BRAIN-BASED LEARNING FOR PRESCHOOLERS

by

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Table of Contents

"Brain-based Learning for Preschoolers"

ABSTRACT: The nineties have been called the Decade of the Brain and the Decade of Education. Because of new technology we know more about the function of the brain than ever before. We now know that, in an enriched environment where a person is actively engaged with their surroundings, the cortex of their brain actually increases. Because a thicker brain cortex produces smarter lab animals, scientists have drawn the inference that the same is true for humans (Jacobs, Schall, Scheibel, 1993).[1] The science of deliberate enrichment, to stimulate the student's development, is called "brain-based education." For the preschool child there are fundamentally basic elements that must be a part of their education. These are: helping the preschooler make sense of their world; helping them feel safe and secure; teaching them that learning is fun; and empowering them with a thirst for knowledge that lasts a lifetime. A preschool classroom and environment that uses brain-based education techniques can achieve these elements.

INTRODUCTION

Preschool education is defined, for the purpose of this paper, as all education that takes place in a child's life from birth to the beginning of Kindergarten. Preschool education begins at birth. It determines the potential that the child will have as an adult. Some people involved in preschool enrichment programs are absolutely certain that deliberate enrichment at this age can increase children's intelligence, improve their educational and life outcomes, and by inference, enlarge their cerebral cortex and mental capacity (Diamond, Hopson, 1999).[2]

The purpose of this study, after reviewing the current research on brain development, is to determine how brain-based learning might serve the preschool child as a means to help them reach their full potential. Once the current findings on brain development are surveyed, a determination of the validity of the findings will be examined. The pros and cons will be discussed. If brain-based learning for preschoolers is found to have some merit, the design of a classroom and curriculum will be discussed. Brain-based learning for preschoolers may become another option for the parents of preschoolers.

Preschool education in this country has many forms. Children are taught at home. Some children are sent to preschool class several times a week. Some are placed in a daycare setting where basic babysitting takes place. Others attend child development centers where preschool and childcare are allencompassing. At-risk children attend a government program called Headstart. It has reached over 17 million children since its beginning in 1965.[3]

I. The Responsive Brain and learning from birth.

Jesse Conel, the famous American neurologist, spent 30 years writing an eight-volume series on brain maturation and proved that human brain development is very protracted affair compared to other mammals, but also that the brain triples in weight after birth. Most of our brain growth takes place after birth; we keep producing new neurons, nerve cells, until seven months of age.

The Myelin keeps growing after this stage. Myelin is sheets of fatty material that wrap around axons like insulation around a lamp cord. Axons in the brain stem (which lies at the base of the brain above the spinal cord) as well as axons in the major nerves running to the face, limbs, trunk, and organs, all receive myelin sheaths before and during infancy. This allows all the infant's basic survival function – breathing, heartbeat, body temperature, reflexes, sensation, seeing, and hearing – to work fairly efficiently early in life. Adult levels of *myelin* are reached at two years of age in humans. This is reflected in the child's growing coordination while walking, running and manipulating objects.

Areas of the brain that govern the highest function take the longest to mature. The hippocampus, the six layers of the neocortex, and the reticular activating system all require 10 or more years to mature in a child. This long maturation accounts for our higher order of thinking. It allows for abstract thought, language, reasoning, decision making, and self-control. The number of neurons, or nerve cells, will remain about the same for a person from seven months until seventy or eighty years of age. The branches and spines of those neurons however continue growing.

The spines are called axons; the branches are called dendrites. Axons are the transmitters, and the dendrites are the receiving antennae. Axons have a little button-like ending called a bouton. The end of the dendrite is called a boulbous ending. There is a minute gap between them like a firing surface of a spark plug. This bulb-and-button unit is a synapse (literally, a clasp). When an electrical signal traveling down one neuron's axonal wire reaches the button-like ending at the wire's terminus, a chemical charge crosses the gap in the synapse.

If the information is compelling enough to spark interest in the receiving cell, the electrical transmission continues down to the cell's receptive antenna or dendrite to its cell body and to its axon wire. From there, it synapses to another neighboring cell. Spark and transmission is going on a billion times per second. These branches are very responsive to input, increasing in number with use and decreasing in number with disuse (Diamond, Hopson 1999).[4] "Use it or lose it" is the principle here.

Neurologist Peter Huttenlocher, from the University of Chicago, found that from birth to age one, neurons becomes less tightly packed as the dendrites grow and branch and push them apart. The cerebral cortex (bark-like layer) grows thicker and heavier. From age one to adolescence, the density declines due to selective pruning of redundant connections even as new dendrites grow and branch. This gradual loss does not reflect a decline of mental maturity and learning. It is just the opposite; intelligence, physical coordination, and language skills emerge (Huttenlocher, DeCouten, 1987).[5]

Arnold Scheibel of UCLA in the early 1970's began studying the area of the brain that controls language. He found three important generalities about the brain. First, the area of the brain that controls speech is the left side in about 90% of people. Second, in the so-called Wernicke's area, the area responsible for understanding speech, he found that the more educated a person was, the higher order of branching was observed. Third, he found that the cortex region that controls hand/finger movement had fuller dendritic branching when the person had a job demanding dexterity and less branching when the job was less hand oriented. Scheibel remains convinced that the human brain responds to stimulation. He says, "Correlation says nothing about causality, but based on what we know, and have seen from animal experiments, it seems a likely inference."

Increases in brain growth, as a consequence of stimulating environmental input, have been demonstrated at every age level including old age. The greatest gains have been noted during the period when the cerebral cortex is growing most rapidly, the first ten years. By providing young children with an enriched education and environment, we will get their brains growing and off to a good start (Simonds,Scheibel, 1989).[6]

In the first two years of life, a normal child's senses develop. They learn to crawl, walk, run, babble, talk, play with toys, feed themselves, listen to and understand spoken language, interact with family and others, and explore all of their surroundings. By instinct, babies and toddlers are creatures of learning and play. The child begins to make sense of the world around them. These activities help shape the developing brain. By using all of their senses, babies provide themselves with most of the experiences they need in order for their brains to develop normally. Parents must provide certain kinds of experiences, emotional support, and language to foster the child's fullest potential for development at this stage.[7]

The newborn baby appears to be helpless, and yet it has many natural reflexes and has some degree of self-defense. Babies startle at loud sounds or bright lights. They lift their head and turn when laying down. They will root for a nipple and suck on it. If a napkin falls on their face they will fling it off with flailing arms. If stroked, the babies hand and foot will grasp. If held vertically, babies will make stepping movements. If held horizontally in water, they will make swimming movements. Their eyes can track movement within inches of their face. By one month, the baby can start perceiving high-contrast patterns. They can hear and respond to voices and cry intentionally to get attention. They prefer and recognize soft objects, not coarse; gentle handling, not rough; sweet smells, not bitter or acrid.[8]

Kurt Fischer, an educator from Harvard University, is a cognitive neuroscientist. He also is a "neo-Piagetian." Jean Piaget (1896-1980) was a Swiss biologist and psychologist was is famous for constructing a model of child development and learning. He proposed four stages of development. They are: *sensorimotor stage (birth- 2 years old); preoperational stage (ages 2-7); concrete operation (ages 7-11); formal operations stage (11- adulthood)* (Fischer, Rose, 1994).[8]

Fischer updated Piaget's model by matching emerging behaviors with brain changes. One way he monitored growth was to measure the size of the child's head as he grew. He found the child's growth was marked by growth spurts between 3 & 4 weeks, 7 & 8 weeks, 10 &11 weeks that coincided with spurts of other babies from other studies. He also found that when the child had a cold there was no growth. This shows that a little environmental input can dramatically change growth curves for the brain. Fischer's model shows brain development grows in fits and starts throughout childhood. The changes in the brain are myelin accumulation, dendritic branching, synaptic formation, and the pruning of weak or unused connections. Between a child's birth and his twenty-first birthday, his brain exhibits a series of growth spurts, reflected in head growth, brain activity (measured through EEG recordings of brain waves), and the density of synaptic junctions between dendritic branches (Fischer, Rose, 1994).[9]

Fischer says that during the first growth spurt, between 3 & 4 weeks, a baby begins to follow a ball with her eyes and to grasp a soft object placed in her hand. During the second growth spurt, between 7 & 8 weeks, the baby starts to build reflex upon reflex. She will turn her head in the direction of her mother's voice, seeing a ball, she will reach her arm. Between 10 & 11 weeks, when she hears her mother's voice she will look at her and smile and coo. When she sees a ball, she will reach for it and open her hand. Fischer says the baby experiences three more growth spurts that will trigger new *sensorimotor* responses. At fifteen to seventeen weeks, brain growth spurts, and the baby follows a moving ball with her eyes, reaches with fingers wide, and moves her arm to track the object's path. At seven to eight months, the baby sees a ball, grabs it, and brings it over to look at it closely. Between 11 & 13 months, the baby grabs a rattle and moves it around so she can see the front, back and sides. She hears people speak and forms her mouth and lips to imitate the words of ball, ma-ma, da-da, cookie, etc.

