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ABSTRACT

New research on brain development has profound implications in the areas of child development and education. This review of the research describes how the brain develops to shape children's growing intelligence, addressing such questions as: (1) What are the brain's functions? (2) What are the critical or sensitive periods in brain development? (3) How can teachers take advantage of these "windows of learning?" (4) How much is mental ability influenced by environment and how much by heredity? (5) Is it better to teach to the whole brain, or is left brain/right brain theory better? (6) How does brain development influence language? and (7) How can parents get involved in their child's learning? The paper begins with a presentation of relevant definitions, such as brain development, cerebrum, dendrites, neurons, and plasticity. It next presents brief histories of early childhood education, discussing such theorists as Froebel, Montessori, and J. M. Hunt, and of brain studies, including the work of Wiesel and Hubel and of Epstein. The paper then discusses major issues and controversies in brain research, such as the windows of learning for various functions and subjects, the inseparability of brain structure and function (or of heredity and environment), and left brain/right brain learning. The paper next explores important programs and contributors to the incorporation of brain research into early childhood education, including Caine and Caine's (1995) Dry Creek Elementary in Rio Linda, California, and Blythe and Gardner's (1990) Project Spectrum, based on his work with multiple intelligences. The paper concludes with a synthesis and analysis of brain research's relationship to early childhood education, including brain-based learning, and with a set of recommendations for educators. Contains 28 references. (EV)

Brain Development and its Relationship to Early Childhood Education

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Introduction

At the urging of the National Institute of Mental Health and other organizations, President Bush declared the 1990s the Decade of the Brain (Jones, 1995). Technology has come a long way in the last part of the twentieth century. One of the questions Kotulak (1996) tried to answer in his book was "How can a newborn with thousands of muscles, scores of organ systems, 100 billion brain cells, and trillions of connections between these cells ever figure out how to get them all working together to produce consciousness, reason, memory, language, and a seemingly infinite array of adaptations to any environment in which it finds itself?"

The new research has profound implications in the area of child development and education. The purpose of this review of the research is to learn how the brain develops in order to shape our children's growing intelligence.

Parents need to learn that nutrition is very important to the health of the brain. Research shows the need for good nutrition before a child is even born (Jones, 1995). Mothers who limit their food intake during pregnancy have children with a smaller brain structure and a great deal less ability to learn.

Parents also need to know the importance of early learning opportunities for the very young (Jones, 1995). The brain remains plastic--that is, it retains the ability to make new neural connections--throughout life, but it is most plastic in the first five or six years of life. Parents need to use this knowledgeby taking advantageof an appropriatepreschool education.

It is important for educators to learn more about the brain so that they can provide children with the best opportunities they can. Information flows easily into the brain through "windows" that are open for only a short duration (Kotulak, 1996). These windows of development occur in phases from birth to age twelve when the brain is most actively learning from its environment. It is during this period that the foundations for thinking, language, vision, attitudes, aptitudes, and other characteristics are laid down. Then the windows close, and much of the fundamental architecture of the brain is completed (Kotulak, 1996).

Statement of the Problem

The problem facing educators and parents today is that the old methods of teaching are not working because young brains have not been shaped around language as an important tool for analytic thinking. The results are inevitable: declining literacy, falling test scores, faltering or circuitous oral expression, ineptitude with the written word that extends from elementary school into the incoming ranks of professionals (Healy, 1994). Also at risk are sustained attention and problem solving (Healy, 1990).

There are many problems that need to be addressed. The questions that the author of this paper hopes to answer are: What are the brain's functions? What are the critical (or sensitive) periods in brain development? How can teachers take advantage of these "windows of learning?" How much is mental

ability influenced by environment and how much by heredity? Is it better to teach toward the whole brain, or is left brain/right brain theory better? How does brain development influence language? How can parents get involved in their child's learning?

Definitions

Brain Development - The International Encyclopedia of Education (1994) defines it as follows: "Brain development in mammals is characterized by numerous, in part precisely timed changes which start within the embryo, but continue during postnatal life. For humans, these alterations and adaptations continue for years and sometimes even for more than a decade during postnatal life, but have their major impact during the first months and years, when a number of critical periods exist which require a specific environmental input for an optimal development of the brain."

Most of the brain's growth occurs during the last three months of gestation and the first year of life. Brain tissue development, which is in advance of the rest of the body, reaches a peak toward the age of three years (Senemaud, 1988).

