Neurobiological Insight on Learning

Dae Joong Kang
University of Georgia, USA

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Abstract: *This study explored the concept of brain plasticity and three brain metaphors of learning to gain neurobiological insight for understanding learning. The author suggested consideration of culture is essential in constructing alternative brain metaphors of learning.*

Thanks to technological advances such as CAT (Computerized Axial Tomography), fMRI (functional Magnetic Resonance Imaging), and PET (Position Emission Tomography), recent neurobiological findings open a new horizon in understanding adult learning. The findings challenge traditional learning theory and educational policy (OECD, 2002). There are few adult educators who have reviewed the neurobiological findings (Fishback, 1999; Taylor, 1996) even though the brain is an organ for learning. Traditional adult learning theory is largely based on Cartesian dualism and reinforces the exclusive role of the mind while assigning the brain to the body realm. Some learning theories such as emotional learning, embodied learning, and affective learning are proposed as an effort of overcoming this Cartesian dualism. It could be an insufficient effort, in my opinion, without consideration of advances in neurobiological findings.

The underlying assumption of this paper is that the brain creates the mind and the brain is a part of the body. The brain can be a key to dismantle the mind/body binary. Neurobiological findings, therefore, provide different insights into adult learning theory. However, it should be noted that interests of neurobiologists are different from those of practitioners and researchers in the field of education. There is skepticism in connecting the biological brain changes with human learning and teaching (Bruer, 1997). What we need in approaching neurobiological research are realistic inferences or "a healthy sense of skepticism" (Byrnes, 2001, p. 23). We should translate the neurobiological findings into an educational context. One way to do this is using metaphor in that "we live our lives on the basis of inferences we derive via metaphor" (Lakoff & Johnson, 2003, p. 273). In the following, I will review the concept of brain plasticity and neurobiological metaphors of learning. Then I will discuss the neurobiological insight for understanding learning.

The Brain Plasticity

The brain is dynamic and ever changing throughout both an individual's life span and evolutionary history (Bownds, 1999; Molen & Ridderinkhof, 1998). The individual human brain undergoes lifelong changes from conception to death and is the product of more than a million years of evolution. The brain is plastic at all times.

In spite of missing links and lack of concrete evidence, some plausible hypotheses on the evolutionary brain changes have been proposed. The most obvious change is that its volume has increased especially from about 750 ml in late *Homo habilis* to 1500 ml in *Homo sapiens sapiens* while body size increased only a small amount (Holloway, 1996). A model of triune brain suggests the human brain has three structures—reptilian brain, old mammalian brain called limbic system, and neomammalian brain called neocortex (Bownds, 1999; Hart, 1983). The contemporary human brain is composed of these three structures that appeared one after another in mammalian evolution. The reptilian brain is the most inner core of the brain and the seat of basic survival behaviors, such as hunting, feeding, and reproduction. The limbic system, which appeared between 200 and 300 million years ago, is the seat of motives and emotions. It is located between the reptilian brain and the neocortex. The neocortex, which appeared a few million years ago, manages prepositional information and declarative knowledge about the world. Some anthropologists and archaeologists have attempted to explain the evolution of brain function by connecting human cognitive/behavioral change with cultural developments such as bipedalism, hunting and gathering, tool making, and language use (Donald, 1991; Mithen, 1996).

The matured human brain has approximately 100 billion neurons with 1,000-10,000 synapses in each neuron. During gestation, the brain grows from virtually nothing to approximately 350 grams at birth. However, within two years it increases to about 75% of adult brain weight. The prefrontal cortex appears to be one of the last brain regions to mature (Molen & Ridderinkhof, 1998). Although there are some limitations in brain research using recent technologies (Byrnes, 2001, pp. 18-22), reliable new knowledge about the plasticity of a healthy adult human brain has been reported.

It is commonly believed that our brain loses 100,000 neurons as we grow old (OECD, 2002). Terry, DeTeresa, and Hansen (1987) challenged this truth. They counted the number of neurons in the cerebral cortex of 51 healthy individuals aged from 24 to 100 years old. The number of neurons is unchanged. Age-dependence is a factor only when the number of large neurons is counted. These large neurons shrink with the resulting consequence of increasing the number of small neurons. Even more, it is reported that the matured human brain generates new neurons in the hippocampus (Kempermann & Gage, 1999), which is very important area in the brain for learning. People with hippocampus damage have difficulty in learning something new even though they can recall old knowledge. These findings challenge traditional 'bell curve' or 'hill' metaphor in the development theory in general (Molen & Ridderinkhof, 1998). It is assumed that there is a peak moment or period in the lifespan development process. But, the neurobiological findings suggest it is not a linear process; rather, progressive development and regressive development happen throughout life. It is much more complex process.