For Fischer, a toddler by her second birthday has piled up experiences provided by chains of reflexive and sensorimotor actions, and these have helped the brain develop to a new level of potential: the ability to represent objects, people, or events through mental symbols. The growth spurt between eighteen months and two years allows this symbolism in the mind. It unlocks not just simple words, but short sentences, as well as imaginative play. The growth spurts are synchronized with the accumulating myelin in various parts of the brain. This explosion of synaptic junctions and blooming activity other researchers have seen in very young children's brain cells (Fischer, Rose 1994). [10]

In the book "Magic Trees of the Mind," Marian Diamond, Ph.D. and Janet Hopson, MA say that, "Crawling is a good example of an activity of cognitive bootstrapping in the busy brain. " [11] They explain that bootstrapping is another term for the way brain growth leads to new experience and new experience unlocks more brain growth. They go on to say that crawling, which occurs between eight and nine months, can itself boost other kinds of brain maturation. Two researchers divided more that 100 babies into three groups: those who had not started crawling, those who had, and those that could not yet crawl but could scoot around in a plastic baby walker. The groups were shown hidden toys. The babies who were more mobile had better spatial intelligence than the less mobile children did. Children who were not as mobile could not find a toy hidden beneath a handkerchief. Another researcher, Joseph Campos discovered that babies who crawl are wary of heights, while those who did not, had not developed a similar fear of heights (Bertenthal, Campos, 1987).[12] Diamond and Hopson say that finding hidden toys and fearing heights are both spatial skills as well as examples of sustained attention.

Neuroscientists know more about babys' development of such skills, and the responsible brain regions, than they do about any other aspect of early cognitive development. Adele Diamond, a psychologist from MIT, has studied spatial reasoning in hundreds of infants. Her research involved infants finding a toy in one or two wells on a tabletop. The toys are covered, and the infant must retrieve them from the correct well. If an infant seven and a half to nine months old is delayed by two to five seconds they will choose the wrong well. By the child's first birthday, it could tolerate a delay of 5 to 10 seconds. The same was true for retrieving a toy in a plastic box. The baby six and a half months to eight months would reach for the toy bumping into the plastic box. The nine and a half month old will tip the box or rotate it to get the toy. The one-year-old simply looks at the box and reaches for the toy in the open side. The same proved true for monkeys when given a similar test (Diamond, 1991).[13]

Yale researcher Patricia Goldman-Raqkic found that the front section of the brain's cerebral cortex must mature before the animal can find toys in these tests. Diamond and Hopson say that, in the young science of cognitive neuroscience, this is one of the very few links anyone has been able to forge between a specific behavior and the development of particular cells or parts of the brain. Adele Diamond says this maturing of the prefrontal cortex allows us to exercise choice and control over what we do instead of just being creatures of habit. "It allows us to solve problems in our minds, to hold onto the information

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Table of Contents

long enough to be able to manipulate it in the mind so we can start to plan, and to relate one thing to another (Diamond, 1991)." [14]

Diamond and Hopson say that neuroscientists can connect things like a four-month-old's ability to focus and see at a distance for the first time with the surge of synaptic connections in the visual cortex. They can also connect the growing coordination between eye and hand movements, like picking up a rattle and bringing it to the mouth, with connections between the visual cortex and its counterpart in the motor cortex. They say that someday a specific connection between one particular column of maturing cells in the prefrontal cortex and success on the hidden toy test will be made, but this will await new ways of studying the child's brain (Diamond, Hopson, 1999).[15]

We've seen that maturing frontal lobes during the second half of a baby's first year allows the child to begin controlling her own behavior. The growth helps her inhibit certain automatic responses, such as reaching for a hidden toy. Researchers know that normal emotional responses involve (a) circuits in the frontal cortex, the brain's seat of planning and organizing; (b) additional circuits in the amygdala, hypothalamus, and the thalamus – all part of the limbic system that governs emotion and memory; and (c) other circuits in the brain stem's reticular formation which controls alertness (Diamond, Hopson, 1994).[16]

We know that the reticular system (a set of nerve tracks in the brain stem) is fairly mature at birth, since the baby's brain stem is itself already full functioning to regulate the newborn's heart rate, blood pressure, body temperature, and calmness or anxiety. The amygdala and other limbic structures mature next; these govern sleep, appetite, alertness, sexual behavior, and emotional reactivity, as well as the ability to form attachments to other people, to feel emotions, and to help regulate one's own reactions. The cerebral cortex, including the frontal cortex, does some maturing in the first year, but continues to develop for many years. The long maturation allows for abstract thought, language, reasoning, decision making and self-control to develop. In his book *Emotional Intelligence,* Daniel Goldman refers to the amygdala as the "seat of all passion." Emotional development happens long before we have words to describe our feelings. Our experiences with parents, siblings, and caregivers, loving or harsh, supportive or destructive, help establish a mental map that guides our emotional life and, in turn, influences our thinking processes.

Brain researchers Karl Pribram of Radford University and Virginia and Deborah Rozman of the HeartMath Institute in Boulder Creek, CA, have found evidence of how parental behavior may influence a child's brain development. They recorded the effects of love, care, and other positive emotions in creating coherent electrical patterns in children's heartbeat rhythms. They also measured the effects of stress, anger and negative emotions in creating jagged incoherent electrical patterns. They connected the heart rhythms to the developing amygdala along with its connections to the frontal lobes and other areas. Based on their research, they feel the first few years of life to be crucial in this "imprinting" of emotional brain regions (Diamond, Hopson, 1994).[17]

Bruce Perry, a child psychologist and developmental neurobiologist at Baylor College of Medicine in Houston, Texas, has documented many cases of serious emotional abuse and their measurable effects on the brain. Perry explains that there is a link between emotional abuse and brain structure. He says, "from a lack of experiences during a critical period for affective development in the first three years of life when your brain is organizing, a person will not be able to function as an independent person." When he compares the magnetic resonance images of normal children to ones who have suffered profound emotional abuse, he found that the frontal cortex did not grow. He says, "One of the hardest things to communicate to people in our culture is not just that hitting kids and screaming and yelling at them leads to injuries, but that the absence of touch, the absence of eye contact, leads to something not growing (Perry, 1994)." [18]

If children do not have the right kind of experiences as an infant, their brains do not grow and develop properly. They are not able to think and learn as other children do. Something that may have even more ramifications for our society is that these children do not develop the emotions of caring, empathy, and bonding with another person. Babies need to be held, touched, loved, talked to, sung to, have eye contact, cuddled and nurtured as much as they need food and water to become healthy well developed children.

II. Learning Theories and Brain-Based Learning

Learning is the acquisition of new information, which is processed and leads to further understanding and demonstration of new skills (Franklin, 2000).[19] Psychologists have had many theories of how humans learn. Pavlov, whose experiments with stimulus and response proved that the environment could affect learning, first introduced the behaviorist theory. Classic conditioning occurs when a natural reflex responds to a stimulus. Behaviorists believe that people are biologically "wired" so that a certain stimulus will produce a specific response. B. F. Skinner expanded upon Pavlov's theory by using operant conditioning to teach pigeons to dance and bowl a ball in a mini alley. Behavioral or operant conditioning occurs when a response to a stimulus is reinforced. Operant conditioning is a simple feedback system. If a reward or reinforcement follows the response to a stimulus, then the response becomes more probable in the future. This theory is still being used in some educational settings. This theory is not compatible with brain based learning because it does not account for all kinds of learning, since it disregards the activities of the mind. For the behaviorist theorist, the cause of learning is external, the stimulus comes from the environment.

Behaviorism does not explain some learning such as the recognition of new language patterns by young children for which there is no reinforcement mechanism. Research has shown that animals adapt their reinforced patterns to new information. This theory is relatively simple to understand because it relies only on observable behavior and describes several universal laws of behavior. Its positive and negative reinforcement techniques can be very effective, both in animals, and in treatments for human disorders such as autism and antisocial behavior. Teachers, who reward or punish student behaviors, often use behaviorism (Mischel, 1993). [20]

Swiss biologist and psychologist Jean Piaget is renowned for constructing a highly influential model of child development and learning. Piaget's theory is based on the idea that the developing child builds cognitive structures, mental maps, and networked concepts for understanding in response to the physical experiences within his or her environment. He identified the four stages of development: sensorimotor *stage, preoperational stage, concrete operations, and formal operations.*

For Piaget, these stages were biologically driven, and they occurred as the child interacted with its environment. When the child interacts with its environment, the child can assimilate the environment and reach a stage of equilibrium. When a new thing occurs, there is a loss of equilibrium, and the child must learn to accommodate the new learning to reach equilibrium once again. Piaget thought that, once a child was out of a stage, it is as though the prior stage never happened. While many researchers acknowledge Piaget's genius, have found it necessary to take issue with nearly all of the Genevan psychologist's principal claims (Gardner, 1991).[21]

Researchers who are faithful to Piaget are dubbed the neo-Piagetians. Kurt Fischer, of Harvard University mentioned in chapter 1 and Robbie Case of Stanford University are prominent neo-Piagetians. For them, Piaget got right the big picture of development, but they now examine a wider gamut of behavior than Piaget did. They are both interested in the emotional development of children. For brain-based learning emotional health is fundamental to effective learning (Gardner, 1991).[22]

John Dewey, like Piaget, thought that learning occurred within the culture or environment, but he did not base it on developmental stages as Piaget. John Dewey (1859-1952) was an American philosopher and educator whose writings and teachings have had profound influences on education in the United States. Dewey's philosophy of education, instrumentalism (also called pragmatism), focused on learning-by-doing rather than rote learning and dogmatic instruction, the current practice of his day. For John Dewey, learning is the "reconstruction of experience." Dewey's theory of learning was that children must be interested in a subject in order to learn. He felt that education needed to be taught with the traditional disciplines such as mathematics, chemistry, literature, history, and physics as the goal, but children would learn those subjects best by learning about their roots. He felt that through gardening, children could learn chemistry, and that through the use of storytelling, children could learn history and literature.