Cerebrum - "The largest part of the brain, which is divided into two hemispheres with four lobes each, contains an outer layer of gray matter called the cerbral cortex and underlying white matter that relays information to the cortex. The cortex handles the most sophisticated functions of the brain, from processing visual images to thinking and planning" (Lemonick,

1995).

Corpus Callosum - "A large band of nerve fibers through which information flows back and forth between the left and the right hemispheres of the brain" (Lemonick, 1995). "The corpus callosum seems vital to the transfer and facilitation of associative information between hemispheres" (Hynd et al., 1991).

Dendrites - A neuron has a central nucleus with outreaching "fingers" that are the dendrites. "These microscopic projections extend in treelike formations to act as intake systems, picking up messages from other neurons and relaying them to the cell body" (Healy, 1990).

EEG - stands for electroencephalograph. It outlines localized brain activity (Kotulak, 1996).

Genes - The chemical blueprints of life. They establish the framework of the brain and work in tandem with the environment.

MRI - stands for magnetic resonance imaging. It allows scientists to watch the blood flow to different parts of the brain so they can see what areas are activated for the neural firings that mean connections are being made and learning is taking place (Jones, 1995). Functional Magnetic Resonance Imaging machines can now distinguish between neuronal groups that are only one millimeter apart (Sylwester, 1994).

Neurons - "Basic unit of the nervous system; the nerve cell. Its function is to transmit and store information; includes the cell body (soma), many processes called dendrites, and an axon" (Kolb and Whishaw, 1991).

PET - stands for positron emission tomography, a technique that measures the activity of cells in different areas of the brain (Kotulak, 1996). Patients are injected with radioactive glucose which mixes with the blood and goes to the brain. The more active a part of the brain is, the more glucose it uses (Begley, 1992).

Plasticity - Kotulak (1996) defines plasticity as "the tremendous flexibility which enables the brain to constantly undergo physical and chemical changes as it responds to its environment." Peterson (1994) states that it is "the species' capacity to adapt to its environment and to recover from deprivations, illnesses, and injuries to the brain."

Reticular Core - a network of nerves and fibers located in the brain stem (Jones, 1995). Psychiatrist Arnold Scheibel (as quoted in Jones, 1995), who is a previous director of UCLA's Brain Research Institute, said, "It's a very primitive area and one of its most important roles is to make quick-and-dirty estimates as to whether input is strange and unexpected or dangerous. It is the reticular core, apparently, that triggers the upper part of the brain to be the most active."

Synapse - The point of electrical or chemical interaction and contact between two neurons or between a neuron and a muscle fiber or neurosecretory cell. It is often used synonymously with synaptic gap (Languis et al., 1980).

Synaptic gap - A very small space between the two contacting surfaces (Languis et al., 1980). The strength and efficiency of

synaptic connections determine the speed and power with which the brain functions. They are formed, strengthened, and maintained by interaction with experience (Healy, 1990).

History of Childhood Education

The first area of history that will be covered is early childhood education as it relates to brain development. The 1800's started off as the "age of reason". Logic and experience overshadowed faith and religion as the source of truth (Spodek et al., 1991). Empiricism and rationalism became the basis for the school curriculum. Lectures and recitations changed to direct experience and exercises in reasoning (Spodek et al., 1991).

Then Friedrich Froebel brought kindergarten to the United States in 1856 (Spodek et al., 1991). Froebel viewed the mother as central to the proper education of the young. Froebel was a philosphical idealist, like Plato, who believed that ideas could be validated abstractly, without experience (Spodek et al., 1991). He believed that education should follow development, protecting children who learned through self-activity.

Maria Montessori sought keys to unlock intellectual potential in children. She explored the work of earlier philosophers and educators, including Rousseau, Pestalozzi, Froebel, Itard, and Seguin (Spodek et al., 1991). She started out working with mentally defective children in Italy, but then extended her approach to normal children. Montessori viewed development as a process of unfolding and that environmental influences also

played an important role (Spodek et al., 1991). Her curriculum was designed to influence sensorimotor, intellectual, language, and moral development. These diverse elements were interrelated, which may be seen as a precursor to Gardner's seven intelligences.

John Dewey started the progressive kindergarten, as opposed to Froebel's approach to symbolic education. According to Dewey, the social life of the community was the source of children's education. Children were given direct experiences with both physical and social phenomena and were asked to reconstruct these experiences through play (Spodek et al., 1991).

