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CHAPTER 1

The Case for Neuroscience in the Art of Teaching

Mind, Brain, and Education (MBE) Science is the new and improved *brain-based learning*. It is the scientifically substantiated art of teaching. It is the intersection of neuroscience, education, and psychology. And it is a paradigm shift in formal education. This chapter explains its basic parameters and history.

Although concepts from MBE Science have been applied indiscreetly and inconsistently to classroom teaching practices for many years, modern technology now allows a glimpse into the functioning human brain and how it learns, which helps us judge the quality of these claims. But with this knowledge comes responsibility. For example, between the 1950s and the 1980s, the idea of "enriched environments" stirred the educational community. If children were given "extra" stimulus as babies, they would grow up to be "Baby Einsteins." These claims were based on discoveries of increased synapses, or connections between brain cells, in young rats living in "enriched" settings (Diamond, Krech, & Rosenzweig, 1964; Rosenzweig, Krech, & Bennett, 1958). The rats were given cages with extra toys and running wheels, then sacrificed; their brains showed increased synapses. Despite being based on nonhuman subjects, this finding led to a proliferation of educational recommendations about improving learning environments for infants and young children. Most of us have seen, read, or experienced the "enriched environment" enthusiasm. In fact, as new parents or good teachers, we would feel remiss if we did not try to create an "enriched environment."

The authors of the original rat studies now believe, however, that the "enriched" laboratory environments were actually more like "normal" rat environments (i.e., sewers), which does not prove enriched environments are better, but rather that poor environments are worse than normal environments. This means bad environments can harm, but it does not necessarily prove that enriched environments help. Despite this new knowledge, there is a million-dollar industry dedicated to training parents and teachers to design enriched environments. To heighten concerns, it is not known whether or not overstimulation within an enriched environment causes harm. Though it seems that enriching an environment should not be a bad thing, there is little science to prove this. What we do know is that investment in the equivalent of extra rat mazes or running tracks for kids may not necessarily be required to enhance learning; simply providing normally stimulating environments (e.g., helping children learn to ride a bike or skateboard; talking to them over dinner; engaging them in board or ball games; playing circus, house, or school) is probably just as effective.

Substantiating the art of teaching in science represents a paradigm shift in teaching practices. More and more educators base their practice on proven methods grounded in empirical evidence rather than gut feelings. This in no way limits a teacher's creativity in the classroom, but rather stimulates new ways of thinking about activity design, classroom planning, and course structures. This is not only logical; it is also the law.

In the United States, the move toward scientific grounding for education was legalized in 2001 with the No Child Left Behind legislation in which scientifically based research in education was noted as a priority (Eisenhart & DeHaan, 2005). This points to a shift in education that includes a new academic discipline that is nurtured equally by mind (psychology), brain (neuroscience), and education (pedagogy). Education can no longer go it alone; the task is too great. But how do we know what information is proven in the new field? To answer this, we first need to understand the equation making up the new academic discipline.

WHY PSYCHOLOGY + NEUROSCIENCE + EDUCATION = MBE SCIENCE

When the 20 international experts were asked from where MBE Science principles were derived, this is how they responded:

> The emerging field of Mind, Brain, and Education brings together natural, life, neural and social sciences from which the major guiding principles are derived. The most prominent among these disciplines are education, neuroscience, and psychology. Sub-fields of education (i.e., pedagogy, special education, gifted students), neuroscience (i.e., cognitive neuroscience, neuroethics, neuroscience, neuropsychiatry, developmental neuroscience and pediatrics) and psychology (i.e., developmental psychology, and neuropsychology) comprise the major foundations of Mind, Brain, and Education. (Tokuhama-Espinosa, 2008b, p. 215)

The intersection of neuroscience, education, and psychology has been referred to in many ways over the past three decades. The most popular terms are *brain-based teaching*, *brain-based education*, *educational neuroscience*, *educational psychology*, *cognitive neuropsychology*, *cognitive neuroscience*, and *educational neuropsychology*. To be sure that MBE Science was distinct from all the others mentioned above, the experts specifically considered whether the emerging discipline was simply a subdiscipline of one of the parent fields of education, neuroscience, or psychology, or whether it was, indeed, a new, independent academic field. After 3 months of discussion, the majority of the experts concurred that MBE Science is an independent academic discipline, though it probably grew out of the same cognitive neuroscience from which many wonderful educational contributions have emerged.

Readers of this book—educators, psychologists, neuroscientists—are potential MBE scientists. Despite different initial disciplinary roots, these professionals can now share a new trajectory of development at the graduate level, where programs began to increase greatly starting around 2003. This new field is nourished by the different approaches that professionals from different disciplines bring. A neuroscientist might work in a lab tracking neural changes in the brain due to different types of learning experiences, for example, while a teacher in a classroom documents her MBE practice for review by peers, and a psychologist uses therapy to stimulate certain behavioral changes in a student. All three professionals are potentially MBE scientists.