For Dewey, if children learned to cook, they would learn chemistry, and through measuring and building with blocks, children would learn mathematics and physics. Dewey felt that the interests of children and the disciplines of society were the same. He felt that curriculum needed to recapitulate the original form of learning that led to the discipline. Hence, cooking or gardening would lead to learning chemistry.

Dewey was the first person to initiate hands-on-learning experiences. He felt the best way for children to learn was to do. Dewey felt that the map and the explorer had the same reality. The map is the curriculum, logical, organized and orderly. The explorer is the child. Without exploring and experiencing the reality that the map represents, the map is just a symbol. Without the experience of exploring and experiencing, learning doesn't take place (Dewey, 1920). [23] Some researchers blame Dewey for the ills of public education, others claim they misunderstand him and that his theories have a lot to offer. His theory of learning by experiences and through one's own culture is compatible with brain-based learning.

Another Cultural Psychologist was L. S. Vygotsky. He sought a comprehensive approach to learning that would make possible description and explanation of higher psychological functions in terms acceptable to natural science. Vygotsky had a notion that language was the key to social and developmental growth. He said learning occurs in a social context, cognitive development results from dialectical process where the child learns through problem solving experiences shared with someone else. Mental growth can only occur in a social group and by being internalized by the student. The child's own language comes to serve as her primary tool of intellectual adaptation. Eventually children can use internal language to direct their own behavior. Internalization refers to the speech within one's mind, intramental speech that creates a rich body of knowledge and tools of thought that first existed outside the child. This happens through language. Central to learning is the mediation, the elements in culture that bring about learning. The relationship between the society and individual is reciprocal, each influences the other. Vygotsky believed that each child had a Zone of Proximal Development. There were four stages for this development. Stage 1, someone or some mediating device assists the performance. Stage 2, the performance is assisted by the child. Stage 3, the performance is automatized or fossilized. Stage 4, a new performance is deautomized and leads back through the Zone of Proximal Development.

Vygotsky felt that play for the preschool child leads to the Zone of Proximal Development. "In play a child always behaves beyond the average age, above his daily behavior; in play its as though he were a head taller than himself. As in the focus of a magnifying glass, play contains all developmental tendencies in a condensed form and is itself a major source of development." Through play-development relationship can be compared to the instruction-development relationship, play provides a much wider background for changes in needs and consciousness (Vygotsky, 1978).[24]

Brain- based learning is based on the structure and function of the brain. As long as the brain is not prohibited from fulfilling its normal processes, learning will occur. Renate and Geoffrey Cain, in their book, *Making Connections: Teaching and the Human Brain* have developed 12 core principles for brain-based teaching. These core principles are:

1. ***The brain is a complex adaptive system***. Thoughts, emotions, imagination predisposition, and physiology operate concurrently and interactively as the entire system interacts and exchanges information with its environment.

2. ***The brain is a social brain***. Researcher Darling says, "For the first two years of life outside the womb, our brains are in the most pliable, impressionable, and receptive state they will be ever in." We begin to be shaped as our immensely receptive brain/minds interact without early environment and interpersonal relationships. Vygotsky was partially responsible for bringing the social construction of knowledge to our awareness. Both Vygotsky and Piaget felt that learning must take place in a social environment.

3. ***The search for meaning is innate.*** The search for meaning is survival-oriented and basic to the human brain/mind. Although the ways in which we make sense of our experience change over time, the central drive to do so is life long. At its core, our search for meaning is driven by our purposes and values.

4. ***The search for meaning occurs through "patterning."*** In patterning, we include schematics, maps, and categories, both acquired and innate. The brain/mind needs and automatically registers the familiar while simultaneously searching for and responding to novel stimuli.

5. ***Emotions are critical to patterning.*** What we learn is influenced and organized by emotions and mind-sets involving expectancy, personal biases and prejudices, self-esteem, and the need for social interaction. Emotions and thoughts literally shape each other and cannot be separated. Emotions color meaning.

6. ***Every brain simultaneously perceives and creates parts and wholes.*** Although there is some truth to the "left-brain-right-brain" distinction, this is not the whole story. In a healthy person, both hemispheres interact in every activity, from art and computing to sales and accounting. The "two-brain"

doctrine is most useful for reminding us that the brain reduces information into parts perceived wholistically at the same time.

7. ***Learning involves both focused attention and peripheral perception.*** The brain absorbs information of which it is directly aware, but it also directly absorbs information that lies beyond the immediate focus of attention. In fact, it responds to the larger sensory context in which teaching and communication occur. "Peripheral signals" are extremely potent. Even the unconscious signals that reveal our own inner attitudes and beliefs have a powerful effect on students. Educators, therefore, can and should pay attention to all facets of the educational environment.

8. ***Learning always involves conscious and unconscious processes.*** One aspect of consciousness is awareness. Much of our learning is unconsciously experienced, and sensory inputs are processed below the level of awareness. Thus, much understanding may not occur during a class, but rather hours, weeks, or months later. Educators must organize what they do to facilitate that subsequent unconscious processing of experience by students. In practice, teachers should properly design the context, incorporate reflection and metacognitive activities; and provide ways to help learners creatively elaborate on the ideas, skills, and experiences. Teaching largely becomes a matter of helping learners make visible what is invisible.

9. ***We have at least two ways of organizing memory.*** Although many modes of memory exist, one that provides an excellent platform for educators is the distinction made by O'Keef and Nadel (1978) between taxon and local memories. They suggest that we have a set of systems for recalling relatively unrelated information (taxon systems, from "taxonomies"). Reward and punishment motivate these systems. O'Keef and Nadel also suggest that we have a spatial/autobiographical memory that does not need rehearsal and allows for "instant" recall of experiences. This is the system that registers the details of your meal last night. It is always engaged, inexhaustible, and motivated by novelty. Thus, we are biologically supplied with the capacity to register complete experiences. Meaningful learning occurs through a combination of both approaches.

10. ***Learning is developmental.*** Development occurs in several ways. In part, the brain is "plastic," which means that much of its hard wiring is shaped by people's experiences. There are predetermined sequences of development in childhood, including windows of opportunity for laying down the basic hardware necessary for later learning. Such opportunities are why new languages, as well as arts, ought to be introduced to children very early in life. There is no limit to growth and to the capacities of humans to learn more. Neurons continue to be capable of making, and strengthening, new connections throughout life.

11. ***Complex learning is enhanced by challenge and inhibited by threat.*** The brain/mind learns optimally, it makes maximum connections, when appropriately challenged in an environment that encourages taking risks. The brain "downshifts" under perceived threat. It then becomes less flexible and reverts to primitive attitudes and procedures. This is why we must create an atmosphere of relaxed alertness, involving low threat and high challenges.

12. ***Every brain is uniquely organized***. We all have the same set of systems, and yet we are all different. Some of this difference is a consequence of our genetic endowment. Some of it is a consequence of differing experiences and differing environments. The differences express themselves in terms of learning styles, differing talent and intelligences, and so on. An important corollary is to appreciate that learners are different and need choice, while ensuring that they are exposed to a multiplicity of inputs. Multiple intelligences and vast ranges In diversity are, therefore characteristic is what it means to be human (Caine, Caine, 1994).[25]

With these twelve core principles in mind instructional techniques associated with brain-based learning are:

Orchestrated immersion – creating learning environments that fully immerse students in the educational experience.

Relaxed alertness - the goal is to eliminate fear in learners, while maintaining a highly challenging environment.

Active processing - the learners are allowed to consolidate and internalize information by actively processing it.

Brain based learning makes an impact on education in that a teacher must design learning around students' interests and make learning contextual. John Dewey argued this was the best way for children to learn. Since all students are learning, their assessment should allow them to understand their own learning styles and preferences. The students monitor and enhance their own learning process. Renate and Geoffrey Caine in their book, *Making Connections: Teaching and the Human Brain,* say that teachers must immerse learning in complex, interactive experiences that are both rich and real. One excellent example is immersing students in a foreign culture to teach them a second language. Educators must take advantage of the brain's ability to parallel process. Students must have a personally meaningful challenge. Such challenges stimulate a student's mind to the desired state of alertness. In order for a student to gain insight about a problem, there must be intensive analysis of the different ways to approach it, and learn about it in general. This is what is known as the "active processing of experience."

Multiple Intelligence is a theory of human intelligence, developed by psychologist Howard Gardner. Gardner posited that all human beings are capable of at least seven different ways of knowing the world. Gardner labels each of these ways *the seven human intelligences.*

Gardner defines an "intelligence" as a group of abilities that is somewhat autonomous from other human capacities. They have a core set of information-processing operations. Each intelligence has a distinct history in the stages of development we each pass through. Each has plausible roots in evolutionary history.