The 1960's showed a greater awareness for the needs of early childhood education. J.M. Hunt's (1961) volume, <u>Experience and Intelligence</u>, synthesized a great deal of theory and research that challenged the maturational point of view (Spodek et al., 1991). Hunt suggested that human development, including intellectual development, was modifiable through environmental experiences. The work of Jean Piaget, a developmental epistemologist, and B.F. Skinner, a learning psychologist, served as the inspiration for many new program. Some of the curriculum models that evolved are the "Planned Variations" model of the Head Start and Follow Through programs, and the High/Scope model (Spodek et al., 1991).

The 1980's became a period of conservatism in the field of early childhood education. A narrowing of standards can be seen in the National Association for the Education of Young Children's

(NAEYC) established guidelines for developmentally appropriate kindergarten practices, which were later expanded to include the entire age range from birth through age eight (Bredekamp, 1987). However, the exclusive use of developmental guidelines for judging programs has been criticized as inadequate (Spodek et al., 1991). No attention has been given to the content of the programs. This may be an issue in the future.

History of Brain Studies

In the 1950's, a man known as H.M. opted for surgery to stop the seizures that medication couldn't control (Jones, 1995). His medial temporal lobes, located near the bottom of his brain, were removed, and the seizures stopped. So did his ability to form a memory.

> "Now in his 60s, H.M. still has a normal IQ, can still carry on a conversation, and can still learn new things. He just can't remember anything that's happened in the 40 years since his surgery. (He has vivid memories of earlier years, though.) If someone shows him how to perform a task, he can do it until he is distracted. Then he immediately forgets everything he has learned; when he goes back to the task, he needs the instructions repeated (Jones, 1995).

What fascinates neuroscientists is that, although H.M. can't remember learning the task, his performance on the task steadily improves at the same pace as someone who remembers the instructions. This oddity was their first clue that the brain stores different kinds of memories in different locations (Jones, 1995).

In the 1960's, Torsten Wiesel and David Hubel sewed shut one

eye of newborn kittens to test the effects of sensory deprivation (Kotulak, 1996). "When the eyes that had been stitched closed were opened a few weeks later, the eyes were not able to see. But, suprisingly, the eyes that had remained open could actually see better than normal eyes" (Kotulak, 1996). The brain cells from the closed eye had failed to learn their task, but they had gone off to help the other eye.

Wiesel and Hubel won a Nobel Prize for their important discoveries. They showed that sensory experience is essential for teaching brain cells their jobs, and after a certain critical period, brain cells lose the opportunity to learn those jobs (Kotulak, 1996). What was true for cats was also true for humans. Based on the discoveries of Wiesel and Hubel, surgeons no longer wait until a child is several years old before removing cataracts. They prevent blindness by removing cataracts early, which allows visual experiences to reach the brain (Kotulak, 1996).

Herman T. Epstein identifies stages of cognitive growth that correlate with the development of the brain (Cooke and Haipt, 1986). His experimentally based intervals of growth are similar to those described by Jean Piaget, except for an extra stage, problem solving, which is beyond Piaget's formal operations (Cooke and Haipt, 1986: Languis et al., 1980). Epstein suggests that times of rapid brain growth mostly associated with growth of glial cells, myelination, and dendritic branching are sensitive periods when new learning might be introduced (Languis et al.,

1980). Epstein invites educators to design curricula and programs that take advantage of the mental growth spurts that he describes.

Another historic brain study is Goldman-Rakic's work with rhesus monkeys (1981, as cited in Peterson, 1994). Brain damage was introduced to the prefrontal cortex of rhesus monkeys during their prenatal development. After full-term gestation and birth, the monkeys were presented with easy tasks early in their lives. "Their brain injuries led to no significant difference in their performance compared with their non-brain-injured peers of the same age. However, a delayed effect of brain impairment was observed as the experimental monkeys reached an age when advanced cognitive functions were required to solve complex tasks" (Peterson, 1994). Goldman-Rakic's research provides evidence that prenatal brain injuries can have delayed effects.

In 1981, Dr Roger Sperry, professor of psychobiology at the California Institute of Technology, received a Nobel Prize in Physiology and Medicine for his work on split-brain research. Sperry and his colleagues demonstrated the unique functions of each hemisphere (Cooke and Haipt, 1986). They proved that split-brain patients have difficulty integrating information from both sides of the brain. The connecting fibers of the corpus callosum relays information between the right and left hemispheres of the brain (Cooke and Haipt, 1986).

Major Issues and Controversies

When a baby comes into the world her brain is a jumble of

neurons, all waiting to be woven into the intricate tapestry of the mind. If the neurons are used, they become integrated into the circuitry of the brain by connecting to other neurons; if they are not used, they may die (Begley, 1996). Yet, once wired, there are time limits to the brain's ability to create itself. These critical periods are windows of opportunity that start before birth and end at differing times.