So how does MBE Science differ from the existing and already recognized fields of neuroscience, psychology, and education? MBE Science is distinct in its emphasis on teaching versus the more narrow focus of just how people *learn.*

IT IS NOT ENOUGH TO KNOW HOW WE LEARN, WE MUST KNOW HOW TO TEACH

Neuroscientists, psychologists, and educators have studied learning for centuries. It is apparent, however, that while the science of learning is well established, the science of *teaching* is not as advanced. This means that while neuroscience and psychology have been very helpful in establishing theories of learning, education has been more or less left on its own to develop teaching. Usha Goswami, who is a member of the University of Cambridge's distinguished faculty of Psychology and Neuroscience in Education, confesses that "neuroscience does not as yet study teaching." This is ironic, she notes, as "successful teaching is the natural counterpart of successful learning" (Goswami, 2008a, p. 34). Goswami goes on to acknowledge that "[t]he identification and analysis of successful pedagogy is central to research in education, but it is currently a foreign field to cognitive neuroscience" (2008, p. 35).

The recognition of this missing link between learning and teaching is becoming more and more apparent through MBE Science. Thousands of studies

CHAPTER 7

Principles: Applying Universal Concepts About the Brain and Learning to Classroom Teaching

Principles are fundamental concepts upon which all activities and methodologies should be designed. In the best cases, all classes that adhere to MBE Science should apply the following principles. For the most part, the foundational principles of MBE Science are related to concepts that were deemed to be "well-established" or "probably so" and received vast support from the meta-analysis of the literature. Unlike the tenets, the principles are "universals"—that is, they are true for all learners and express fundamental aspects of the learning brain.

There are 21 principles in all, covering the gamut of human learning (see Figure 7.1). The principles can be divided into five broad categories:

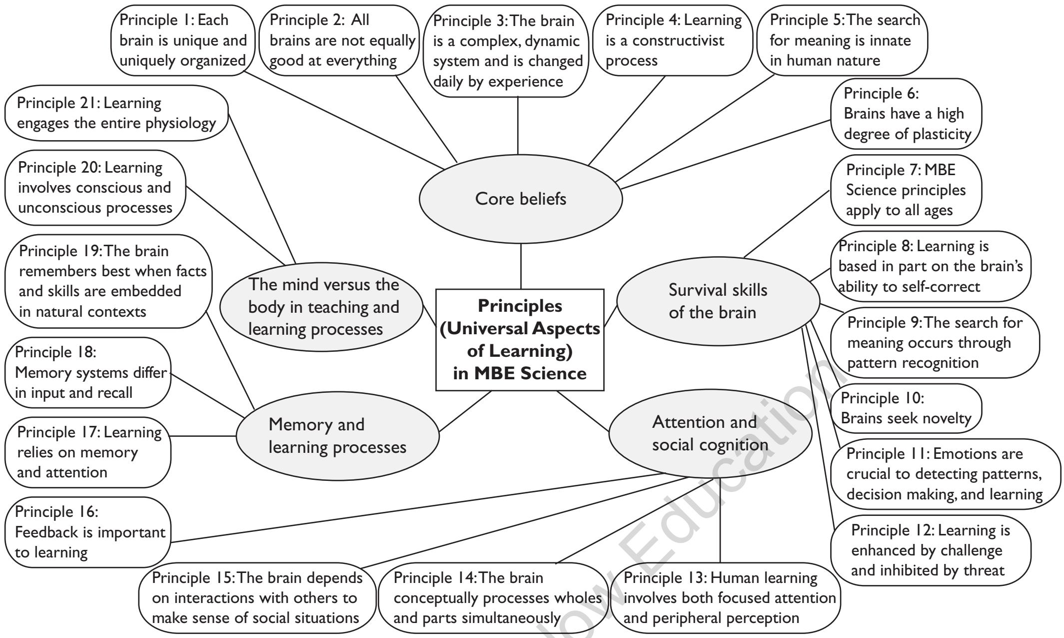
1. Core beliefs
2. Survival skills of the brain
3. Attention and social cognition
4. Memory and learning processes
5. The mind versus the brain in the teaching and learning process

CORE BELIEFS

Principle 1: Each Brain is Unique and Uniquely Organized

This is based on the well-established belief that human brains are as unique as faces; while the basic structure is the same, no two brains are identical. Despite general patterns of organization in how different people learn and which brain areas are involved, each brain is unique and uniquely organized.

Figure 7.1. Principles in MBE Science



Source: Bramwell, 2009.

Some studies in this field are related to which aspects of learning are easy to generalize and appear to involve similar mechanisms across all learners. Some of the studies—such as those by McCann and Garcia (1999); Pelegrina, Bajo, and Justicia (1999); Thompson (1999); and Sohn, Doane, and Garrison (2006)—delve into the individual strategies used by learners to approach problems. The journal *Learning and Individual Differences* is a major source of information in this field. There are several studies that demonstrate how different people learn different skills, such as Korenman and Peynircioglu's (2007) work documenting differences in how people learn music. It should be noted that Principle 1 is elementary in the foundations of MBE Science, which justify a more individualized approach to teaching.