Gardner suggests his list of intelligences may not be exhaustive, he identifies the following seven:

1. ***Language*** -- The ability to use words and language
2. ***Logical-Mathematical Analysis*** -- The capacity for inductive and deductive thinking and reasoning, as well as the use of numbers and the recognition of abstract patterns
3. **Spatial representation** -- The ability to visualize objects and spatial dimensions, and create internal images and pictures
4. ***Body-Kinesthetic*** --The use of the body to solve problems or to make things.
5. ***Musical Thinking*** -- The ability to recognize tonal patterns and sounds, as well as a sensitivity to rhythms and beats
6. ***Interpersonal --*** An understanding of other individuals.
7. ***Intrapersonal*** -- An understanding of ourselves.[26]

Gardner argues that everyone learns differently. He challenges an educational system that assumes that everyone can learn the same materials in the same way and that a uniform, universal measure suffices to test students learning. He feels that our current system is heavily biased toward linguistic modes of instruction and assessment and to a lessor degree towards logical–quantitative modes. Students learn in ways that are identifiably distinctive. Gardner feels that the society as a whole would be better served if disciplines could be presented in a number of ways and learning could be assessed through a variety of means. The use of multiple intelligences is one of the strategies for motivation brain-based learning. (Jensen, 1996). [27]

Research in brain-based learning suggests that emotional health is fundamental to effective learning. According to a report from the National Center for Clinical Infant Programs, the most critical element for a student's success in school is an understanding of how to learn (Goldman, 1997). [28] The key ingredients for this understanding are:

Confidence
Curiosity
Intentionality
Self-control
Relatedness
Capacity to communicate
Ability to cooperate

These traits are all aspects of Emotional Intelligence. Basically, a student who learns to learn is much more apt to succeed. Emotional Intelligence has proven a better predictor of future success than traditional benchmarks like the GPA, IQ, and standardized test scores. Emotions are a critical part of a learner's ability to think rationally and experience meaning. The learner must be in a relaxed state of positive expectancy or very little of a constructive nature can take place. Teachers have the power to influence the emotional state of the children with activities that release stress, increase bonding, and give the emotions a chance to be expressed. (Jensen, 1996)[29]

III. BRAIN-BASED EDUCATION- MYTH OR MERIT?

Neuroscience, the study of the brain, and psychology, the study of the mind, emerged as scientific disciplines in the late nineteenth century. Both existed as very separate entities. Neuroscientists were biologists who studied brain anatomy and physiology. This was considered more of a hard science based on biological data. Psychologists were behavioral scientists who studied behavior, and mental processes. Psychologists were not concerned with what actually made the brain function the way it did; they only looked at behavioral patterns and how the mind worked. It is only in the last fifteen years that these two disciplines have started serious collaborative research to study how the biological brain implements mental processes. It is as if psychologists are the software engineers and the biologists are the hardware engineers (Bruer, 1999).[30]

Cognitive neuroscience is now an interdisciplinary course of study drawing from cognitive science, psychology, neuroscience, and linguistics. Over the past thirty years, the mind sciences have developed a picture not only of how our brains are built but also of what they were built to do. Every baby is born with circuits that compute information enabling it to function in the physical world (Gazzangia, 1998).[31] When all of the disciplines are collaborating we will learn how our neural hardware could run our mental software, how brain structures support mental functions, and how our neural circuits enable us to think and learn. This is a new scientific endeavor, and as a result there is still a lot that we do not understand when it comes to learning, thinking and remembering and the functions within our brain.

For John T. Bruer, President of the James S. McDonnell Foundation, the research of brain development does not give us enough information to support the claims made by the Brain-based educators. Bruer argues that "brain-based" educators make claims that can not be substantiated by brain research. Among these is the "right brain versus the left brain". According to the traditional view of brain laterality, left-hemisphere-dominant individuals tend to be more verbal, more analytical and better problem solvers. Right-hemisphere-dominate individuals, usually males, tend to paint and draw well, are good at math, and deal with the visual concepts better than verbal concepts. Bruer says, "What brain scientists currently know about spatial reasoning and mental imagery provides counterexamples to such simplistic claims such as these. He feels that such claims arise out of folk theory about brain laterality, not neuroscience (Bruer, 1999).[32]

Dr. Bruer has written several papers on this subject. Among them are *Education and the Brain: A Bridge too Far, Put Brain Science on the Back Burner, Education and the Brain.* He has also written a book on the subject titled *The Myth of the First Three Years.* Bruer says the argument runs as follows.

> *Starting in early innocence, there is a rapid increase in the number of synapses or neural connections in children's brains. Up to age 10, children's brains contain more synapses than at any other time in their*

lives. Early childhood experiences fine-tune the brains' synaptic connections. In a process that we might describe as synaptic pruning, childhood experiences reinforce and maintain synapses that are repeatedly used, but snip away the unused synapses. Thus this time of high synaptic density and experiential fine-tuning is a critical period in a child's cognitive development. It is the time when the brain is particularly efficient in acquiring and learning a range of skills. During this critical period; children can benefit most from rich, stimulating learning environments. If, during this critical period, we deprive children of such environments, significant learning opportunities are lost forever.[33]

Dr. Bruer breaks this argument down into three "misconceptions:"

1...enriched early childhood environments causes synapses to multiply rapidly.

What little direct evidence we have – all based on studies of monkeys – indicates that these claims are inaccurate...The rate of synapses formation and synaptic density seems to be impervious to quantity of stimulations. The rate of synapse formation appears to be linked to animals' developmental age, the time since it was conceived, and to be under genetic control. It is not linked to birth age and amount of post-natal experience. Some features of brain development including the rapid burst of synapse formation in infancy and early childhood, rather than being acutely sensitive to deprivation or increased stimulation, are in fact surprisingly resilient to them.
Early experience does not cause synapses to form rapidly. Early enrichment environments won't put our children on synaptic fast tracks.[34]

2. ...more synapses mean more brainpower.

The neuroscientific evidences does not support this claim either. The evidence shows that synaptic numbers and densities followed an inverted-U pattern - low, high, and low - over the life span. Synaptic densities at birth and in early adulthood are approximately the same, yet by any measure adults *are more intelligent, have more highly flexible behaviors and learn readily than infants. Furthermore, early adulthood, the period of rapid synaptic loss, follows the high plateau period of synaptic densities from early childhood to puberty. Young adults do not become less intelligent or less able to learn once they start to lose synapses. Furthermore, learning complex subjects continues throughout life, with no apparent, appreciable change in synaptic numbers. It is not true that more synapses mean more brainpower.*[35]

3. …the plateau period of high synaptic density and high brain metabolism is the optimal period for learning.

We have not, and probably have no way, to quantify learning and knowledge. Claims that peak learning periods, thus, depend more on one's intuitions than on established scientific claims. When educators say that the first decade of life is a unique time of enormous information acquisition and that the brain is in its most sponge-like phase of learning, they are making an intuitive conjecture not stating research result.

…We do not know what relationship exists between high resting brain metabolism and learning, any more than we know what relationship exists between high synaptic numbers and ability to learn. Any such claims are again conjecture correlating common sense behavior observations with a neuroscientific result in an attempt to understand what the brain is doing[36].

Dr. Bruer's conclusion is:

The neuroscience and education argument attempts to link learning, particularly early childhood learning, with what neuroscience has discovered about neural development and synaptic change. Neuroscience has discovered a great deal about neurons and synapses, but not nearly enough to guide educational practice in any meaningful way. Currently, it is just too much of a leap from what we know about changes in synapses to what goes on in a classroom.

> *Educators, like all well informed citizens, should be aware of what basic science can contribute to our self-understanding and professional practice. However, educators should consider more carefully what neuroscientists are saying before leaping on the brain and education bandwagon.*[37]

Some educators believe that "brain-based education" is the same old time-tested techniques and approaches with new labels. Still others dismiss it as nonsense. However, teachers who are using it swear by it. There are excellent reasons for looking for a new approach to learning. Traditional public schools seem to work poorly for a large number of children.[38]

In the past two decades we have seen an enormous amount of progress in understanding how the brain develops. The balance between the enduring significance of early brain development and its impressive continuing plasticity lies at the heart of the current controversy about the effects on the brain of early experience[39]. Brain development is a coaction of nature and nurture. For the human brain to develop normally it depends on an intimate integration of nature and nurture throughout the course of a lifetime. Developmental neurobiologists have begun to understand how experiences become integrated into the developing architecture of the human brain. When patterned light first hits the retina of the human eye, this experience provokes a cascade of gene expression that commits neural development to certain growth patterns rather than others. This is a genetically guided process of neural development that is designed to capture experience and to incorporate the effects of experience into the developing architecture of the nervous system. Developmental processes of brain growth are based on the expectation that certain experiences will occur that will organize and structure essential behavior systems.[40] These experiences include the infant's need to be exposed to light in order to be able to gain sight. They need to hear speech or see sign language in order to be able to acquire language. They need to be touched and held in order to develop social interaction skills. Deprivation of these ubiquitous and essential forms of environmental input can permanently compromise behavior functioning, which is why it is essential to detect and treat early sensory deficits (Greenough, Black, 1992).[41]

At the present time there are actually few neuroscience studies of very young children, and those that exist have not usually focused on the brain regions that affect cognitive development, emotions, and complex tasks. Recording electrical or magnetic activity of the brain, while a child is presented with different stimuli, has led researchers to realize that babies' brains change as they learn their native language (Nevile, Bavelier, Corina, Rauschecker, Karni, Lalwani, Braun, Clark, Jezzard, Turner, 1998).[42] Researchers do know that the brain requires certain experiences to occur and that these experiences need to happen within critical periods. Normal experiences like good nutrition, and patterned visual information support normal brain development, and abnormal experiences can cause abnormal neural and behavioral development.