> "Long thought to be a clean slate to which information could be added at any time, the brain is now seen as a super-sponge that is most absorbent from birth to about the age of twelve. Thus, the brain can reorganize itself with particular ease early in life during crucial learning periods, when connections between brain cells are being made and broken down at an enormous rate. Information flows easily into the brain through 'windows' that are open for only a short duration. These windows of development occur in phases from birth to age twelve when the brain is most actively learning from its environment. It is during this period, and especially the first three years, that the foundations for thinking, language, vision, attitudes, aptitudes, and other characteristics are laid down. Then the windows close, and much of the fundamental architecture of the brain is completed" (Kotulak, 1996, p. 7).

Researchers have learned a great deal about the circuit for vision. It has a neuron-growth spurt at the age of 2 to 4 months, which correspond to when babies start to really notice the world, and peaks at 8 months, when each neuron is connected to an astonishing 15,000 other neurons (Begley, 1996). The experiments by Wiesel and Hubel proved that a baby whose eyes are clouded by cataracts from birth will be forever blind, despite cataract-removal surgery at the age of 2.

The window for math and logic is birth to 4 years. Circuits for math reside in the brain's cortex, near those for music.

After eight months of piano or singing lessons, preschoolers dramatically improved in spatial reasoning, as shown in their ability to work mazes, draw geometric figures, and copy patterns of two-color blocks (Begley, 1996). Gordon Shaw at UC Irvine suspects that when children exercise cortical neurons by listening to classical music, they are also strengthening circuits used for mathematics (as cited in Begley, 1996).

The learning window for language is birth to 10 years. By six months of age, infants in English-speaking homes already have different auditory maps (as shown by electrical measurements that identify which neurons respond to different sounds) from those in Swedish-speaking homes. Children are functionally deaf to sounds absent from their native tongue (Begley, 1996). Patricia Kuhl from the University of Washington states that "by 12 months infants have lost the ability to discriminate sounds that are not significant in their language, and their babbling has acquired the sound of their language" (Begley, 1996). After about age 12 the ability to learn new languages declines rapidly (Kotulak, 1996).

The subtle interaction between a mother and child is important to learning language. A mother can recognize cues and signals in the child's babbling, clinging, grasping, crying, smiling, and responds to them (Brierley, 1987). Insensitivity of a mother to a child's signals dulls that interaction and keeps it on a concrete level, because the child gets discourages and only sends out the obvious signals for her to respond to. The baby

begins to get understanding and intelligence from his mother's cues.

At age 2, the child's understanding is developing rapidly, but speech lags. At 3 years of age, 97% join words into simple sentences. By age 5-6, girls are advanced in articulation and fluency; boys in vocabulary and verbal understanding (Brierley, 1987).

Dr. Kenneth A Klivington of the Salk Institute in San Diego, California states that, "Structure and function are inseparable. There are some studies currently being done that show profound differences in the structure of the brain depending on what is taken in by the senses" (Healy, 1990). Experience--what children do every day, the ways in which they think and respond to the world, what they learn, and the stimuli to which they decide to pay attention--shapes their brains. Not only does it change the ways in which the brain is used (functional change), but it also causes physical alterations (structural change) in neural wiring systems (Healy, 1990).

How much is mental ability shaped by environments and how much is in the hands of heredity? For example, a learning disability that runs in families may result from changes in the child's brain before birth. Cells in the fetal brain get rearranged by chemicals produced because of an inherited response of the mother's own autoimmune system--which the child may also inherit (Healy, 1990). Would this disability be caused by heredity or by the prenatal environment?

In another controversial example, children from lower socioeconomic groups tend to score below average on standard IQ tests. Is this because poor environments depress their intelligence, or because they never learned good test-taking skills, or because, as some believe, families with nonstandard intellectual endowment might get trapped in lower socioeconomic groups (Healy, 1990)? It is difficult to sort out these factors.

Brain research is now giving these old issues an interesting new dimension by changing the focus from heredity versus environment to heredity plus environment. When inherited patterns interact with the child's environment, plasticity guarantees an unlimited number of interesting variations (Healy, 1990). Children change, both psychologically and physiologically, as they "absorb" life (Caine and Caine, 1991). Neither inherited characteristics nor the environment can ever be the sole determinant of development and behavior. According to Howard Gardner (1995), "I reject the 'inherited versus learned' dichotomy and instead stress the interaction, from the moment of conception, between genetic and environmental factors." Winston Churchill is reputed to have said to Parliament, "We shape our houses and then they shape us" (Caine and Caine, 1991). We could also say our experiences shape our brains, and then our brains shape our experiences.

