textbook and/or curriculum guides, experience, or mentorship from experienced teachers. Learning styles, cooperative learning, Madeline Hunter's work, and personality tests were offered as possible components of brain-based instruction, but no one, except for Robin, was really sure yet what this entailed. "The kind of brain-based teaching that educators should strive for is that which is informed by the most up-to-date research knowledge of the role

of the brain in teaching and learning reading, writing, math and other content domains", cites Theorist H. Theorist D adds, "One needs a good introduction to awaken people to the fact that all learning comes from the brain, and give them an idea as to its magnitude." In the case of the exemplary teachers interviewed in this school district, my study indicates an existing gap in the teachers' ability to articulate their work. This finding is reinforced by Theorist A, who notes, "sometimes we [teachers] are not considered to be professional because we cannot articulate our craft and what we do."

Conclusions

This study sought to explore the characteristics of brain-compatible instruction and to determine if those characteristics are incorporated into teacher preparation programs and classroom practice by identified exemplary teachers. My comprehensive study has identified six characteristics of brain-compatible instruction that were validated and expanded upon by a panel of ten educational theorists. The door is left open to discover other relevant characteristics that may emerge through future brain research. Memory, transfer of learning, attention, brain plasticity, perception, and consciousness are just a few of the possible areas for future study.

The question of application of neuroscience in the context of education remains controversial. The theorists interviewed for this study held different views on this issue. Some believed that there are direct applications possible between current neuroscientific research and classroom practice. Others were more cautious, citing the model of neuroscience should be first linked to cognitive science, and cognitive science then linked to educational theory. They stated that brain-compatible or brain-based instruction is not a program, a model or a package for schools to follow. "Brain research is not a panacea

that is going to solve all of our problems," according to Theorist A. It is difficult to find irrefutable "proof" in this field. The theorists encouraged educators to learn about brain physiology, to keep up-to-date on current research through professional development, and to participate in bi-directional classroom research with cooperating universities.

Teacher preparation was a topic often mentioned in my interviews with the educational theorists. Theorists D and H advocate for formal pre-service training in neuroanatomy so prospective teachers "will learn where learning really starts." Theorist H states that it is "best not to rely solely on the media, popular books, or workshops for valid information about neuroscience, which requires concentrated training in a discipline that has a knowledge base that has to be mastered." Theorist G validated this idea by saying, "teachers need to be cognizant of how the brain constructs knowledge and build students' learning in a similar manner." Theorist J wonders if teaching would improve if we knew more about the biological basis of learning.

The concept of "rough draft" learning, where we [teachers] often sacrifice accuracy for simply getting something "close", was offered by Theorist F. Teachers should know how to increase the importance and relevance of learning in order to upgrade rough drafts to improve meaning and accuracy. Both teacher preparation programs and classroom instruction can benefit from the rough draft concept.

Theorist B would like to see teacher preparation programs embrace the educational equivalent of a teaching hospital. He cites the necessity for practice and research conducted between classrooms and universities as a way to promote connections within brain and cognitive sciences, and education.

Only one of the interviewed teachers had any background in brain research offered through a university, and that was at the graduate level, not a pre-service level.

Professional development was another topic that was addressed by both the teachers and theorists in my study. I discovered that, unless teachers actively seek out opportunities to learn about brain research, it is not often available through local school districts. Other stumbling blocks to learning about brain research that were revealed in this study are: the time and diligence required to understand it, poorly-communicated or boring presentations by presenters, professional development that is not based on current peer-reviewed research, and the fact that brain-compatible learning is focused on learning, not test scores, which can make it unpopular with administrators.

Trying to define what a brain-compatible teacher looks like is a difficult task. The teachers who participated in this study embodied many of the brain-compatible characteristics identified by Caine and Caine (1997) and Smilkstein (2003). Their classrooms were student-centered, where students did the work of learning, personal connections were made with the content, and learning was scaffolded to meet students' needs. Other brain-compatible descriptors fit these teachers: many of their instructional ideas come from non-traditional sources, they are authentic and embrace change, they are reflective, and they are able to choose an instructional approach based upon context.

As far as the brain-compatible instructional characteristics discovered in this study and validated by a panel of educational theorists, these too were integrated into classroom practice. The overarching concept of an enriched environment was supported in each teacher's classroom by the sub-themes of emotion, physical systems, reduced stress and threat, authentic, relevant, challenging work, and the added role of experiential learning.