The brain's neurochemistry is exquisitely sensitive to behavioral and environmental stimuli. Scientists are still looking at the link to specific types or amounts of experience and developing structure or neurochemistry of the immature human brain. Neurochemical-receptor systems lie at the heart of how the brain alters its physical structure. A variety of different nerve growth factors have been identified. These growth factors are present in different quantities and locations at different points in development of the brain, regulated by genes involved in normal brain development. The NMDA (N-methyl-D-aspartate) receptor is one receptor that plays a role in neural plasticity. It appears to support learning by helping to foster what is termed "long-term potentiation." Long-term potentiation, a memory "model" involving increased synaptic strength, is brought about by sustained, rapid activity in the neural circuits involved in newly acquired information. This is analogous to repeating a new phone number in order to memorize it. It appears that, at critical points in the development of neural systems, there is sometimes an increase in NMDA receptors. This increase seems to open the window for the development of that neural system, allowing stimulation to have large effects, with the window closing when the number of NMDA receptors decreases.[43]

There is increasing animal evidence that the environment plays a role in regulating aspects of brain neurochemistry. The licking and grooming that the mother rat does of her pups appears to enhance the production of serotonin and thyroid hormone, both important in the neurochemistry of the brain. There is also increasing evidence that elements of early caregiving may help modulate the neurochemicals in pain and distress. Fats and sugars in breast milk appear to stimulate taste receptors linked to opiod (natural painkiller) pathways, stimulating mild analgesia. Tactile stimulation of the mouth appears to operate through neurochemical mechanisms, not involving opiods that affect brain pathways controlling distress. [44] The brain's neurochemistry is exquisitely sensitive to behavioral environmental stimuli. Much more is known about the negative consequences for brain development of harmful environments than about the benefits of advantageous environments.[45]

In brain development there are "critical periods" in the nature and timing of formative experiences. These are unique episodes in development when specific structures of functions become especially susceptible to particular experiences in ways that alter their future structure or function. Early experiences uniquely prepare the young child for the future by establishing certain capabilities at a time when development is most plastic and responsive to stimulation. The young child is highly vulnerable to absence of these essential experiences, and the result may be permanent risk of dysfunction. [46] The brains of rats raised in more complex environments show more mature synaptic structure, more dendritic spines, larger neuronal dendritic fields, more synapses per neuron, more supportive glial tissue, and increased capillary branching that increases blood volume and oxygen supply to the brain. Environments with greater diversity can have beneficial effects.[47]

Moving from these animal studies to humans application is a big leap for some researchers, but they admit that there is a need for research that can illuminate how environments that exceed some minimal threshold affect brain development. For biologist and author Marion Diamond, this is not a leap at all. She explains it this way; "We work with rats because I have yet to find a human being who's willing to give me a piece of cerebral cortex to study. We investigate the changes in the structure of the nerve cell in the cerebral cortex when rats are exposed to either an enriched or an impoverished environment." They found that rats living in the enriched environment had developed a thicker cortex than the rats living in the impoverished environment. Their cortex had grown as a result of interacting with other rats and with objects to explore and climb upon. As nerve cells get stimulated by new experiences they grow new branches called dendrites. With use, you grow branches; with impoverishment, you lose them (D'Arcangelo, 1998).[48]

Negative environmental aspects can also hinder normal brain development. Psychosocial risks such, as poverty and family violence can be detrimental. Stress can also affect the developing brain. Research provides preliminary insights into how alterations of the early caregiving environment affect neurochemical aspects of early brain development. Stress refers to the set of changes in the body and the brain that are set into motion when there are overwhelming threats to physical or psychological well-being. When threats begin to overwhelm one's immediate resources to manage them, a cascade of neurochemical changes that begin in the brain temporarily puts on hold processes in the body such as digestion, resistance to disease, and the ability to learn. Many of these neurochemical changes take place in the very same brain structures that function to regulate heart rate, respiration, food intake, digestion, reproduction, growth, and the building-up versus breaking-down of energy stores (Statakis, Chrousos, 1995).[49]

There is a great deal to learn about how the social environment connects the biology of growth and the regulation of stress physiology in human infants and children. Intriguing research is emerging to suggest that the development of stress regulation in young children may be a very promising place to look for brain-experience dynamics. Both failure to thrive and psychosocial dwarfism in which children's pituitary glands fail to secrete sufficient growth hormone are associated with failures in social environment. We are barely at the beginning of exploring these issues in human babies (Skuse, Albanese, Stanhope, Gilmour, Voss, 1996).[50]

Dr. Harry Chugani, MD, is a professor of pediatrics, neurology and radiology at the Wayne State University School of Medicine, and director of the Positron Emission Tomography Center at Children's Hospital of Michigan. Dr. Chugani and his colleagues have observed patterns of complex brain maturation, which shape a child's learning capacity and behavior at very precise times. Using Positron Emission Tomography (PET), Dr. Chugani is able to measure the amount of glucose and oxygen consumption in various parts of the brain. More glucose indicates more activity, and more activity is proof of learning and thinking processes at work. A direct link has been drawn between the focal area of energy concentration and the development of certain behaviors.

Dr. Chugani argues that our brains are open to certain stimulation at certain times. He feels that young children should be exposed to playing a musical instrument and learning a second language very early when he feels their brains are wired for such skills. Behaviorists have known for a long time that if you want a child to be a good gymnast, or swimmer, or athlete, it is much easier for them if they begin learning the skills as a young child. Dr. Chugani says, "It's a balance between nature and nurture. All kids who take music lessons won't be great musicians; likewise we can't teach kids to throw a ball and automatically expect them to be great athletes. But if a child isn't exposed to those experiences early in life, the natural potential is lost. The related neuron connections are eventually shut down and destroyed, so you'll never know your full potential." Dr. Chugani also thinks we should teach our very young children basic forms of complex skills such as reading, writing, and reasoning. We shouldn't be afraid to get children interested in seemingly difficult subjects (D'Arcangelo, 1997).[51]

A Canadian report of the full Early Years Study, called, *Reversing the Real Brain Drain, Early Years Study, Final Report* named six key issues drawn from neuroscience and evidence from human and animal studies. They are:

- Early brain development is interactive, rapid, and dramatic.
- During critical periods, particular parts of the brain need positive stimulation to develop properly.
- The quality of early sensory stimulation influences the brain's ability to think and regulate body function.
- Negative experiences in the early years have long-lasting effects that can be difficult to overcome later.
- There are initiatives that can improve early development.[52]

Cognitive neuroscience is in its infancy, and there is much more to learn about the mind-brain connection. But given all we know now, can we set up classrooms that will be conducive to better learning? Are we able to keep the natural learning process going that young children have had since infancy? For some educators the answer is yes, we do know enough to set up brain-based learning. For others like Dr. Bruer the answer is not yet. Therefore the foundation that he is president of, James S. McDonnell Foundation, and John D. and Catherine T. MacArthur Foundation are funding a Research Network on Early Experience Brain Development. The major areas of study are:

- Effects of Early Experience on Brain-Behavioral Development
- Development of Methods for Studying Brain-Behavior Relations
- Comparative Studies of Early Brain-Behavior Relations
- Impact on Public Policy: Educating Educators and the Media.

This is an inter- and multi-disciplinary team drawing on experts from developmental psychology, developmental neurobiology and developmental/behavioral pediatrics. Ultimately their goal is to apply their findings to improve the lot of children. The network explores how knowledge of brain development can guide us in our understanding of behavioral development and vice versa. It focuses specifically on critical periods and neural plasticity, the reciprocal phenomena whereby a) the brain is deleteriously affected if certain experiences fail to exist within a certain time period and b) the brain is altered by experience at virtually any point in the life span. They are looking at how the structure of experience is incorporated into the structure of the brain, but also how this knowledge can influence decisions about intervention in the lives of children.[53]

The researchers and educators who feel there is enough evidence to merit brain-based learning are: Marion Diamond and Janet Hopson, Geoffrey and Renate Nummela Caine, Eric Jensen, Robert Sylwester an Pat Wofle and M. Sorgen. All are authors and are advocates of brain-compatible learning. They studied the brain research and have advised educators or have used the methods in their own classrooms (D'Arcangelo, 1997). [55]

There is a lot more to learn about cognitive neuroscience but we can use what we know so far to set up classroom environments that are more brain-compatible for learning by using:

- Holistic themes that integrate subjects
- Alternate focus-diffusion learning
- Time for processing and feedback and down time
- Emphasis on relationships and meaning
- Rich talking, music, and movement
- Use of all the senses in teaching
- Use of multiple intelligences
- Removal of threats
- Real-world experiences, simulations
- Positive daily, purposeful rituals
- Learning for joy
- Play-based learning
- Positive language
- Celebration of the positive
- Enrichment of learning with music, posters and aromas
- A child centered classroom

These things are not new. They are the way some teachers have been teaching intuitively for a long time. What is new is why we are doing these things. Educators can intentionally set up the classroom and curriculum so that every preschool child will have the access to the best educational environment. This has high probability of enhancing their brain development and helping them reach their fullest potential for learning.

IV. BRAIN-BASED LEARNING FOR THE PRESCHOOL CHILD

Brain-based learning for the preschool child looks a little different than the brain-based education for the kindergarten through twelfth grade student. This is because the needs of the preschool child are more specific. Preschool education as defined in this paper is all education that takes place in a child's life from birth to the first day of kindergarten. The context for this education would be in a childcare center. There is more evidence that preschool education should be structured on researched knowledge of how the brain develops during those years.