In 1981, Dr. Roger Sperry, professor of psychobiology at the California Institute of Technology, received a Nobel Prize in Physiology and Medicine for his work on split-brain research

(Cooke and Haipt, 1986). Sperry proved that split-brain patients have difficulty integrating information from both sides of the brain. His research shows the role of the corpus callosum in achieving complete mental activity. The connecting fibers do more than hold the left and right hemispheres together. They relay information between the left and right hemispheres.

Using brain-imaging devices like MRI's and EEG's, researchers found that children with normal language skills have lopsided brains--the left side is bigger and more active than the right side (Kotulak, 1996). This shows how the brain has partitioned itself to handle specialized jobs--the right side preferring music and orienting its owner in space, the left processing language, math, and logic.

Studies by Paula Tallal, co-director of the Center for Molecular and Behavioral Neuroscience at Rutgers University, and others found that the brains of children with language disorders had balanced brains (Kotulak, 1996). Both sides were of equal size and activity. Having the left and right hemispheres equally active meant that the left hemisphere was underpowered: it was not fast enough to adequately process the rapid staccato of speech.

The left and right sides of the brain appear to become specialized during fetal development (Kotulak, 1996). The right hemisphere grows faster and favors more primitive characteristics, like emotion. The left hemisphere starts growing later and is in charge of newer acquisitions, such as language. During

this crucial period, many things can go wrong, especially with the late-blooming left hemisphere. These problems show up later as an increased rate of language problems in boys such as stuttering, dyslexia, and language delays (Kotulak, 1996).

Caine and Caine (1991) have stated that research on hemisphericity, at this point, is inconclusive. The left brain processes are enriched and supported by right brain processes. For example, great artists do not just set up an easel and paint; they may do a significant amount of preliminary design and analytic thinking. The artistic process involves a substantial amount of analytical and segmented thinking. The right side relies on the left for success (Caine and Caine, 1991).

As a result of split-brain research, Caine and Caine (1991) understood that parts and wholes always interact. The brain can deal with the interconnected, interpenetrating, holographic world, provided it is encouraged to do so. Some of the new methods of teaching have a sense of wholeness that sees how academic subjects relate to each other and how human beings relate to the subjects (Caine and Caine, 1991). Thematic teaching and the integration of the curriculum are two approaches to learning that epitomize this kind of teaching. They do not limit the brain by teaching the memorization of isolated facts and skills.

Programs and Contributors

Maria Montessori explored the works of earlier philosophers and educators like Rousseau, Pestalozzi, Froebel, Itard, and Seguin. Because she worked with mentally defective children and

then handicapped children, Montessori's methods owed more to the study of physical anthropology than to the developing field of child development (Spodek, et al., 1991). Montessori's curriculum included exercises in practical life, education in basic academic skills, language education, muscular education, and the education of the senses. These elements were interrelated.

In Making Connections--Teaching and the Human Brain, Caine and Caine (1991) outlined a new theory of how people learn based on current research in the cognitive and neurosciences. Together with Sam Crowell, they have applied their theory in Dry Creek Elementary, a K-6 elementary school in Rio Linda, California. Most children at this Chapter 1 school come from low socioeconomic--and often dysfunctional--families (Caine and Caine, 1995). They have done poorly on standardized tests. The school has a high turnover rate--49 percent of all students in the 1993-1994 academic year.

Traditionally, instruction has focused on memorizing surface knowledge and it has been teacher-dominated. Caine and Caine (1995) wanted to encourage a process of change to brain-based teaching and learning taking a holistic approach--looking at teaching developmentally, socioculturally, and in other broad ways. Brain-based learning stresses the importance of patterning, that is, the fact that the brain does not easily learn things that are not logical or have no meaning. Teachers must help their students see the meaning of new information.

Brain-based learning also stresses the principle that the brain is a parallel processor--it performs many functions simultaneously (Caine and Caine, 1995). Therefore all meaningful learning is complex and nonlinear. This means that teachers must use all available resources--including community resources and multiple apprenticeships--to orchestrate dynamic learning environments.

The restructuring at Dry Creek was not without problems. However, by the end of the third year standardized test scores were showing steady improvement, especially among special education students. The school is commited to the ideas expressed in the California Elementary Task Force report "It's Elementary," which is highly compatible with brain-based instruction.