My study revealed that these exemplary teachers are caring encouragers, teachers who foster and nurture students through positive emotional and physical classroom climates. They offer their students relevant, challenging work. They empower their students. Some salient quotes from the teachers support this finding:

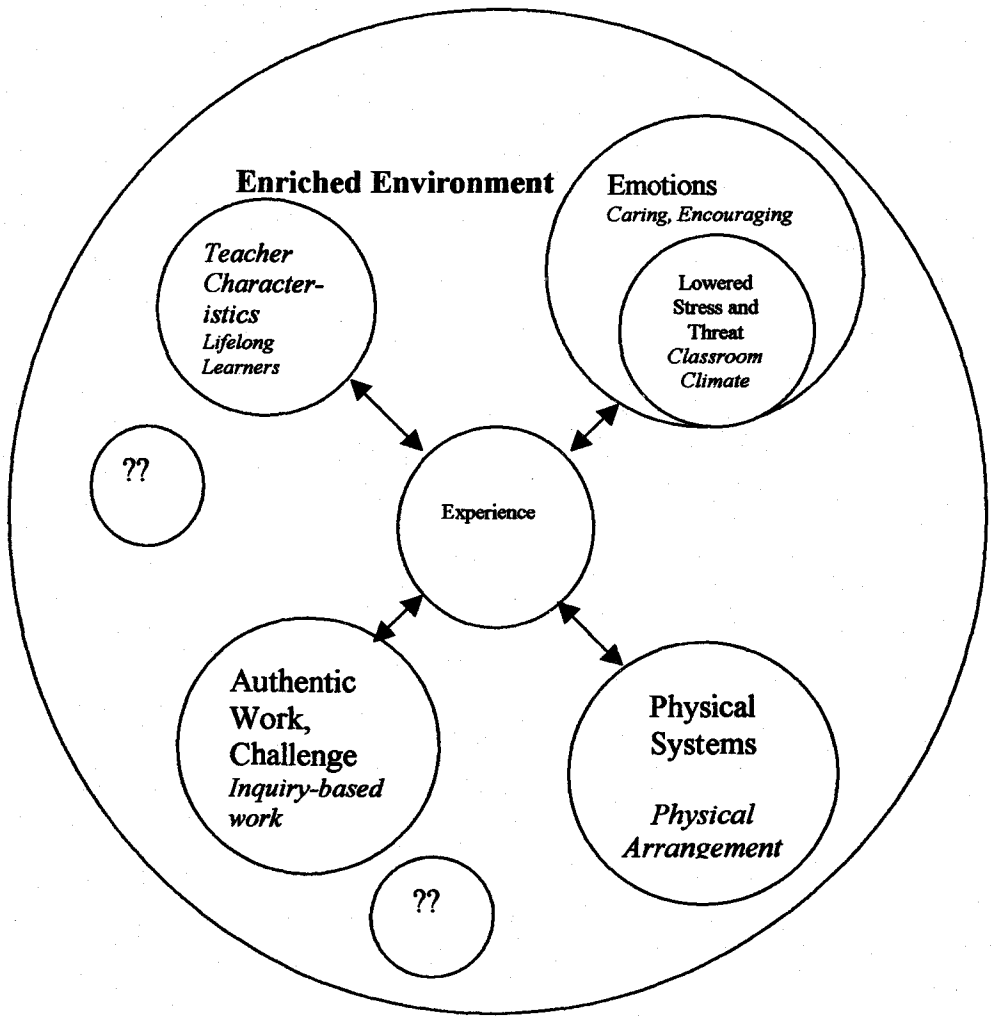
> I realized that this place [her junior high school] has my soul. (Kathy)
>
> That's what you try to emphasize with the kids, that "family". You fight together, you work together, and get through and you grow together. And that's the biggest part. And that they are ultimately responsible for their education. That they have an inner fire in them that they were born with, and it's a flame. Life will do its very best in all parts of life to douse that flame and put it out. But no matter what life does, they're the keepers of that flame and they are responsible for having that flame lit. Now if it's flickering, they are responsible for giving it kindling so that it can rejuvenate and go. I think that many of them sensed afterwards that when it was all said and done [his class], that they had someone that cared. (Ed)
>
> I tend to make things work instead of hiding from it [problems, challenges], or trying to do the minimal. You have no control over them learning, you can only influence them. (Heather)
>
> I feel I can make a difference in the lives of students. Not just academically, but personally, too. When my students are successful I feel I am successful. I get a kick out of their successes. (Todd)
>
> I try to just be positive, a positive role model for my peers, teaching and also for [students]. I've never been one of those that just complain, complain, complain. I like getting evaluated. (Jan)
>
> I think it's real important that the kids know there are 30 teachers in that classroom, not one. And usually the first time I ask that they'll say "one." They don't anymore because they know that they're learning from each other and that I'm learning from them, too. And that I'm not on some kind of pedestal. It's almost like a cheerleading thing. You know, you're just cheering them on all the time. They've become their own cheerleaders, too. (Robin)

