Brain Science and Education
—A Frontier of Neuro-Engineering—

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I. Concept of Brain Science and Education

In a new area called "Brain Science and Education," to understand learning and education from the perspective of natural science we have newly defined *learning* and *education*: Learning is a process to form neural circuits by receiving external stimuli, and education is a process to control and supplement external stimuli and prompt learning. The issue of values in education from the perspective of the humanities and social sciences has been handled separately in a new area called "Brain Science and Ethics." We have continued these efforts to understand learning and education objectively from the perspective of neuroscience (natural science) and develop the resulting knowledge for educational engineering to create new learning and teaching methods.

In line with these efforts, we developed and applied new methodologies for high-level brain-function imaging to understand the intra-brain mechanism of learning and education as neuroscience. Such methodologies include functional magnetic resonance imaging (fMRI) and near-infrared spectroscopic optical topography (NIR-OT). Through complementary uses of these methods, as well as magneto-encephalography and the electro-encephalography, the intra-brain mechanism for learning and education gradually has been unraveled. The applications of such results are diverse, including special education (e.g., treatment and education for children with a developmental disorder) and general education (e.g., education of a second language). This paper mainly focuses on creative education, which is directly linked to innovation.

II. Importance of Motivation, which Leads to Innovation

In *Theorie der wirtschaftlichen Entwicklung* (1912), Joseph Alois Schumpeter called the process of creating a new system by combining inherently unrelated phenomena "innovation (new combinations)"

Furthermore, he refers to Motivation being driven by "Hungry Spirits" and that material affluence from the progression of capitalism could lead to a risk of losing Motivation, which could otherwise trigger innovation. Although Japan until recently had the world's second highest GDP, the Programme for International Student Assessment (PISA) in 2006, which measured 400,000 students at age 15 from 57 countries, showed the lowest indicators of science-related learning motivation were among 15-year-olds in Japan. As Japan is a well-known science and engineering-based country with a high knowledge level, it would seem to be in extreme contrast with low learning motivation.

On the other hand, the history of socialist economies has shown that an extreme emphasis on the social order can restrict individuals' freedom, which makes it difficult to maintain the

driving force for innovation. The author contends that it is important to analyze the neuro-scientific mechanism for motivation and create a new direction of educational engineering because this issue could emerge as a common problem for people after the gradual fusion and optimization of capitalism and socialism.

III. Innovation and SET (Science/Engineering/Technology)

Understanding innovation in the existing framework of science and technology is not sufficient when we consider that education nurtures innovators. Let us reflect on history. Before recorded history, during the Bronze Age more than 5,000 years ago, we already saw the budding of science, engineering, technology and art. The use of bronze ware requires knowledge and production technologies for smelting/refining, forging and alloying.

On the other hand, the concepts of modern science, engineering, technology and art developed independently after the 17th century and these concepts have been partially overlapped or multi-tiered. The etymology of the word stem of each concept helps us understand the inherent content of each concept. The origin of the stem of science, "sci," is from the ancient Greek "*skei,*" which means "split/divide," implying reductionism, or part of the basic concept of science—break down a system and clarify the cause-and-effect relationship of each element. The word stem of "engineering" is "gin," which is from "*gen,*" meaning to "give birth." The verb "engineer" means "to create a system to obtain an intended output by inputting data or information." The word stem of "technology" is "techno," from "*tekhne,*" meaning "to craft something or imitate nature by humans," which is the same as "*ars,*" the word stem of "art."

An important point is that science refers to activities that unravel the world of nature, including human beings, by human wisdom. The counterpart of "science" is "engineering," which refers to activities to create something that does not exist in the world of nature. In engineering, which brings new man-made items into the world of nature, ethics emerges as a central issue.

IV. Current Global Trends

In Japan, the study of brain-science and its application to education have been promoted as a national program, "Brain-Science and Education," since a four-day international forum in 2000 ("Developing the Brain: Science of Learning and Education") by the Japan Science and Technology Agency (JST) at the Oiso Prince Hotel. Similarly, an international program by the OECD, "Learning Science and Brain Research," has progressed. In addition, the International Mind, Brain, and Education Society (IMBES) has been promoted by Harvard University and the Pontifical Academy of Sciences. Also, as the area director of "Brain-Science and Society" at JST, a member of the International Advisory Committee on the OECD-CERI project and a founding Director of the IMBES, the author has made efforts for collaboration and development among the three organizations. China is also directing its attention to this field. Moreover, the United States is about to launch K-12 STEM (kindergarten through Grade 12 science, technology, engineering and mathematics) education, separately from the MBE.

In line with aforementioned efforts, the author and his colleagues have been making focused efforts for more than a decade to nurture the motivation and enthusiasm for learning and, in particular, nurturing the mind-set for science among preschool students.

Reference

1. Koizumi, H. (Ed.). (1995). *Proceedings of the trans-disciplinary symposium on the frontier of mind-brain science and its practical applications*. Tokyo: Hitachi, Ltd.
2. Koizumi, H. (1999). A practical approach to trans-disciplinary studies for the 21st century. *Journal of Seizon and Life Science, 9B,* 5–24. (Partly reprinted as Guest Editorial, 2001, *Neuroendocrinology Letters, 22,* 219–221.)
3. Koizumi, H. (2008). Developing the brain: A functional imaging approach to learning and educational sciences. In A. Battro, K. Fischer, & P. Lena (Eds.), *The educated brain.* Cambridge, U.K.: Cambridge University Press.
4. Koizumi, H. (2010). Toward a new educational philosophy. In M. Suarez-Orozco & C. Sattin-Bajaj (Eds.), *Educating whole child for the whole world.* New York: New York University Press.
5. Koizumi, H. (2012). Brain-science and education in Japan. In S. Della Sala & M. Anderson, (Eds.), *Neuroscience in education.* Oxford, U.K.: Oxford University Press.