Project Spectrum is based on Howard Gardner's work on the theory of multiple intelligences. At Project Spectrum, intelligence-fair assessment measures are used to identify and describe the various intellectual strengths exhibited by preschoolers (Blythe and Gardner, 1990). The evaluation measures--number games, storytelling activities, and creative movement exercises--are a part of the classroom curriculum and free-play activities. In this way the students can be assessed in natural, familiar, and non-threatening contexts, as opposed to standardized testing procedures.

Project Spectrum also seeks to create thematic ties between preschool curricula and museum exhibits through the use of kits

(Blythe and Gardner, 1990). The kits provide activities which can be used in school, museum, and home settings to stimulate a range of intelligences. Books and related storyboards stimulate language skills, while math and science activities encourage the students to actively investigate.

Children are allowed to explore freely and encouraged to ask questions. Teachers and observers make notes about the student's skills, interests, and progress. At the end of the year, parents receive a Spectrum Report including the child's intellectual profile and suggested home or community activities that would foster growth in areas of weakness.

The schools at Dry Creek and Project Spectrum are compatible with brain-based learning. They both indicate that home, school, and community must work together to provide the best education for our youth. Both schools show that it is difficult to change and restructure education, but they will better educate a range of human intelligences.

One of the biggest contributors in the area of brain-based childhood education is Howard Gardner. His intelligences--musical, logical/mathematical, interpersonal, intrapersonal, bodily/kinesthetic, linguistic, spatial, and naturalist--are meant to be interrelated in school. Gardner states that it is "more important to discover areas of strength and to build on them than it is to fret too much about areas of weakness" (Gardner, 1995). He advises teachers to carefully observe students and to forget about formally testing or assessing

preschool children.

Jane Healy is an internationally recognized authority on learning and brain development. She holds a PhD in educational psychology from Case Western Reserve University in Cleveland, Ohio and has more than thirty years' experience as a teacher, administrator, educational psychologist, consultant, and university professor (Healy, 1994). Her book, Endangered Minds: Why Children Don't Think and What We Can Do About It, tells how language shapes culture, language shapes thinking, and language shapes brains.

Some of the great minds of the past include Jean Piaget, who researched the stages of cognitive development; Friedrich Froebel, who did not separate the education of children from their life in the family (Spodek, et al., 1991); and Jerome Bruner, who feels that teaching children to speak helps them not only organize words in a sentence but also to organize their minds (Healy, 1994). Other contributors to brain research are Torsten Wiesel and David Hubel, P. Goldman-Rakic, and Roger Sperry. Without their contributions, medical procedures related to sight, hearing, seizures, motor ability, and many other skills would not have benefited as they did.

Synthesis and Analysis

In our recent history, the brain was thought to be a "black box" that could not be opened (Kotulak, 1996). Now we can ask "how does the brain work?" because of the work in molecular

biology, genetics, new imaging technology, and the neurosciences. Scientists can "see" the chemical traces of thoughts and emotions with the help of EEG's, PET scans, and MRI's. We have learned that children must be stimulated--through touch, speech and images--to develop fully (Shatz, 1992).

Most biologically informed scientists stress the interaction between genetic and environmental factors. Gardner (1995), Caine and Caine (1991), and Healy (1990) all agree on this point. It appears that human abilities have a genetic base, but environment plays a large role in intelligence also.

Research is abundant in the field of hemisphericity, or left and right brain studies. Kotulak (1996) found that children with lopsided brains have normal language skills. In Thinking with the Whole Brain, Cooke and Haipt (1986) discuss how the right and left hemispheres of the brain complement, interact, and collaborate with each other to create a very complex organism. Washington University's Steven Petersen (Jones, 1995) believes that people use all of their brain. He says, "The right-brained kids aren't turning off their left brains, and the left-brained kids aren't turning off their right brains."

In Early Childhood Education, edited by Persky and Golubchick (1991), studies show that a child uses the right hemisphere of the brain for nearly all learning until the age of five. Starting with day one of kindergarten there is a strong increase in strategies that are left brain oriented. The child is trained to sit and listen, follow only the directions given by

the teacher, not to ask any questions that are not directly answerable from the material being presented and to read and follow the directions. Their studies show that the brain is not as receptive to carefully organized, sequenced material as it is to random appropriation of the bits and pieces the mind picks up as the whole is actualized in the mind. The key idea is to see inferences or relationships between what the child already knows and what is being taught. These ideas fit in well with what Caine and Caine (1995) used at Dry Creek, teaching brain-based, nonlinear learning with an emphasis on patterning and meaning.