Figure 3 depicts the integration of the six brain-compatible teaching and learning characteristics from the Phase I theorists with the emergent themes from the teachers in Phase II in italics. The role of experience is placed in the center of the model, with the added roles of emotion, physical systems, authentic work, stress and threat, and teacher

characteristics revolving around it. Smaller circles with question marks indicate other components of an enriched environment that were not identified in this study, but may include novelty, feedback, perception, prior knowledge, and other possible components.

Figure 3

Model 3: Brain-Compatible Principles Integrated with Teachers' Themes



From the theorists' definition of a brain-compatible teacher, the missing component in describing these teachers as brain-compatible is a working knowledge of the brain. Intuitively these teachers are doing the right things, but the problem with intuition, according to Theorist A, is that it's "sterile." Kovalik and Olsen (1998a) also point out that practicing teachers are often unaware of the research regarding how the brain learns best. Several quotes from the theorists confirm the need to incorporate knowledge of how the brain operates into teacher preparation programs:

> Right now our better teachers are doing a seat-of-the pants thing, you know they've got a feel for it. "This really works." But I think we can narrow it down so we're not guessing so much. (Theorist C)

> When I mention to colleagues in disciplines outside education that teachers receive no formal training in the brain, the organ of learning, as part of their formal pre-service teacher education, they are appalled. Yet, when I suggest to colleagues within the field of education that there be such a requirement, they are equally appalled. They retort that teachers have been teaching effectively without knowledge of the brain for years. That is and is not true. Many master teachers have been effective without knowledge of the brain. At the same time, many students with learning differences (normal variations) or learning disabilities (atypical variations) have not had their educational needs met. If more teachers had greater understanding of the brain, we might be able to optimize the learning of all students. (Theorist H)

> [A brain-compatible teacher] draws on cognitive neuroscience, psychological, and educational research in a continual search to provide the best possible instructional environment for students. (Theorist I)

> A [brain-compatible] educator is one that understands why she does what she does. It is also one who stays constantly updated through continuous professional development. (Theorist F)

> So a teacher that I think is brain-compatible is aware of how the brain learns, and how kids learn, and is using that information to engage students in a meaningful, relevant curriculum. Brain research is a piece of the big picture. (Theorist A)

In my analysis I have found that brain research helps provide a part of a conceptual framework for educators as they seek to enhance effective teaching. A conceptual

framework recognizes the "system of interacting components, all of which must be orchestrated to achieve literacy and numeracy goals" (Berninger & Richards, 2002, p. 304.) The interacting components of neuroscience combined with cognitive science, psychology, biology, linguistics and educational research can validate good teachers' practices and motivate other teachers, including pre-service teachers, to begin to articulate their craft. This conceptual framework will also aid teachers to become highly qualified and to optimize achievement for all students. As noted by the American Federation of Teachers (2000), it is vital that teachers learn from scientific research how people learn.

> Imagine all the teachers teaching well, experts in nature-nurture interactions, who *fill the mind* in individually tailored ways, guided by scientifically supported principles of the brain and instruction, and by cultural sensitivity. (Berninger & Richards, 2002, p. xvii).

Recommendations

The purpose of this study was to explore the characteristics of brain-compatible instruction and to determine if these characteristics are incorporated into teacher preparation programs and classroom instruction by identified exemplary teachers. The following recommendations may be beneficial to students, teachers, teacher educators, administrators, policy makers and staff development personnel.

1. An enriched environment is identified as the major component of ideal teacher preparation and classrooms. Students learning to be teachers should experience their profession in an enriched environment that includes the components of emotions, physical systems, relevant work and problem-solving, caring and encouraging, and positive role modeling by instructors. Experience is what shapes

the brain. Students need to learn through experience how to create and work in an enriched environment. The university setting may not be the optimal place for teacher training.