It is also reported that the adult brain changes depending on environmental input. Maguire, Frackowiak, and Frith (1996, 1997) compared structural MRIs of licensed taxi drivers' brains with those of control subjects who did not drive taxi. They found that a more anterior hippocampal region was larger in control subjects than in taxi drivers, and that the posterior hippocampal volume of taxi drivers increases with the amount of time spent as a taxi driver. The posterior hippocampus stores spatial representation of the environment and can expand to accommodate a high dependence on navigational skills. Pantev et al. (1998) report that auditory cortex of highly skilled musicians were about 25% larger than that of those who never played an instrument. Enlargement was correlated with the age at which musicians began to practice. Pascual-Leone et al. (1995) go further and report that mental practice of piano playing alone led to the same plastic changes in the cortical motor area. They suggest that mental practice seems to place the learner at advantage for further skill learning with minimal physical practice.

Brain Metaphors of Learning

Pribram (1981) suggests three modes of reasoning that guide research and provide understanding of its results: (1) the induction of principles from data, (2) the deduction of logical relationships among principles, and (3) abductive reasoning by analogy that attempts to place these relationships into wider contexts. Educational translation of neurobiological findings can be juxtaposed with these modes. The induction mode presents a set of principles that can be applied to educational practice like Caine and Caine's (1991) twelve principles of brain-based learning. Since the purpose of this section is to review the metaphor, I will focus on deduction and abduction modes.

Deduction mode: Proster Theory. Hart's (1983) proster theory is based upon two fundamental ideas. The first idea is that the brain is by nature a "pattern-detecting apparatus" (p. 67). Pattern is defined as "an entity, such as an object, action, procedure, situation, relationship or system, which may be recognized by substantial consistency in the clues it presents to a brain" (p. 190). The brain detects pattern by using clues in a probabilistic way, and depends on prior experiences. Therefore, the process of learning is "the extraction from confusion of meaningful patterns" (p. 67). The learning process in real life is random and fortuitous, because the world in which the learner lives is complex. However, as the learner sorts out more and more patterns, more sense is made of a complex world and the pattern discrimination power is increased. The second idea is that "we live by programs" (p. 80). Program is defined as "a sequence of steps or action, intended to achieve some goal" (p. 89). It is stored in the brain and recalled repeatedly whenever it is needed to achieve the same goal.

The term proster, from a compression of program and structure, is defined as "a collection of stored programs, related to a particular pattern, which can be used as alternatives" (Hart, 1983, p. 95). Some programs are transmitted genetically; many others are learned. Some programs, such as language, require a lot of sub-programs, while others, for example crossing fingers, are relatively short. Hart's definition of learning is, therefore, "the acquisition of useful programs" (p. 86). Hart's theory seems to be based on a "computer analogy" (Byrnes, 2001). First, good programs stored in the brain are like good software programs installed in a computer. This is another manifestation of Cartesian dualism—program/brain and mind/body. Hart continues to ask, "What program is being used?" (p. 89). Second, his program implementation cycle is too linear—evaluating the situation (involving pattern detection and recognition), selecting the program that seems most appropriate from our storage, and implementing it.

Structural Abduction mode: Brain-cycle of Learning. Zull (2002) declares, "learning is about biology" (p. xiii) and everything we learn is related to the physical and biological brain structure. The brain is governed by physical and chemical rules. Learning is physical. "Physical brain means a physical mind; meaning itself is physical" (p. 6). Zull uses Kolb's (1984) experiential learning cycle to explain brain functions. He hypothesizes correlation between four different parts of the cerebral cortex and four different phases of Kolb's experiential learning cycle: "Concrete experience comes through the sensory cortex, reflective observation involves the integrative cortex at the back [of the brain], creating new abstract concepts occurs in the frontal integrative cortex, and active testing involves the motor brain" (Zull, 2002, pp. 18-19). The four regions have extensive connections with amygdala and basal structures that are closely related to emotions. This implies, "all parts of the learning cycle are influenced by emotion" (Zull, 2002, p. 223). Zull describes feeling as an awareness of emotion and locates it in the body. The brain always interacts with other parts of the body through the operation of millions of cellular wires and chemicals in the bloodstream, therefore, "learning engages the brain and other parts of the body as well" (p. 71).

Zull (2002) reinforces Kolb's theory by adding neurobiological evidence. He argues, "without biology, the learning cycle [of Kolb's] is theoretical. But with biology, it seems that we are closer to fact. The brain is actually constructed this way" (p. 27). Zull describes the transformation of experience into knowledge occurs between the integrative cortex at the back of the brain and the frontal integrative cortex. Zull's theory also appears to overcome weaknesses in Kolb's learning cycle by adding the role of emotion and feeling in learning. However, it is not quite clear how we learn emotional, affective, or physical knowledge according to the brain cycle. An active response to the emotional experience seems to happen without reflection and abstraction.