Most of the research agreed that the left hemisphere of the brain specializes in words, numbers, and language while the right hemisphere responds primarily to images, visual patterns, and spatial relationships (Cooke and Haipt, 1986). Many researchers agreed that each side of the brain processes information differently, but that the full potential of the human brain can only be reached when both hemispheres work together.

Research is lacking on the topic of brain development and how it applies to curriculum in schools. Although there have been several attempts to integrate brain-based learning into the curriculum, these curriculums have not had wide spread acceptance throughout the nation. For example, Gardner has several projects using his Multiple Intelligences Theory that are receiving wide acclaim, but they are limited to local areas. Likewise, Caine and Caine's (1995) contributions are limited to Dry Creek Elementary School in Rio Linda, California. Researchers and

administrators need to use these new teaching techniques because they are an improvement over what is being used now.

Scientists insist it's far too soon to reach any conclusions from brain research that might change the way a school or a curriculum is designed (Jones, 1995). John Bruer, president of the James S. McDonnell Foundation that funds research in cognitive neuroscience, figures it will be at least 25 years before the benefits of brain research reach the classroom (Jones, 1995).

Brain research can be classified by the stages of human development. The first stage is during human fetal development. About 200 billion brain cells are created in several months. Half of the brain cells die off by the twentieth week of fetal life because they fail to connect to some part of the awakening body. The brain is organized into more than forty different physical "maps," which broadly govern such things as vision, language, muscle movement, and hearing. Sex hormones can physically shape a male or female brain and influence its skills, favoring such things as language in females and spatial abilities in males (Kotulak, 1996).

From birth to age five an enormous number of connections, called synapses, are made between brain cells (Kotulak, 1996). Between birth and about eight months of age, the number of connections increases from about 50 trillion to 1,000 trillion. Connections not reinforced by voices, sights, smells, and touch shrink and perish. The brain cells form "maps" of these

experiences.

The IQs of children born into poverty, or of those who were premature at birth, can be significantly raised by exposure to toys, words, proper parenting, and other stimuli. Babies whose mothers talked to them more had a bigger vocabulary (Kotulak, 1996). At twenty-four months, babies of talkative mothers knew 295 more words than infants of less talkative moms.

A third critical restructuring of the brain occurs between the ages of five and twelve. Using PET scans to follow the brain's consumption of sugar, pediatric neurologist Harry Chugani of Wayne State University in Detroit was the first to see an energy spurt during this time (Kotulak, 1996). Connections that are not reinforced by stimuli from the outside world are pruned away; and things that a child experiences become part of his mental architecture. Windows of learning are evident from birth to about age twelve. After age twelve, learning a foreign language becomes more difficult.

As an adult, the human brain learns and remembers throughout life by employing the same processes it used to shape itself in the first place: constantly changing its network of trillions of connections between cells as a result of stimuli from its environment (Kotulak, 1996). After puberty one must work harder to enrich the brain. The brain never stops learning.

It is important to keep the brain fit to ward off Alzheimer's disease in old age. Mental exercise can create new neural connections that can keep one's brain sharp (Jones, 1995).

According to Arnold Scheibel, a former director of the Brain Institute at UCLA, neural growth slows after puberty and a gradual loss of neural tissue and connections begins in adulthood (Jones, 1995). By age 50 or 60, the brain may even shrink a little. Brain researchers advise older people to take up new challenges and develop new skills, such as solving math problems, taking up art, or playing the violin.

Conclusions

The author of this research review has learned that structure and function of the brain are inseparable. The way that children use their brains causes physical changes in them, and the way children use their brains changes the way in which the brain is used (Healy, 1990).

The critical periods of brain development are crucial in the areas of teaching and curriculum planning. Children can benefit from learning language, math, logic, and music in their own special time periods. The windows of learning occur between birth and twelve years of age (Kotulak, 1996 and Begley, 1996).

Researchers have learned that nature and nurture (or heredity and environment) are inseparable. Biology doesn't determine exactly what we'll do in life. It determines how different environments will affect us (Cowley, 1995). The old nature-nurture dichotomy is an illusion. Everything we associate with "nurture" is at some level a product of our biology--and every aspect of our biology, from brain development to food preference, has been shaped by an environment (Cowley, 1995).

According to Caine and Caine (1991), Cooke and Haipt (1986), and Kotulak (1996), the left and right hemispheres of the brain must work together for maximum usage. The left and right hemispheres of the brain complement, interact, and collaborate with each other via the corpus callosum, the fibers that connect them (Cooke and Haipt, 1986). According to Madeline Hunter, there is strong evidence that schools have been instructing with curriculum that emphasizes "the basics"--reading, writing, and mathematics. Our schools and culture values and rewards those who are primarily left-brain learners, thereby handicapping all learners (Cooke and Haipt, 1986).