The Governing Board of the National Research Council and the Institute of Medicine commissioned 17 members with backgrounds in neuroscience, psychology, child development, economics, education, pediatrics, psychiatry, and public policy to do a two and a half year study that integrated and evaluated the current science of child development. The result of this study is now a report called, "From Neurons to Neighborhoods: The Science of Early Childhood Development." A summary of their findings is:

1. Early experiences affect the development of the brain and lay the foundation for intelligence, emotional health, and moral development, but the focus on the period from "zero-to-three" is too narrow. Early brain development is clearly promoted by nurturing adults. There is considerable evidence that early experiences influence brain development, the neurological window of opportunity does not slam shut at age 3 or 5. Stated simply, the

disproportionate focus on "zero to three" begins too late and ends too soon. The development of the human brain begins well before birth, continues throughout life, and is influenced by both nature and nurture.

2. Healthy early development depends on nurturing and dependable relationships.
3. How young children feel is as important as how they think, particularly with regard to school readiness. The social and emotional development of children are just as important as their intellectual advancement. Scientific evidence shows that very young children are capable of experiencing deep anguish and grief in response to trauma, loss, or personal rejection. And yet, many early child-care and education programs fail to apply such knowledge in their everyday dealings with children.
4. And although society is changing, the needs of young children are not being met in the process. [55]

Part of the committee's responsibilities was to dispel fiction concerning early childhood practices. They found that, contrary to the large and increasing number of commercial products on the market that claim to boost babies' intelligence, there are no special programs or materials that are guaranteed to do so. Young children thrive naturally when adults routinely talk, read, and play with them in a safe and encouraging environment. A theory that suggests that exposure to classical music may boost brainpower, the so-called "Mozart effect," has never even been studied in infants and toddlers. [56]

This committee cited another study about early child care and youth development done by the National Institute of Child Health and Human Development of the U.S. Department of Health and Human Services. This agency developed a comprehensive, longitudinal study about the relationships between children's experiences in childcare and their development over time. This NICHD Study of Early Childcare is the most comprehensive childcare study to date in the United States. This was a study of 1,364 children and their families. It began in 1991 the research team observed their child care settings at regular intervals, beginning at 6 months and ending at 54 months. A summary of their findings is:

- Intensive, high quality, center-based interventions that provide learning experiences directly to the young child have a positive effect on early learning, cognitive and language development and school achievement.
- Some of these effects dissipate during the early school years, but the impacts of some programs have been found to continue well into the school years and even into adulthood.
- High quality care in the infant and toddler years is also associated with children's cognitive and linguistic development in the correlational research on typical childcare settings.

High quality care is provided when the caregivers provide ample verbal and cognitive stimulation, are sensitive and responsive and give generous amounts of attention and support. More stable providers have been found to engage in more appropriate, attentive, and engaged interactions with the children in their care. Warm, sensitive and stimulating interactions between the child and the care provider are a mark of quality care. Caregivers with more child-centered and less authoritarian beliefs about child rearing have also been found to provide warmer and more sensitive care. Infants in centers with ratios of three or fewer children per caregiver were found to receive significantly more sensitive, appropriate caregiving.[57]

Both of these studies stress the importance of human relationships and the effects of these relationships on the development of the child. The study by the National Research Council examines the research on brain development and what effects that development. They are very explicit to say that much further research is needed to make a direct correlation between brain development and education. While neither of these organizations endorses brain-based learning, they do give guidelines for the quality childcare and quality environment for the preschool child to thrive. The items needed to ensure the best learning environment for the preschool child from these studies could be incorporated into brain-based learning.

Infants and toddlers, in a childcare center, need to have a primary caregiver. Many of the regulatory systems that are essential for infant survival and emotional organization require consistent caregiving attention. The essential features of healthy, growth-promoting relationships in early childhood are best embodied in the concepts of contingency and reciprocity. When young children and their caregivers are tuned in to each other, caregivers can read the child's emotional cues and respond appropriately to his or her needs in a timely fashion. Their interactions tend to be successful and the relationship is likely to support healthy development in multiple domains, including communication, cognition, social-emotional competence, and moral understanding.[58]

The caregiver must be warm, sensitive, and very responsive to the needs of the child. They need to talk, sing, laugh, and interact with the child in a very meaningful way. They must respond to crying in a caring way, holding and cuddling the child while seeking out what is wrong. The child must be held, loved, and praised with consistency. This is how the child learns their value. The infant needs to have pictures of themselves and their families on the wall. They need a very consistent schedule that is, in fact, dictated by the child's needs and originally set by the mother. Caring for infants and toddlers is a team effort of the caregiver and the parents. Written communication needs to flow back and forth from the home to the center. Books that are read, songs that are sung, and games and activities that are played need to be the same at the center and at home. A good center is an extension of what happens in the child's home environment.

A ratio of three infant or toddlers per one caregiver must be maintained for optimal care.[59] Infants and toddlers need to be fed on demand. Their schedules for food and water must come from the child's needs. Once they no longer have a bottle, a sippy cup with juice, water or milk should be offered to the child often.

The activities for infants and toddlers need to encompass all of the child's senses. The room needs to be painted a pastel color; this has a calming effect on the child. It must be furnished with toys of bright colors and contrast so that it gets the child's attention. The lighting in the room needs to be a soft light. The room must be well lit especially during the winter months. The temperature in the room needs to remain between 68-72 degrees Fahrenheit. But this may not be ideal for every child, the caregiver must give be alert to how the child is dressed to keep them comfortable. Extreme, too hot or too cold, is not conducive to optimum learning. Fresh air is an important ingredient for optimal learning. Brains require oxygen to function properly. Ventilation in the room is significant. Infants and toddlers must have a safe environment where they are free to move around and explore the room (Jensen, 1996).[60] It must be a clean room, with ease of movement for the child who is mobile, either crawling or walking. Soothing music can be played. Toys and objects of different textures, shapes and colors should be part of the room. Different smells should be used in the room. Scented playdough is fun for the toddler to play with. This can be scented with vanilla, lemon, spices, etc.

The room should be set up so that it welcomes the child and has a lot of centers set up for them to play and explore. By instinct, babies and toddlers are creatures of learning and of play, exploring every detail of their surroundings with intense curiosity. Through their constant touching, looking, tasting, listening, and moving, babies provide themselves with most of the experiences they need in order for their brains to develop normally. The room should be set up in a manner that is "user friendly" for the child. Wastebaskets and other similar items should be out of reach for the child. This will alleviate frustration for the child and the caregiver. The caregiver's use of the word "no" should be limited. Also avoid using words like bad, messy, or negative terms. Instead, focus on the behavior you wish to see. Redirect the child's attention, and keep the atmosphere positive as much as possible. Marion Diamond says, "Make your language enrichment fun so the child equates learning and communicating with pleasure (Diamond, Hopson, 1999)."[61]

Children of this age are not too young to learn and develop using the **seven intelligences** as defined by Howard Gardner.[62] Emotional security is at the top of the list for enrichment in infants and toddlers; second to that is **language.** They need an environment rich in spoken, written, and gesture language. They need to hear the voice of their parents and their caregivers as they interact together. Babies need to be talked to all the time. Tell them what you are doing; name all the things in the room. Make up stories. Sing lullabies, and kids' songs. They should be read to 20 minutes per day (Diamond, Hopson, 1994).[63] They are not too young to have "themes," such as Halloween, Christmas, and other seasons, with stories and decorations. Infants can even identify objects in terms of **numbers**. Psychologist Karen Wynn, working in a laboratory discovered that five-month-olds have a form of numerical reasoning that amounts to baby arithmetic. Infants and toddlers are not too young to begin deductive thinking and reasoning (Diamond, Hopson, 1999).[64] **Spatial representation,** ability to visualize objects and create internal pictures, develops as the child interacts with its environment. Toddlers love trying to fit things together and especially love taking them apart. Finding hidden toys and fearing heights are both spatial kills as well as examples of sustained attention. **Body-kinesthetic,** toddlers and infants love crawling over things to get to where they want to be in a room, or to retrieve an object. **Musical thinking,** babies will bounce to a beat of music. Toddlers will squat down and pop up to music like "pop goes the weasel." Clapping to the beat, dancing and singing to music enhances language acquisition and helps children identify musical tones. **Interpersonal,** infants learn very early that their actions elicit reactions from other people. When they cry, someone comes to comfort them. When they smile, someone smiles back and talks to them. **Intrapersonal,** the child begins to realize they are somebody, and soon they learn they are loved by those in the world around them. Love and nurturing is modeled for the infant, and this teaches them to love others. Infants and toddlers need to live in a world that is responsive to them and their needs.