Biofunctional Abduction mode: Brain-Mind Cycle of Reflection. Iran-Nejad and Gregg (2001) propose a brain-mind cycle of reflection metaphor by interpreting Dewey's reflective thought and Schön's reflection-in-action in terms of brain function. They critique dominant description of reflective practice as either 'input-adaptation-output' or 'input-elaboration-output.' Both adaptation and elaboration assume that the learner can internalize input and recite it. They argue this internalization-recitation results in what they call a symbol-grounding problem. The teacher provides the learner with more and more words and symbols to guide meaningful adaptation and elaboration for problem-solving reflection. However, they argue the learner is unavoidably trapped in "overelaboration, overabstraction, and overparticularization" that prevent "deeper understanding" (p. 873).

Iran-Nejad and Gregg (2001) propose 'brain-awareness-mind' as an alternate description of reflective practice. They assume that "*the mind has no direct access to the outside world—only brain does*" (p. 874). The brain does this by relentlessly creating a live intuitive self-awareness. Iran-Nejad and Gregg posit three dispositional modes of brain functioning—habitual/creative, active (explicit)/dynamic (implicit), and constructive/unconstructive—that are used in accessing the world. They define the brain as an intuitive knowledge base (IKB) that is "a coordinated combination of knowledge, experience, wisdom, beliefs, affects, emotions, interests, hopes, and aspirations" (p. 876). They view the intuitive self-awareness to be manifested as thematic knowledge that has two forms. First, wholetheme knowledge is ever-expanding divergent momentum toward the ultimate cross-domain wholeness. Second, theme knowledge is convergent momentum toward within certain domain wholeness. Ideas, concepts, and images are momentary figures out of the ground of theme and wholetheme knowledge. Iran-Nejad and Gregg, therefore, define learning as "wholetheme reorganization of the learner's own intuitive knowledge base" (p. 886). It concerns with not internalization of external knowledge but understanding one's brain-mind cycle in creating momentums. They argue the right relationship between the teacher and the learner could be "intuition exchange" (p. 886).

Iran-Nejad and Gregg's (2001) theory, however, seems overly psychological and presupposes a metaphysical mind that is created by the brain has an independent power to "use the brain" (p. 874). This supposition cannot avoid brain/mind or intuition/thinking dualism that is an extension of Cartesian dualism.

Discussion

From the neurobiological perspective, "the creation of neural network[s] and synapses are what constitutes learning" (Fishback, 1999, p. 19). Learning can be defined as "stabilizing through repeated use, certain appropriate and desirable synapses in the brain" (Leamnson, 1999, p. 53). In other words, "learning is achieved either through the growth of new synapses, or the strengthening or weakening of existing ones" (OECD, 2002, p. 44). Learning is a process of biological changes in the brain and teaching, therefore, is the art of changing the brain (Iran-Nejad & Gregg, 2001; Zull, 2002). The plasticity of the brain is at the core of learning as biological change.

It appears that brain plasticity depends on a genetic code. However, there is no deterministic correspondence; for example, monozygotic twins who have the same genetic blueprint result in different brains. Other factors, such as nutrition, environment, and hormones, play together in the development of the brain (Bownds, 1999; Byrnes, 2001). In this sense, brain plasticity sheds new light on the 'nature-nurture' debate (Ceci & Williams, 1999). Neurobiological insight claims that the debate is not about the problem of either nature or nurture; rather it is both because "evidence for nurture is not evidence against nature, nor is the converse true" (Ridley, 2003, p. 253). Therefore, instead of "nature vs. nurture," or "nature plus nurture," new perspectives such as "nature via nurture" (Ridley, 2003) or "the dependent gene" (Moore, 2002) are proposed. Moore writes:

> The common belief that genes contain context-independent "information"—and so are analogous to "blueprints" or "recipes"—is simply false. The existence of alternative splicing ultimately requires us both to change how we think about what "genes" are and to broaden our understanding of the way in which cells can be influenced by interactions with their local environments. (p. 81)

Translating neurobiological findings into an educational context, therefore, should count on the brain's environmental dependence, as Hambley and Richardson (1974) argue, "to understand the truly distinctive feature of human learning is to understand the nature of the human brain and the phenomenon of human culture" (p. 37). Therefore, learning can be understood as an interplay between individual genes and cultural memes. The term meme, which is coined by Richard Dawkins, refers to "a unit of cultural information that replicates itself reliably" (Bownds, 1999, p. 112). Wilson (1998) states the relationship between culture and the brain as follow:

> Culture is created by the communal mind, and each mind in turn is the product of the genetically structured brain….The mind grows from birth to death by absorbing parts of the existing culture available to it, with selections guided through epigenetic rules inherited by the individual brain. (p. 127)

The three brain metaphors of learning reviewed in this paper do not actively take culture into account. Constructing alternative metaphors requires considering both the brain's function in learning, which is interdependent on other parts of the body, and co-evolution or co-emergence of the learner and the culture, which means they create each other. In this perspective, learning can be defined as *a process of recreating culture in the learner and creating differences in a given culture by the learner*. This is a quite complex and dynamic phenomenon. It seems chaotic in that there are so many factors involved. Diverse socio-cultural perspectives could provide a break-through for the new brain metaphor of learning.

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