2. University School of Education faculty should lead the way in role modeling best instructional practices, not only for teacher preparation programs, but across the university, through conferences and symposia. University faculty should strive to provide enriched environments in their courses.
3. In addition to being taught in enriched environments, teacher preparation programs should include coursework on current brain research as it connects to educational theory and pedagogy. Teachers expressed their sense of frustration in planning lessons and teaching well during their beginning years of teaching. Sylwester (1997), Caine and Caine (1997), and Jensen (1998) are concerned that pre-service teachers have access to recent brain research and findings in cognitive science. Teachers should become articulate about what they do and why.
4. Professional development opportunities for some teachers are limited or poorly conceived. Staff development personnel should base their presentations on current peer-reviewed research and make the applications of the research relevant to practicing educators, keeping in mind the differing levels of teacher expertise and needs.
5. Practicing teachers in this study cited the desire and need to learn from others. The elements of peer coaching and mentoring should be built into professional development programs for both beginning and experienced teachers.
6. "Teacher educators develop, grow, and change, but the literature on them fails to

reflect these conditions" (Ducharme & Ducharme, 1996, p. 1043). If pre-service teachers are expected to learn about recent developments in neuroscience and cognitive science, then their teachers (university faculty) should know about these topics in depth (Smilkstein, 2003). Teacher educators should educate themselves about the interaction of neuroscience, cognitive science, and educational theory to better prepare teachers to be competent and highly-qualified. This includes faculty who teach graduate-level courses, for the exemplary teachers in this study indicated that they were not articulate about their profession and often functioned on intuition.

Needs for Future Research

As a result of this study, several recommendations are made regarding future research around the topic of brain research and classroom practice. The following are suggestions for future research:

1. This study focused on exemplary secondary teachers only. A similar study should be conducted on middle school or elementary teachers to ascertain their perceptions and integration of brain research into classroom practice.
2. Teacher preparation was a topic of discussion in this study. Further research should be conducted with teacher educators to ascertain their levels of familiarity and integration of brain research into teacher preparation programs at the post-secondary level.
3. An extension of this study would be to interview the students of the exemplary teachers to determine their level of satisfaction and achievement in their classes.
4. Studies should be undertaken to determine how teaching and learning are improved

when a teacher has an understanding of the biological basis of teaching.

5. More bi-directional research is needed between universities and schools in the area of brain research and its applications to educational practice. Professional Development Schools or other partnership models between universities and schools provide an excellent opportunity to pursue bi-directional research.

Final Summary

"Teaching is the art of changing the brain....creating conditions that lead to change in a learner's brain" (Zull, 2002, p. 5). If teachers are to assume the roles of brain changers or brain sculptors (Expert A), knowledge of current brain research as it applies to education is valuable and enriching. In this era of high accountability, educators need to continue to better understand what conditions, environments and instructional practices can improve learning for all students. The purpose of this study was to discover recommendations for best brain-compatible instructional practices from the current literature, and to investigate to what extent these brain-compatible characteristics were integrated into classroom practice by exemplary secondary teachers. Through the review of literature, the interviews with brain experts and practicing exemplary teachers, the creation of the Brain-Compatible Teaching Model, the expanded description of a brain-compatible teacher, and the reflections about the existing gap between theory and practice, this study sought to provide direction for future teacher preparation, classroom practice and professional development in order that teaching would "become the applied science of the brain" (Zull, 2002, p. 4) and "move beyond isolated acts of intuition to a comprehensive set of brain-compatible strategies and thus to new and more powerful outcomes" (Kovalik & Olsen, 1998b, p. 33).

EPILOGUE

Epiphanies

While writing the conclusions and recommendations portions of this study, I had an epiphany: I realized that I personally am a brain-compatible teacher! This is a very validating thing to discover about myself. Reflecting on the interviews I conducted with the exemplary teachers, I ultimately began to see myself in them: I was identified as an exemplary teacher in my home state, and as explained in the "Researcher's Perspective" part of Chapter One, I was successful in the classroom. My students were engaged and achieved at a high level. I implemented all of the components of the Brain-Compatible Teaching Model, yet I was unable to articulate why I was successful. This study and my recent doctoral work in brain research have led me to understand that indeed, I did "put the cart before the horse." I am now in the same camp with Robin, the exemplary teacher that I described as truly brain-compatible because she had a working knowledge of the brain in addition to providing an enriched classroom environment. My goal is to be one of the persons who bridge the gap between the theorists and the practitioners through my dedication to teacher preparation and by sculpting my students' brain through enriching experiences.