Human development is now described in interactive terms reflecting the essential characteristic of a living organism. Virtually all-contemporary researchers agree that the development of children is a highly complex process that is influenced by the interplay of nature and nurture. The influence of nurture consists of the multiple nested contexts in which children are reared, which include their home, extended family, child care settings, community, and society, each of which is embedded in the values, beliefs, and practices of a given culture. The influence of nature is deeply affected by these environments and, in turn, shapes how children respond to their experiences. Children affect their environments at the same time that their environments are affecting them. No two children share the same environment, and no two different children experience an environment in exactly the same way. Two youngsters living in the same home influence each other and are affected by the other members of the family in unique ways. If one child is active and aggressive and the other is passive and subdued, each will elicit different responses from the parents -- and each will be influenced differently by the behavior of the other.[65]

It is important that each child be accepted for who they are, not who we want them to be. Mary Rothbart, a psychologist who studies temperament at the University of Oregon in Eugene views temperament as multidimensional, and thinks those children must receive unconditional acceptance as well as certain specific kinds of experiences. Rothbart argues that subtle changes are both possible and desirable for some children.[66]

Memory is another important aspect of learning. Cognitive scientists call the built-in mental features of our minds "cognitive architecture." This part of the mind builds and executes programs much like a computer. Information from the external world comes to us through our sensory systems. Some of the information is used immediately this is called short-term memory or working memory. Other chunks of information are stored in our long-term memory. Long-term memory is our storehouse of knowledge and skills. Psychologists call this an associative structure. Associative links tie the items together into networks of related information. The chunks have associative links when they are used repeatedly or experienced together. Physical attributes or skills are stored in the part of memory that is not always open to conscious recall. This is called nondeclarative memory. It is our memory for procedures. Psychologists call the conscious part of our memory declarative memory. There are two parts to declarative memory: episodic memory, a system for remembering general facts, and semantic memory, for word meaning.[67]

Short-term memory has a limited capacity. George Miller's research showed our short-term capacity is 7 digits plus or minus two. He says this is why we can remember phone numbers, which are seven digits, two sets of numbers, a set of three and a set of four. When we add the area code we have two sets of three and one of four. The task of working memory is to hold and process information. It can only handle a limited amount of information for only short periods of time. John Bruer in his book, "The Science of the Mind" says, "Skilled thinking, problem solving and learning depend on how well we can manage this limited resource - on how efficiently we can store, process and move information into and out of working memory."[68]

Because memory is associative it is important that we use all five senses when teaching preschoolers. Children will remember an experience if it is associated with a smell, a sound, a sight, a taste, or a touch. These are powerful tools for learning. Making positive memories that last a lifetime should be a goal in preschool experience.

The room environment for children two to four years old is similar. For the two-year-old it should have lots of room for their perpetual motion. There should be tricycles to ride, areas for climbing, throwing balls, running, and jumping. There should also be also be constraints for safety because their abilities far outstrip their judgement and self-control. There is a danger of bumping, falling and darting in front of cars. Two's are developing a longer attention span than toddlers are, but there are a lot of mood swings, tantrums, fears, and anxieties that can overwhelm the child and test the parent or caregiver's patience. They need centers in their room where they can build with blocks, play with clay, play with dolls, look at books, listen to music, sing, and dance. Movement is very important for this age.[69]

Much attention needs to be placed on the relationship of the caregivers to the child. Two-year-olds need someone who loves and is kind and who understands the stages of their development. The same things are important in this environment that were needed in infants and toddlers. The room should be well lit, with soft lighting. The temperature needs to remain between 68 and 72 degrees Fahrenheit. The color of the room should be pastel, with a lot of contrast colors for the children to see. Children at this age have a vocabulary of around 900 words. They need to be read lots of stories. They enjoy hearing their favorite story over and over again. Themes can be used for the two-year-olds. They enjoy celebrating the seasons. The room should have furnishings that are the size of small children and should be safe for the child to constantly explore using all their senses. Children of this age should have a sippy cup of water or juice available whenever they feel thirsty. The aromas in the classroom should be pleasant, like those of spice, lavender, orange or floral.[70]

The room for three and four-year-olds is similar to the two-year-old but becomes a little more sophisticated with each age. Three-year-olds are still exploring and active, chasing, tricycling, or catching balls, and love hands-on activities like using construction sets, art materials, and puzzles. They love to experiment with blocks, sand, water, bubbles, seeds, and other objects in the environment. Language and musical skills can be built through conversations, stories, songs, rhymes, and instruments.[71]

Four-year-olds can experience field trips to the pumpkin patch, the zoo, the theatre, etc. They need learning centers where they can choose to dress-up and have dramatic play, do math games, science games, blocks, listen to CD's, play on a computer, look at books, and do art projects. Simple problem solving should be included using cooking ingredients, gardening, tools, wood, measuring devices. They develop more in language through storytelling, poems, playacting, and drawing, copying letters, singing and using musical instruments.[72]

Three and four year old children should have their own canteen of water or juice because children who are bored, listless, drowsy, and who lack concentration may be dehydrated. A cool, fresh drink of water should be available to the child throughout the day. Aromas in the classroom should be pleasant. Current research says that for mental alertness, try peppermint, basil, lemon, cinnamon and rosemary. For calming and relaxation use lavender, chamomile, orange and rose. [73]

Plants in the classroom can raise the oxygen level of the room. The best plants to have for pollutant reduction, fresh oxygen and enhancement of indoor learning environment are: gerbera daisies, yellow chrysanthemums, ficus benjamina, philodendrons, dracena deremensis, peace lilies and bamboo palms. These can be used several ways. They can be planted in a transparent medium so that the children can observe the plant growing below the ground as well as above. The children can take care of the plants, watering them and measuring how much they grow.[74]

The curriculum for preschoolers must be relevant to the children's lives and reflect their culture. Weekly themes are an excellent way of keeping a continuity of information flowing to the children. It is the implementation of these themes that makes a difference in the brain-based classroom. The teacher will present the theme. This can be done in several ways, either through pictures, or an object, or a story, or a song, etc. The children should be given a chance to explore what they know about the subject, or what they would like to know about the subject. This then becomes a project.

The children, with guidance of the teacher design the project, and it is built on real daily life experiences from the child's point of view. Spontaneous play and project work are intertwined and occur side by side in the preschool classroom. In the book, "Engaging Children's Minds: The Project Approach" Lilian G. Katz and Sylvia C. Chard argue that project work takes into account acquisition of knowledge, skills, dispositions, and feelings. It provides learning situations in which context - and content-enriched interactions and conversation can occur about matters familiar to the children. It provides children with activities in which many different ability levels can contribute to the group. They all contribute on their level, so all children feel that learning is fun. They will be eager to participate in another subject. Because project topics are drawn from the children's interests and familiar environments, the knowledge acquired can have real cultural relevance for them. Projects can help them understand and make sense of their world. [75]

The project is explored with the children, using a web approach. The subject is stated in the middle of the paper. All of the ideas about the subject are presented around the edges of the paper. The ideas can become elaborate, as in constructing something, or they may stay simple and be enacted in dramatic play at any of the centers around the room. The teacher can direct the aspects of the project by asking questions of the children. This way they can ensure that all five senses are used when we are doing the project. The teacher can help direct the scope of the project. If it becomes very interesting to the children it can become an ongoing project that would last over the whole year. As the children become engaged in various aspects of project work, their teacher can identify opportunities to enhance their knowledge, improve their skills, strengthen worthwhile dispositions, and ensure healthy feelings about their lives in the community of learners. [76]

There are five stages to implementing the project

1. Planning stage, deciding what component will be in the project
2. Gathering resources
3. Hands on experience with project
4. Feedback and reflection on what we've learned
5. Down time – time for children to do intrapersonal reflection[77]

Howard Gardner's theory of children knowing their world through the capacities of his seven intelligences can be used with the project approach. The classroom using the project approach will be rich in language. The children will be discussing the project with the teacher and everyone will have a chance to be creative, without constraints. Numbers and math will be incorporated in the number of items mentioned and other ways throughout the project. Spatial intelligence will be utilized in the way the web is organized on the paper and implementing the project. The design of a construction will use spatial intelligence. Music is a large a part of the project. Music is used in the classroom to elicit emotions. It can be used for a calming effect. It is used as a teaching tool, and it can be used for transitions. The children could make up a rhyming song about the project, or they could look for songs that are on the subject they are studying. Physical skills will be used when the design is completed. The project should involve physical movement of the children. Interpersonal skills are used in every aspect of the project from the design, to the implementation.

Children are collaborating from the beginning. They learn from one another. Intrapersonal skills are used for the child to think about what they know regarding the subject of the project. They need to detail what they know, and what they want to learn. The knowledge of nature is another intelligence suggested by Gardner. Children could use their knowledge of the outdoors to incorporate it into the project.

Collaborative learning, and constructing ideas, using all of their senses will get and keep the attention of all the children in the classroom. Once the project is designed, the children can interface with it in many ways. The teacher must guide the conversation so that all the centers around the room focus on the project. Once this is completed, spontaneous play around the room has a purpose. The whole room has become a thinking classroom, and all children can feel good about the fact that they had something to contribute to making it happen.

This is a child-centered classroom. Learning is celebrated. A lot of attention is focused on making use of our senses to create meaningful memories. Bold colors are used when we want to make a point. Aromas are used strategically. There are positive daily rituals to so that children safe and secure. Education in this classroom is fun, it's interesting, it's meaningful, and it is relevant to the child. As Gardner puts it, "it seeks to preserve the most remarkable features of the young mind – its adventurousness, its generativity, its resourcefulness, and its flashes of flexibility and creativity.[78]

CONCLUSION

The brain-based learning for the preschool classroom is different from other classrooms because it is a holistic approach to learning. It takes into account how the child's brain is developing, and it sets the stage for the best learning environment. The learning theories incorporated in brain-based learning are not new. The project approach, collaborative learning, and constructivist learning theories have been used for a long time. What is new is knowing how the small child's brain is developing and planning the environment so that the best exchange of nature and nurture can take place and the child may achieve ultimate learning. It will not make children more intelligent, any more than giving a small child piano lessons will create a concert pianist. But it will give the small child a place to be nurtured, loved, and cared for in an environment structured for their best learning to take place. This kind of a classroom makes learning fun and it continues the spontaneous, creative learning the children did before they came to preschool. If the preschool experience is positive, the children will develop a thirst for knowledge and want to go on learning.

