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D. C. PHILLIPS EDITOR

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Rodolfo Leyva

See also Accountability and Standards-Based Reform; High-Stakes Testing; Liberalism; Social Darwinism

Further Readings

Braedley, S., & Luxton, M. (Eds.). (2010). *Neoliberalism and everyday life*. Montreal, Quebec, Canada: McGill-Queen's University Press.

Chomsky, N. (2011). *Profit over people: Neo-liberalism and global order*. New York, NY: Seven Stories Press.

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Harvey, D. (2005). *A brief history of neoliberalism*. Oxford, England: Oxford University Press.

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NEUROSCIENCES AND LEARNING

Educational neuroscience emerged as an interdisciplinary field during the so-called decade of the brain (1990–1999) and has attracted enormous attention in the scientific community as well as among a broader public, including teachers and policymakers, ever since. The connection between neuroscience, psychology, and education is expected to broaden the perspective on human learning and teaching as well as on cognitive and emotional development in general. The field has been stimulated by the improvement of brain imaging techniques, which allow recording electrical activities as well as metabolic processes such as oxygen and glucose consumption going on in the brain while humans are engaged in behavior or exposed to information. As the brain is undoubtedly the most important body part for learning and education, it is no wonder that progress in understanding the structure and the functioning of this organ also affected the way of seeing schooling and other forms of institutional learning. The number of books, journals, academic societies, and study programs focusing on the intersection of brain research and educational science has exploded ever since.

From the very beginning of its emergence, the field was perceived with mixed feelings, particularly among educational scientists. On the one hand, getting information about human functioning beyond testing or observation of behavior by recording brain characteristics was highly appreciated, particularly for explaining learning difficulties such as dyslexia and dyscalculia. On the other hand, educational and behavioral scientists were concerned about the uncritical enthusiasm and the unrealistic expectations among many teachers and policymakers when presented with slogans like "brain-based learning." At least partly motivated by the principle "If you can't beat them, join them," since 2000, many learning researchers with a background in psychology or empirical educational research launched various initiatives that were supposed to develop promising but realistic frameworks for combining neuroscience and educational research.

Well-established academic societies in the field of schooling and education, such as the American Educational Research Association and the European Association of Research on Learning and Instruction, have established special-interest groups with a focus on educational neuroscience. All over the world, private and public science foundations have initiated and launched both permanent centers and temporary research programs on the intersection of learning research and learning, and several universities are offering study programs on this issue. Moreover, a fast-growing international academic society named IMBES (International Mind, Brain and Education Society) was founded and has been editing a journal since 2006. This society seeks to support cooperation between scientists of different disciplines (mainly biology, educational science, and psychology) and to stimulate the dialogue between in the vast illegal trade or trafficking in drugs, guns, women, or anything else illegal for which there is a demand. (p. 185)

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Neurosciences and Learning

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Well-established academic societies in the field of schooling and education, such as the American Educational Research Association and the European Association of Research on Learning and Instruction, have established special-interest groups with a focus on educational neuroscience. All over the world, private and public science foundations have initiated and launched both permanent centers and temporary research programs on the intersection of learning research and learning, and several universities are offering study programs on this issue. Moreover, a fast-growing international academic society named IMBES (International Mind, Brain and Education Society) was founded and has been editing a journal since 2006. This society seeks to support cooperation between scientists of different disciplines (mainly biology, educational science, and psychology) and to stimulate the dialogue between educational practice and science. As a consequence, school teachers are encouraged to join the society as well as attend its biennial meetings.

The Bidirectional View on Neuroscience and Behavioral Research

In their mission statements, the aforementioned societies emphasize that there is no one-way path either from neuroscience to psychological and educational research or from science to educational practice. This is an important point, because it implies a riposte to misguided and simplistic beliefs about what facilitates or impedes learning. Examples of such widespread naive beliefs, also labeled as neuromyths, include the following: Music or brain jogging make us smarter because they promote synaptogenesis, or the formation of synapses between neurons; younger people learn better than older ones because of their greater brain plasticity; and people learn better when they are in a positive mood because it stimulates the amygdala. Considering such statements as being scientifically well-founded goes along with the assumption that neuroscience as the "harder science" can deliver better explanations than psychological or education theories can. Moreover, this assumption implies that progress in understanding brain functioning will inevitably lead to a better understanding of learning and educational practice. Such naive views, however, can easily be reduced to absurdity, as a pertinent example from a different field illustrates. Consider an expert committee of engineers in charge of investigating an air crash coming up with the explanation that the plane came down because of the Earth's gravity. Although this is correct from the perspective of physics, it does not at all explain what technical system had broken down in the particular airplane, and what has to be done to avoid future air crashes—there is not one solitary causal factor at work but rather a set of interacting factors are involved.