Principle 2: All Brains Are Not Equally Good at Everything

This is based on the well-established belief that all brains are not equal in their ability to solve all problems. Both context and ability influence learning. Context includes the learning environment, motivation for the topic of new learning, and prior knowledge. This means that expecting the same results for all students may be unreasonable. The idea that all brains are not equally good at everything goes against the optimistic ideals of the 1970s and 1980s, when teachers were taught that, with the right instruction (behavioral guidance), all children could reach the same levels of achievement (Skinner, 1974). Rather, this principle means that each child is born with a certain genetic learning potential, which can be maximized by good teaching techniques. In this sense, a teacher's role changes from being a behavioral modifier to being a professional who must diagnose the potential of each student and then design an individualized learning program to help that student understand his own strengths and weaknesses (Levine, 2000).

Other studies related to Principle 2 seek to confirm parameters set for "normal" versus "delayed" growth curves for certain skill acquisition. Among others, Miller and colleagues (2002) as well as Voelkle, Wittmann, and Ackerman (2006) have helped determine the broad parameters of "normal" from a neurological perspective, confirming observations in education and psychology. Principle 2 has strong implications for policies, especially those related to standardized teaching and grading as compared with individualized learning practices. Based on this principle, teachers are encouraged to know their students better and to apply differentiated teaching methods.

Principle 3: The Brain Is a Complex, Dynamic System and Is Changed Daily by Experiences

This is based on the well-established belief that the brain is a complex, dynamic, and integrated system that is constantly changed by experience, though most of this change is evident only at a microscopic level. The brain's complexity and the constant changes it experiences refute beliefs, prominent in the 1970s, that personality and intelligence are fixed by a certain age, instead supporting the current belief that learning can and should be a lifelong process.

This also confirms the dictum "Use it or lose it." This is supported by the belief that in terms of synaptic growth, the most active synapses are strengthened, while relatively less active synapses are weakened. Over time, this process shapes brain organization, as is extensively documented in the literature (e.g., LeDoux, 2003; Ortega-Perez, Murray, & Lledo, 2007). Neurons that are linked by continual firings demonstrate greater synaptic growth. Unused neural links may be pruned away (Sylwester, 1985). In this sense, the brain is extremely efficient in managing its resources. The areas that are used more get more in terms of building blocks, and the areas that are used less are reduced. This is important for learners of all ages because it reminds us that if knowledge is left unused, it will be lost. For example, many students go through mandatory foreign-language classes in high school yet find, as adults, that they can't recall a word they learned because the language has gone unused for so many years. The flip side is that continual training of the brain results in continued synaptic growth, even into old age, as Goldberg (2006) has shown. This principle has implications for lifelong learning guidelines.

Some work in this field (e.g., Fischer, 2007) make the link among physical brain changes, behavioral changes, and the implications for education. Other work establishes how and what changes occur in the brain based on new experiences (OCED, 2007). All these studies attest to the ever-changing state of the human brain and the physical changes that occur with new learning across the life span. Principle 3 influences instructional guidelines in that it reinforces both the developmental and constructivist approaches to teaching.

Principle 4: Learning Is a Constructivist Process, and the Ability to Learn Goes Through Developmental Stages as an Individual Matures

This is supported by the idea that a learner who actively constructs knowledge will be motivated and engaged in learning. This is also supported by the educational belief that humans construct meaning from existing knowledge structures. Such existing knowledge structures are individually defined. Additional evidence is found in thousands of studies in the literature. An understanding of the developmental construction of the world by children was introduced in the 1950s in the psychological context (Piaget, 1955) and the neuropsychological context (Berninger & Abbott, 1992), then expanded in the context of neuroscience (e.g., Mareschal et al., 2007; Restak, 2008). Some studies in this field relate to the linkage of constructivist processes and memory (e.g., Schacter & Addis, 2007). This principle illustrates the move away from behavioral theories of learning to the current cognitive-constructivist approach.

Constructivist processes have been linked to learning in educational circles for decades but have been very distant from the neuroscience literature. Good MBE scientists apply this principle by ensuring that new information is embedded in context and can be related to knowledge that the students already possess.

Principle 5: The Search for Meaning Is Innate in Human Nature

Humans are born to learn. The search for meaning is an inborn human need. This is supported by hundreds of works in the literature analysis showing that learning was necessary to survival in the evolutionary processes. If humans did not learn, the species would not survive. Human brain development demonstrates that learning is based on adaptation (e.g., Linden, 2007a; Maloney, 2004) and that the human brain is naturally programmed to learn as a survival function (Calvin, 1996). This principle has led some educators, such as Gunn and colleagues (2007), to promote the idea that there is a "natural" way to teach that is more in synch with ways the brain learns best, which may be contrary to some formal classroom structured learning.