REFERENCES:

[1] Bob Jacobs, Matthew Schall, and Arnold B. Scheibel, "A Quantitative Dendritic Analysis of Wernicke's Area in Humans. II. Gender, Hemispheric, and Environmental Factor," *The Journal of Comparative Neurology,* 327 (1993) 97-111.

[2] Marian Diamond, Ph. D. and Janet Hopson, "*Magic Trees of the Mind,* How to Nurture Your Child's Creativity, and Healthy Emotions from Birth through Adolescence," 150 (1999) Plume Book Penguin Putnam, Inc. New York, NY 10014.

[3] www2.acf.dhhs.gov/programs/hsb/about/99_hsfs.htm.

[4] M. Diamond & J. Hopson (1999) PP 48-51.

[5] P. R. Huttenlocher and Ch. De Couten, "The Development of Synapses in Striate Cortex of Man," *Human Neurobiology,* 6 (1987): 1-9.

[6] Roderick. J. Simonds, and Arnold B. Scheibel, "The Postnatal Development of the Motor Speech Area: A preliminary Study," *Brain and Language,* 37 (1989) 42-58.

[7] American Academy of Pediatric, *Caring for your baby and young child,* Steven Shelov, ed. (NewYork: Bantam Books, 1994), p. 179.

[8] Steven Shelov, ed. (NewYork: Bantam Books, 1994).

[9] Kurt Fischer and Samuel Rose, "Dynamic Development of Coordinations of Components in Brain and Behavior," in Dawnson and Fischer (1994), Ch.1.

[10] Fischer & Rose in Dawnson and Fischer (1994), Ch1.

[11] M. Diamond & J. Hopson (1999) p115.

[12] Bennett I. Bertenthal and Joseph J. Campos, "New Directions in the Study of Early Experiences," *Child Development,* 58 (1987): 560-567.

[13] Adele Diamond, "Frontal Lobe Involvement in Cognitive Changes during the First Year of Life, In Gibson and Peterson (1991), Ch. 7.

[14] Adele Diamond, "Neuropsychological insights into the meaning of object concept development." In S. Carey & R. Gelman (Eds.), *The epigenesis of mind: Essays on biology and knowledge* (1991): 67-110. Hillsdale, NJ: Lawrence Erlbaum Associates. Reprinted in MarkH. Johanson (ED.) (1993), *Brain Development and Cognition: A Reader.* Cambridge, MA Basil Blackwell.

[15] M. Diamond & J. Hopson (1999) p118

[16] M. Diamond & J. Hopson (1999) p 125

[17] M. Diamond & J. Hopson (1999)p 127

[18] Bruce Perry, "Psychophysiological 'Archaeology' and the Impact of Abuse and Neglect on the Developing Brain," in M. Murburg, ed., *Catecholamines in PTSD.* Washington, DC: APA Press, 1994), 253-276.

[19] Class notes 7/17/00 from EDU 530 "Contemporary Issues In Learning and Teaching" Dr. Barry Franklin, The University of Michigan-Flint, School of Education and Human Service, Department of Education

[20] Mischel, W. (1993) "Behavioral Conceptions," In. W. Mischel, *Introduction to Personality* (pp 295-316) New York: Harcourt Brace.

[21]Howard Gardner, (1991) *The Unschooled Mind, How Children Think & How Schools Should Teach* (p.28) Basic Books, New York, NY 10022-5299

[22]Howard Gardner, (1991) p.30

[23] John Dewey,*The Child and the Curriculum* (1920) In. John Dewey (1990) " The School and Society, The Child and the Curriculum," (pp 200-209) The University of Chicago Press, Chicago 60637

[24] L. S. Vygotsky,(1978) *Mind in Society, The Development of Higher Psychological Processes,* (pp 84-104) Harvard University Press, Cambridge, MA

[25]Caine, Renate & Caine, Geoffrey (June , 1994) *Making the Connections:Teaching and the Human Brain* (p 518) Addison-Wesley Publishing Co.

[26] Howard Gardner, (1991) p.12

[27] Eric Jensen (1996), *Brain-Based Learning, (*p.271), Turning Point Publishing, Del Mar, CA 92014

[28] Daniel P. Goldman (July, 1997) *Emotional Intelligence*, (p. 193.) Bantam Books, New York

[29] Eric Jensen (1996) pp 200-201

[30] John T. Bruer (1999) *The Myth of The First Three Years,* (p.34) The Free Press, New York, 10020

[31] Michael Gazzangia, (May,1998) *The Mind's Past,* The University of California Press/ Princeton Fulfillment Services, Inc. Ewing,NJ 08618

[32] Bruer, John, "Insearch of...Brain-based Education," www.pdkintl.org/kappan/kbru9905.htm

[33] "Debunking the Myths of Early Childhood Learning," Reuters new service, *Children Do Not Have Learning Window,* www.icehours.net/lmstuter/page0046.htm

[34] "Debunking the Myths of Early Childhood Learning," www.icehours.net/lmstuter/page0046.htm

[35] "Debunking the Myths of Early Childhood Learning," www.icehours.net/lmstuter/page0046.htm

[36] "Debunking the Myths of Early Childhood Learning," www.icehours.net/lmstuter/page0046.htm

[37] "Debunking the Myths of Early Childhood Learning," www.icehours.net/lmstuter/page0046.htm

[38] M. Diamond & J. Hopson (1999)p 266

[39] Skonkoff, Jack P & Phillips, Deborah A. Eds. (2000) p 182 in From Neurons to Neighborhoods: The Science of Early Childhood Development Committee on Integrating the Science of Early

Childhood Development, The National Research Council, National Academy Press, Washington, DC http://books.nap.edu/books/0309069882/htmlR2.html#pagetop

[40] Greenough, W.T., and J. E. Black (1992) Induction of brain structure by experience: Substrates for cognitive development. Pp 155-200 in *Developmental Behavior Neuroscience,* Volume 24 M.R.Gunnar and C. A. Nelson, Eds. Hillsdale, NJ: Erlbaum

[41] Greenough, W.T., and J. E. Black (1992)

[42] Neville, H. J., Bavelier. D., Corina, D., Rauschecker, J., Karni, A., Lalwani, A., Braun, A. Clark, V., Jezzard, P., and Turner, R. (1998) Cerebral organization for language in deaf and hearing subjects: Biological constraints and effects of experience. *Proceedings of the National Academy of Sciences 95:922-929*

[43] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 192

[44] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 193

[45] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 194

[46] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 195

[47] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 196-7

[48] D'Arcangelo, Marcia (1998) How the Brain Learns,The Brains Behind the Brains, *Educational Leadership,* Volume 56, Number 3

[49] Stratakis, C.A. and Chrousos, G.P., (1995) Neuroendocrinology and pathophysiology of the stress system. Pp. 1-18 in *Stress: Basic Mechanisms and Clinical Implications,* Annals of the New York Academy of Sciences Volume 771. Chrousos, G. P., McCarty, R., Pacak, K. Cizza, G., Sternberg, E., Gold, P.W., Kvctnansky, R., eds. New York: New York Academy of Sciences

[50] Skuse, D. Il. Albanese, A., Stanhope, R., Gilmour, J., and Voss, L. (1996) A new stress-related syndrome of growth failure and hyperphagia in children associated with reversibility of growth-hormone insufficiency. *Lancet* 3489024):353-358

[51] D'Arcangelo, Amy (1997) ***Brain Surges,*** http://www.med.wayne.edu/wmp97/brain.htm

[52] reversing the Real Brain Drain, *Early Years Study Final Report (1999)* Ontario Children's Secretariat, Ontario, Canada. http://www.childsec.gov.on.ca/newsrel/reporten.pdf

[53] The John D. and Catherine T. MacArthur Foundation and James S. McDonnell Foundation Research Network on Early Experience Brain Development http://www.macbrain.org/

[54] D'Arcangelo, Amy (1997)

[55] http://www4.nationalacademies.org/news.nsf/

[56] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 301

[57] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 301-305

[58] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 308

[59] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000),p 309

[60] Eric Jensen (1996),pp 55-68

[61] M. Diamond & J. Hopson (1999)p141

[62] Howard Gardner, (1991) p.12

[63] M. Diamond & J. Hopson (1999) pp 120

[64] M. Diamond & J. Hopson (1999) pp 120-121

[65] Shonkoff, Jack P. & Phillips, Deborah A., Eds. (2000)p 320

[66] M. Diamond & J. Hopson (1999) pp122-23

[67] John T. Bruer, 1999, "Schools for thought: a science of learning in the classroom" A Bradford Book, MIT Press, Cambridge, MA pp23-25

[68] John T. Bruer, 1999, p29

[69] M. Diamond & J. Hopson (1999) p152

[70] Eric Jensen (1996),pp 55-68

[71] M. Diamond & J. Hopson (1999) p 152

[72] M. Diamond & J. Hopson (1999) pp 168-169

[73] Eric Jensen (1996),pp 55-68

[74] Eric Jensen (1996),pp 55-68

[75] Lilian G. Katz, Sylvia C. Chard (1995) 'Engaging Children's Minds: The Project Approach," Ablex Publishing Corp. Norwood, NJ pp 15-63

[76] Lilian G. Katz, Sylvia C. Chard (1995) pp 87-91

[77] Caine, Renate & Cain, Geoffrey (June, 1994)

[78] Howard Gardner, (1991)p111