Learning and education have to be understood as the interaction between an individual (including his or her brain) and the environment. A better understanding of the chemical processes taking place in synaptogenesis will not at all contribute to a better understanding of the difficulties students have with algebra, and, of course, it will not inform teachers about appropriate classroom practice. The scientific concepts and constructs used for understanding the chemical and biological basis of brain functioning are different from the concepts and constructs used in psychology and educational science to explain cognition and learning. Simply recording a person's brain activities does not tell us anything about what she is thinking or learning. On the other hand, observing that a person has reached a particular learning goal after several trials allows us to conclude that synaptogenesis must have taken place, but nothing beyond. Understanding the brain and understanding cognitive and behavioral functioning and education are distinct research goals that need not only different concepts and constructs but also different methods and standards for evidence. The goal of educational neuroscience is not to break off well-established disciplines but rather to provide a forum for addressing interesting and important research questions that go beyond the boundaries of a single discipline. Better understanding under what conditions learning and instruction at school live up to the expectations held in these institutions is a complex goal that requires the concentrated efforts of different disciplines.

Psychology has a long tradition of making quite vague concepts of mental states and mindsets measurable by tests and questionnaires and thereby opening them to scientific investigation—intelligence, reasoning, working memory, executive control, or anxiety are examples. Similarly, neuroscience can not only contribute new methods of brain imaging but also lead to insights into the functioning and the architecture of the brain, including developmental changes across the life span. In this way, neuroscience can contribute to the question of whether particular brain characteristics facilitate or impede learning during a particular period of life. On the other hand, the focus of educational research is on the features of learning environments, including methods of instruction, teacher characteristics, ways of designing and presenting learning material, and many more. In this research tradition, educational scientists have developed valid and usable categories for classifying aspects of learning environments that help systematize the complexity of schooling and thereby make it appropriate for scientific inquiry.

Added Values of Combining Neuroscience and Behavioral Research

Evolution has equipped all animals—from insects to humans—with a mechanism of adaptation to their environments, namely, brains that are prepared for learning. At the same time, learning leaves changes in the brain that result from neural activity and communication between neurons. Decades before brain imaging techniques became matter of course, Donald Hebb formulated the core principle of learning on a neural basis: "Neurons that fire together wire together." Based on this principle, mainly in animal research, neuroscience has uncovered chemical and physical processes taking place in the brain during learning. For instance, the pivotal role of the neurotransmitter dopamine for learning by reward and punishment has been elucidated. This line of research made use of the psychological paradigms of classical and operant conditioning, and it has enriched the explanatory power of the learning theories. Among other factors, dopamine release can determine the speed with which new stimulus–response connections are acquired. Learning by operant and classical conditioning, however, is not the primary goal of institutional learning and education. Rather, the focus of schooling is on the acquisition of symbolic skills in literacy and mathematics, as well as the acquisition of meaningful conceptual understanding in the complex content areas that have been developed. This enormous capacity for learning is unique to human beings.

Understanding the differences between human brains and those of other living beings is still in its infancy. It is, however, known for certain that the area in the human brain labeled as the "prefrontal cortex" is crucial for meaningful cognitive activities and higher-order learning. Malfunctions in this brain area caused by injuries, strokes, or other kinds of brain diseases severely impede the functioning of working memory and executive control, which otherwise enable goal-directed behavior. This happens by storing and processing the relevant knowledge and by simultaneously suppressing irrelevant information. The prefrontal cortex undergoes dramatic changes during childhood and adolescence, and these changes are closely correlated with achievement on tasks of cognitive control and working memory, indicating that brain development determines whether an individual is able to make use of the learning opportunities provided by the environment or not. Identifying neural underpinnings of behavioral and cognitive changes in childhood and adolescence can help prevent parents and teachers from making unrealistic demands. Moreover, when it comes to the identification of children or adolescents at risk, the combination of brain indicators and behavioral data can provide a better basis for decisions on means of prevention than each single predictor can do.

The combination of behavioral research and neuroscience has particularly proven its worth when it comes to the explanation and the identification of developmental and learning disorders. Until the 1970s, it was widely believed that many kinds of psychological disorders—from schizophrenia to autism to dyslexia and dyscalculia—were caused solely by unfavorable family or societal conditions. Thanks to the bidirectional view of educational neuroscience, such oversimple beliefs are things of the past. It is now understood that people can differ in their brain structures from the very beginnings of their lives, and these differences determine the degree to which they can profit from instruction. This is particularly the case for learning to read and to write, as well as for learning arithmetic. Several brain areas involved in the acquisition of these competencies have been identified, and differences between impaired and regularly functioning children have become obvious.

Final Conclusions

Using findings and techniques from neuroscience for researching school-related learning can clarify whether particular pedagogical interventions do not live up to the expectations teachers had placed in them because of students' brain dysfunctions. Apart from that, neuroscience has not at all overturned theories and beliefs about effective instruction and classroom practice that had already been developed on the basis of traditional behavioral research. If anything, findings from behavioral studies were confirmed by results from brain imaging. Hence, there is no reason to consider neuroscience as part of teachers' professional knowledge and to make it part of the compulsory curriculum of teacher education programs. Teachers are in charge of enriching and refining student's knowledge in the respective content areas. Pedagogical content knowledge is the core of teacher expertise, and being aware of the current state of the art in neuroscience does not make them better teachers.

Elsbeth Stern, Ralph Schumacher, and Roland Grabner

See also Cognitive Revolution and Information Processing Perspectives; Learning, Theories of; Pedagogical Content Knowledge: Lee Shulman

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