The second epiphany occurred at my oral defense when one of the committee members thoughtfully mentioned that this dissertation was "one of the scariest he had ever read." When asked why, he explained that this study had made him realize the importance of teaching in a brain-compatible manner, and that by not doing so, could we

be "dumbing down the brain?" Several of us assembled in that room nodded our heads and answered "yes." The committee member seemed almost overwhelmed by the magnitude of the implications, especially at the university level where professors are often not known for being brain-compatible. The ensuing discussion with my committee made me realize the complexity and hugeness of this topic. I am excited to conduct further research around the subject of brain research and its implications for education. I am also excited to keep sculpting my own brain as well as my students' brains!

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APPENDIX A: Letter to Brain Experts Attending Conference

230 Education
Colorado State University
Fort Collins, CO 80523
October 20, 2004

Dr. Marian Diamond
University of California, Berkeley
Department of Integrative Biology
3060 Valley Life Sciences Building #3140
Berkeley, CA 94720-3140

Dear Dr.Diamond,

My name is Jean Radin and I am a doctoral candidate at Colorado State University in the Educational Leadership program. Under the advisement of Dr. James Banning from the School of Education, I am working on my dissertation.

My research concerns brain-based education and its integration into classroom practice. Through a review of literature I have discovered several important principles or concepts for effective brain-based instruction. Your work has frequently been cited in the review of literature.

I am wondering if you would be available for a short (15-20 minute) audiotaped interview with me at the upcoming "Learning and the Brain" conference in Cambridge, MA in November. Your input is vital to confirm or disconfirm my findings. After interviews with other respected experts such as yourself, I plan to conduct interviews with practicing teachers to discover if they are aware of or implementing any of the principles in their classrooms. I will provide a consent form at the time of the interview.

Please contact me at my office phone or via email if you would be willing to participate in my research. I have provided contact information for Dr. James Banning if you need to contact him also.

Sincerely,

Jean L. Radin, M.Ed.
office: 970-491-3808 home: 970-377-2316
email: jradin@holly.colostate.edu

APPENDIX B: Letter to Brain Experts Not Attending Conference

230 Education
Colorado State University
Fort Collins, CO 80523
October 20, 2004

Dr. Rita Smilkstein
Woodring College of Education
Western Washington University
Bellingham, WA 98225

Dear Dr. Smilkstein,

My name is Jean Radin and I am a doctoral candidate at Colorado State University in the Educational Leadership program. Under the advisement of Dr. James Banning from the School of Education, I am working on my dissertation. Your colleague Bob Richburg is also on my doctoral committee.

My research concerns brain-based education and its integration into classroom practice. Through a review of literature I have discovered several important principles or concepts for effective brain-based instruction. Your work has frequently been cited in the review of literature.

I am wondering if you will be attending the upcoming "Learning and the Brain" conference in Cambridge, MA in November. If so, would it be possible to schedule a short (15-20 minute) audiotaped interview with you at the conference? Your input is vital to confirm or disconfirm my findings. If that is not possible, perhaps we could communicate via email, telephone or a video conference.

After interviewing other respected experts such as yourself, I plan to conduct interviews with practicing teachers to discover if they are aware of or implementing any of the principles in their classrooms.

Please contact me at my office phone or vial email if you would be willing to participate in my research. I have provided contact information for Dr. James Banning also.

Sincerely,

Jean L. Radin, M.Ed.
office: 970-491-3808 home: 970-377-2316
email: jradin@holly.colostate.edu

James Banning, Ph.D., Research Advisor
office: 970-491-7153
email: banning@cahs.colostate.edu

APPENDIX C: Interview Protocol for Brain Expert Interviews

Interview Protocol I
Project: "Perception and Integration of Brain Research into Classroom Instruction"
Time of interview:
Date:
Place:
Interviewer:
Interviewee:
Position of interviewee:

(Briefly introduce myself and describe the project using the Interview Protocol I for Phase I document "Introduction and Description of the Project".)

Questions:

1. How would you describe brain-based teaching?

2. Are there certain principles or characteristics about brain-based teaching that you feel are most important?

3. How would you describe a brain-compatible teacher?

APPENDIX D: Informed Consent Form for Experts

Consent to Participate in a Research Study at Colorado State University

TITLE OF STUDY: Integration of Research into Classroom Practice
PRINCIPAL INVESTIGATOR: Dr. James Banning, 970-491-7153
banning@cahs.colostate.edu
PRINCIPAL INVESTIGATOR: Jean Radin, 970-481-3808 jradin@holly.colostate.edu

PURPOSE OF THE RESEARCH:
The purpose of this qualitative research is to interview exemplary secondary teachers in a public school district in a Rocky Mountain state to determine to what extent they are aware of or integrating brain-based teaching principles into their instruction.