Language has a huge impact on brain development . In the words of Jane Healy (1990), "Language shapes culture, language shapes thinking--and language shapes brains." Language helps children learn to reason, reflect, and respond to the world. The brain is ravenous for language stimulation in early childhood (Healy, 1990). Elementary school is the best time to learn second, third, and fourth languages (Jones, 1995).

Society is becoming increasingly "aliterate"--one who knows how to read but chooses not to (Healy, 1990). The rise of television reduces communication skills in the home. People are reading newspaper headlines but not reading extensively for information. Book stores are largely supported by people in their late thirties to mid-fifties. If we want growing brains to build the foundations for academic excellence, we must confront the habits of our culture that are changing the quality and the

quantity of our children's conversation--both interpersonal and with the written word (Healy, 1994).

<u>Recommendations</u>

The average fetus' brain increases by 250,000 nerve cells a minute during pregnancy. Therefore, it is recommended that mothers improve nutrition during pregnancy for optimal brain development (Jones, 1995). Expectant mothers are also advised to avoid prolonged, excessive stress if they possibly can--although the definitions of what constitutes stress are frustratingly vague (Healy, 1990).

Parents can act as a "language coach" while their child's language develops (Healy, 1994).

> "Studies show that mothers instinctively shape and expand their child's language, tailoring their own responses precisely to each child's developmental need. They seem to know just how to pull the youngster's language up a notch by using forms in their own speech that are just one degree above the child's current level" (Healy, 1994).

Fathers, too, may be quite skilled at tailoring language to a child. A child's development is affected when parents hire caretakers with different language patterns from their own (Healy, 1994).

Parents should be alert to their child's talents and help them develop new ones (Fishman, 1996). Parents should expect their child to be intelligent. In this way, they will feel able to meet any challenge that life might offer. Parents can help their child develop practical, as well as academic, intelligence

(Fishman, 1996). If the child can understand others' points of view, he will adapt better in school.

Teachers can improve the learning environment through active listening. The involved, adult listener would provide a positive role model for the child (Languis et al., 1980). The sensitive teacher can increase knowledge about individual children through observation and active listening. Passive "listening" does not build either language or effective listening skills (Healy, 1994). Our children today spend a great deal of time "listening" to the TV or to the teacher, but they need to listen better, not just listen more. Real listening is an active mental process that serves understanding and memory (Healy, 1994).

An activity-based curriculum should become the foundation of an integrated language development program (Languis et al., 1980). Rowe (1978, as cited in Languis, 1980) observed that young children show substantial gains in verbal fluency, language complexity, and logic when they engage in activity-based, inquiry-oriented science programs as a language builder. In early childhood education, such a program is especially significant because of the sensitive sensory, motor, and cognitive learning characteristics of the very young child. Play is an obvious element in establishing meanings. In play situations, children feely explore and establish concepts without the risk of being wrong (Languis et al., 1980).

Teachers can encourage children who are interested in exploring print and spelling. These explorations enhance later

linguistic growth (Languis et al., 1980). Correctness or incorrectness should not be the concern of the teacher, because the young learner is already moving towards more conventional forms. The consistencies demonstrated by the children who are interested in writing may yield valuable information about what the child understands about the reading and writing process.

Teachers can use information about "windows of learning" to help develop appropriate curriculum. For example, foreign languages should be taught before the age of 10 (Begley, 1996). Research also shows that there is a correlation between the age or grade of students, and spurt and plateau periods of brain growth (Patterson, 1983 as cited in Dixon, 1986). These brain growth spurts correlate in age with learning capacity, and may turn out to be the biological basis of Piaget's stages of development (Dixon, 1986).

Administrators are recommended to offer in-service training in brain research and the new direction it is bringing to early childhood curriculum and instruction. In-service training could offer insights to Howard Gardner's MI Theory that is in use at Project Spectrum and Caine and Caine's work at Dry Creek. Some of their styles and techniques could then be used in more schools across the nation.

Administrators could also offer to let teachers observe classrooms or school sites that use brain-based learning. Direct observation would yield better results than in-services only.

Researchers need to do more to link brain research to early

childhood education and curriculum. Researchers have learned more about the inner workings of the brain in the last decade than ever before. Now it is time for education to catch up and incorporate this new knowledge into the curriculum.

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