RESEARCHER:
This study is undertaken to fulfill the dissertation requirement for the Doctor of Philosophy degree undertaken by Jean Radin, a doctoral candidate at Colorado State University.

PROCEDURES/METHODS TO BE USED:
You have been selected to participate in this study because your work was cited in the researcher's review of literature. You have volunteered to participate in an interview. . The interview session will last from fifteen to twenty minutes depending upon your schedule. The interview will consist only of the interviewee and interviewer. The researcher will guide the interview using three questions that deal with brain-based teaching. The intent is to align your responses with the brain-based principles that emerged from a review of literature, and to provide a framework for the second phase of this study that deals with interviewing exemplary teachers. The interview questions are open-ended. The researcher wishes to garner your input regarding brain-based instructional principles. After the interview session, the audiotape will be transcribed. Upon completion of transcription, the audio tape(s) will be kept in a locked filing cabinet for three years and will then be destroyed by erasure. The transcript will be sent to you for review approximately ten days after the interview. Any email texts will be kept for three years and then destroyed.

RISKS INHERENT IN THE PROCEDURES:
There are no known risks in this interview. It is not possible to identify all potential risks in research procedures, but the researcher has taken reasonable safeguards to minimize any known and potential, but unknown, risks. Your participation in the interview is completely voluntary. Only the interviewee and interviewer will be present during the interview. After transcription, the audiotape will be destroyed by erasure after three years.

BENEFITS:
There is no known benefit in participating, but we hope the research will provide information about brain-based instructional principles for your continued research. The data will contribute to the discussion of the awareness and application of brain-based instructional principles.

PARTICIPATION:
Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled. No compensation will be provided.

CONFIDENTIALITY:
The researcher will keep private all research records that identify you, to the extent allowed by law. Your information will be combined with information from other people taking part in the study. When the researcher writes about the study to share it with other researchers, it will include the combined information we have gathered. You will not be identified in these written materials. The researcher may publish the results of the study; however, your name and other identifying information will be kept private. Each participant will be identified only with an alphabetical code name. The researcher will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key. The audiotapes from the interviews will be stored in a locked filing cabinet and will be destroyed by erasure after three years.

LIABILITY:
The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

QUESTIONS AND CONCERNS:
Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Jean Radin, at 491-3808. If you have any questions about your rights as a volunteer in this research, contact Celia Walker, Director of Regulatory Compliance, at 970-491-1553. You will be given a copy of this consent form to take with you.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 3 pages.

Signature of person agreeing to take part in the study	Date
Printed name of person agreeing to take part in the study	
Name of person providing information to participant	Date
Signature of Research Staff	

APPENDIX E: Letter to Teachers

230 Education
Colorado State University
Fort Collins, CO 80523
November 1, 2004

Dear Mr. Smith,

My name is Jean Radin and I am a doctoral candidate at Colorado State University in the Educational Leadership program. Under the advisement of Dr. James Banning from the School of Education, I am working on my dissertation.

My research concerns brain-based education and its integration into classroom practice. The study requires interviews with identified exemplary middle school and high school teachers from the Poudre School District. Through the Poudre School District Foundation you have been identified as a recipient of, or a nominee for an Excellence in Education award. I am inviting you to participate in this study. The individual audiotaped interview should last about an hour to an hour and a half, and will be conducted after school hours in your classroom. There are no known risks to your participation in this study. I will provide a consent form for you to sign at the time of the interview. All data will remain anonymous.

Please contact me at either my office or home phone or via email if you would be willing to participate in my research. I have provided contact information for Dr. James Banning if you wish to reach him also.

Sincerely,

Jean L. Radin, M.Ed.
office: 970-491-3808 home: 970-377-2316
email: jradin@holly.colostate.edu

James Banning, Ph.D., Research Advisor
office: 970-491-7153
email: banning@cahs.colostate.edu

APPENDIX F: Informed Consent Form for Teachers
Consent to Participate in a Research Study at Colorado State University

TITLE OF STUDY: Integration of Brain Research into Classroom Practice

PRINCIPAL INVESTIGATORS: Dr. James Banning, 970-491-7153
banning@cahs.colostate.edu
Jean Radin, 970-481-3808 jradin@holly.colostate.edu

PURPOSE OF THE RESEARCH:
The purpose of this qualitative research is to interview exemplary secondary teachers in a public school district in a Rocky Mountain state to determine to what extent they are aware of or integrating brain-based teaching principles into their instruction.

RESEARCHER:
This study is undertaken to fulfill the dissertation requirement for the Doctor of Philosophy degree undertaken by Jean Radin, a doctoral candidate at Colorado State University.

PROCEDURES/METHODS TO BE USED:
You have been selected from a list of Excellence in Education awardees and nominees from a Rocky Mountain public school district. Strict selection criteria were utilized to identify the participants. You have volunteered to participate in a personal interview that will be conducted in your office or classroom after school hours. The interview session will last from one to two hours depending upon your schedule. The interview will consist only of the interviewee and interviewer. The researcher will guide the interview using nine questions that deal with brain-based teaching. The intent is to align your responses with the brain-based principles that emerged from a review of literature. The interview questions are open-ended. The researcher wishes to determine to what extent you are aware of brain-based instruction. After the interview session, the audiotape will be transcribed. Upon the completion of transcription, the audiotape will be kept in a locked filing cabinet for three years and will then be destroyed by erasure. The transcript will be sent to you for review approximately ten days after the interview.

RISKS INHERENT IN THE PROCEDURES:
There are no known risks in this interview. It is not possible to identify all potential risks in research procedures, but the researcher has taken reasonable safeguards to minimize any known and potential, but unknown, risks. Your participation in the interview is completely voluntary. Only the interviewee and interviewer will be present during the interview. After transcription, the audiotape will be destroyed by erasure after three years.

BENEFITS:
There is no known benefit in participating, but we hope the study will provide information about brain-based instructional principles for your classroom practice. The data will contribute to the discussion of the awareness and application of brain-based instructional principles.

PARTICIPATION:
Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled. No compensation will be provided.

CONFIDENTIALITY:
The researcher will keep private all research records that identify you, to the extent allowed by law. Your information will be combined with information from other people taking part in the study. When the researcher writes about the study to share it with other researchers, it will include the combined information we have gathered. You will not be identified in these written materials. The researcher may publish the results of the study; however, your name and other identifying information will be kept private. Each participant will be identified only with a pseudonym. The researcher will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key. The audiotapes from the interviews will be stored in a locked filing cabinet and will be destroyed by erasure after three years.

LIABILITY:
The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

QUESTIONS AND CONCERNS:
Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Jean Radin, at 970-491-3808. If you have any questions about your rights as a volunteer in this research, contact Celia Walker, Director of Regulatory Compliance, at 970-491-1553. You will be given a copy of this consent form to take with you.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 3 pages.

Signature of person agreeing to take part in the study	Date
Printed name of person agreeing to take part in the study	
Name of person providing information to participant	Date
Signature of Research Staff	

APPENDIX G: Interview Protocol and Interview Questions for Teachers

Interview Protocol II
Project: "Perception and Integration of Brain Research into Classroom Instruction"
Time of interview:
Date:
Place:
Interviewer:
Interviewee:
Position of interviewee:

Questions:

1. Can you describe the environment in your classroom?
   Extender: What is the physical/emotional environment like?
   (Addresses: Enriched environment, Stress and Threat)

Observations:

2. Where do the ideas for your teaching come from?
   Extender: Is your department collegial?
   (Addresses: Emotions, Challenge/Problem-Solving/Authentic Work)

Observations:

3. What kinds of activities or experiences do you use in your teaching?
   Extender: Can you describe a lesson that you are especially proud of?
   (Addresses: Emotions, Movement, Stress/Threat, Challenge/Problem-Solving/
   Authentic Work)

Observations

4.How do you get the highest achievement out of your students?
Extender: How do you get your students prepared for the CSAP tests?
(Addresses: Emotions, Movement, Authenticity, Stress/Threat, Enriched environment)

Observations:

5. What does order in your class mean? How do you maintain order?
Extender: What kind of a role, if any, do students have in maintaining class order?
(Addresses: Stress/Threat, Emotions)

Observations:

6. What is your approach to grading and evaluation? Please be specific.
(Addresses: Stress/Threat, Authenticity, Emotions)

Observations:

7. Why do people think you are exemplary?
(Addresses: Description of a Brain-Based Teacher, Enriched environment)

Observations:

8. What are you learning about now?
(Addresses: Description of a Brain-Based Teacher)

Observations:

9. What kinds of brain-based instruction or professional development have you had? (Addresses: Description of a Brain-Based Teacher)

Observations:

APPENDIX H: Audit Trail for Phase I

Procedural Steps	Decisions	Analysis Operations	Conclusions Drawn
1. Discover several principles of brain-compatible teaching from literature review.	Which articles and studies are appropriate for this context?	Common themes or principles emerged as I read. What are most experts or theorists stressing?	5 principles: enriched environment, emotions, stress and threat, relevant, challenging work, and movement
2. Secure approval from Human Subjects Committee to proceed with study. Discuss design with adviser.	Questions of confidentiality, procedures and benefits discussed with adviser.	Work through HRC forms, reflect on questions to ask the theorists.	Three broad questions will be sufficient to address the 5 principles. Alphabetical code names will be utilized.
3. Send letters to educational theorists presenting at Learning and the Brain conference.	How to word letters: approachability, professionalism, purpose		Theorists are friendly and excited about participating.
4. Send letters to educational theorists not presenting at conference, but possibly attending.	How to word letters: approachability, professionalism, purpose		Theorists are friendly and forthcoming about sharing their expertise.
5. Set up interview schedule: personal, phone, email.	Scheduling conflicts		Interviews may take longer than I expected.
6. Conduct interviews	Digital recorder, phone or email? Should I write notes while interviewing? Are questions being adequately addressed?	I used probes and/or extenders to focus on the 5 principles.	Personal interviews are interesting. It's hard not to engage and let interviewees talk! Digital recordings are very clear.
7. Transcribe interview texts.	Time better spent transcribing myself or having a transcription service do this?	Problems with semantics.	I transcribed a few. Transcription service worth the money.

8. Send copy of transcription and thank-you letter to each participant for review	How will each person access the finished dissertation?		Minimal revisions received from participants. Satisfaction inferred.
9. Code each transcript.	Are other themes emerging? Are they important?	How do all of these principles/themes fit into my research questions?	Theorists confirmed the 5 themes, added one more and changed one.
10. Check in with adviser for verification.		Open codes and axial codes	On the right track.
11. Create Model of Brain-Compatible Teaching using principles from literature review and interviews.	Name of model? Incorporate theorists' names? Will this be changed throughout the study?	How to visually depict that these themes are interrelated and subtopics under an enriched environment.	Circles will show relationships best. Model will be modified as study progresses.

APPENDIX H: Audit Trail for Phase II

Procedural Steps	Decisions	Analysis Operations	Conclusions Drawn
1. Discuss possible population samples with advisers.	Include student teachers, pre-service teachers? How to group teachers: by content area, experience?	Study should investigate classroom teachers, otherwise it's too broad.	Sample: exemplary secondary teachers from local school district.
2. Contact personnel at local school district office for criteria and list of Excellence in Education winners and nominees	Was strict selection criteria used every year? Should be 6-12th grade teachers. Male/female? Is participant pool big enough?	Align sample population with qualitative research guidelines. Align sample with research questions.	Sample exemplary teachers 6th-12th grade only, from 2002-date. Would like 8, but 6 will be sufficient.
3. Secure approval from Human Subjects Committee to proceed with study. Discuss design with adviser.	Questions of confidentiality, benefits, incentives, procedures discussed with adviser.	Work through HRC forms, reflect on questions to ask teacher participants.	Nine questions (already approved at proposal meeting) will be asked to teachers. Identification by pseudonyms. Interviews to take place outside of school hours.

3.Send letter to potential teacher participants.	Offer incentive? Wording of letter: inviting, professional?		Teachers are busy people. Even finding six participants was difficult.
4. Set up interview schedules.	Scheduling conflicts.		Interviews may take longer than expected.
5. Conduct interviews	Are questions being addressed adequately?	Use probes and/or extenders to focus on the main topics.	Keep myself from engaging in long, extended interviews.
6. Transcribe interview texts	Time better spent transcribing myself of having a service do this?	Words do not always convey feelings. Note emotions during interview.	Transcription service worth the money.
7. Send copy of transcribed text and thank-you letter to each participant for review	How will each person access the finished dissertation?		Minimal revisions received. Satisfaction inferred.
8. Code each transcript	Coded with colored markers. Decide which comments fit into broad categories.	Discover broad categories Group sub-themes under broad categories. Align categories and quotes with brain-compatible principles embedded in the questions.	Two broad (open) codes emerged, each with several sub-themes. Teachers are doing the right things, have no knowledge of brain research (except Robin).
9. Check with adviser for verification			Adviser helped label the open codes. I'm on the right track.
10. Create Model 3 of Brain-Compatible Teaching, integrate teacher, lit review and theorist info.	How will this model show all info from this study? Should I use arrows to show relationships?	How is all of this info connected and related? How will this help write the conclusions and recommendations? Does the model show that my research questions were answered?	Teachers are "brain-compatible", but cannot articulate what they are doing. Enriched environment is the key component. Recommendations need to integrate this information.