The Educated Brain

The emerging field of neuroeducation, concerned with the interaction between mind, brain, and education, has proved revolutionary in educational research, introducing concepts, methods, and technologies into many advanced institutions around the world. *The Educated Brain* presents a broad overview of the major topics in this new discipline: part I examines the historical and epistemological issues related to the mind/brain problem and the scope of neuroeducation; part II provides a view of basic brain research in education and use of imaging techniques, and the study of brain and cognitive development; and part III is dedicated to the neural foundations of language and reading in different cultures, and the acquisition of basic mathematical concepts. With contributions from leading researchers in the field, this book features the most recent and advanced research in cognitive neurosciences.

ANTONIO M. BATTRO is a member of the National Academy of Education, Argentina, and the Pontifical Academy of Sciences.

KURT W. FISCHER is Charles Warland Bigelow Professor of Education & Human Development, and Director of the Mind, Brain, & Education Program at the Harvard Graduate School of Education.

PIERRE J. LÉNA is Emeritus Professor of Astrophysics at the Université Paris VII, member and delegate for education of the French Académie des Sciences, and a member of the Pontifical Academy of Sciences.

The Educated Brain

Essays in Neuroeducation

Antonio M. Battro,
Kurt W. Fischer,
&
Pierre J. Léna
Editors

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521876735

First published 2008

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this book is available from the British Library

ISBN 978-0-521-87673-5 hardback

This volume is dedicated to the beloved memory of
His Holiness, Pope John Paul II.

The opinions expressed with absolute freedom during the presentations of the papers of the meeting on *Mind, Brain and Education* at the Pontifical Academy of Science represent only the points of view of the participants and not those of the Academy.

Contents

Figures

Tables

Contributors

ANTONIO M. BATTRO, Pontifical Academy of Sciences and National Academy of Education, Buenos Aires.

JOHN T. BRUER, The James McDonnell Foundation, St. Louis

DANIEL P. CARDINALI, Department of Physiology, School of Medicine, University of Buenos Aires.

STANISLAS DEHAENE, Collège de France, Paris.

KURT W. FISCHER, Graduate School of Education, Harvard University.

USHA GOSWAMI, Faculty of Education, University of Cambridge.

HIDEAKI KOIZUMI, Advanced Research Laboratory, Hitachi Ltd, Japan.

PIERRE J. LÉNA, Pontifical Academy of Sciences, Observatoire de Paris, University of Paris VII.

RITA LEVI-MONTALCINI, Pontifical Academy of Sciences, Institute of Neurobiology, Rome.

JÜRGEN MITTELSTRASS, Pontifical Academy of Sciences, Center of Philosophy and Science Theory, University of Konstanz.

LAURA-ANN PETITTO, Department of Psychology, University of Toronto, Scarborough.

MICHEL I. POSNER, Department of Psychology, University of Oregon.

MARY K. ROTHBART, Department of Psychology, University of Oregon.

M. ROSARIO RUEDA, Department of Psychology, University of Oregon.

WOLF SINGER, Pontifical Academy of Sciences, Max Planck Institute for Brain Research, Frankfurt.

HENDERIEN STEENBEEK, Faculty of Behavioral and Social Sciences, Department of Psychology, University of Groningen.

PAUL VAN GEERT, Faculty of Behavioral and Social Sciences, Department of Psychology, University of Groningen.

FERNANDO VIDAL, Max Plank Institute for the History of Science, Berlin.

MARYANNE WOLF, Center for Reading and Language Research, Tufts University.

Preface

In his address of November 10, 2003 to the members of the Pontifical Academy of Sciences gathered in Rome to celebrate the 400th Anniversary of the Foundation of the Accademia dei Lincei, origin of the Academy, and in reference to our meeting on *Mind, Brain, and Education*, which is the source of this book, His Holiness Pope John Paul II, said:

> Scientists themselves perceive in the study of the human mind the mystery of a spiritual dimension which transcends cerebral physiology and appears to direct all our activities as free and autonomous beings, capable of responsibility and love, and marked with dignity. This is seen by the fact that you have decided to expand your research to include aspects of learning and education, which are specifically human activities.

We will always remember the support of His Holiness for the challenging work of the neurocognitive scientists engaged in the field of education, a most humane and humanitarian endeavor.

The editors of this book are pleased and honored to present the work of the distinguished scientists who were invited to discuss their research at the workshop on *Mind, Brain, and Education* held at the Vatican (November 7–8, 2003). This volume has been edited from the papers presented by the authors and organized in a book that will be of interest not only to experts but also to a larger audience of educators and teachers. We are thankful for the effort the authors have made to fulfil this extended purpose well beyond the strict proceedings of a scientific meeting. Indeed it was a great honor to all of us to have shared this important anniversary meeting of the Pontifical Academy of Sciences with a second advanced workshop dedicated to *Stem Cell Technology and other Innovative Therapies*. This is a good match for our *Mind, Brain, and Education* topic, which represents also a new scientific frontier for the new century.

This workshop was attended by the presidents of the academies of sciences of many nations, special guests from all around the world, and a full audience of Pontifical Academy members, who participated in the

lively discussions at the Casina Pio IV, a Renaissance jewel in the beautiful Vatican gardens. We thank all of them and in particular we are grateful to Professor Nicola Cabibbo, president of the Pontifical Academy of Sciences, to the Chancellor of the Academy, Monsignor Marcelo Sánchez Sorondo, and to the Honorary President of our meeting, Professor Rita Levi-Montalcini, for their generous and continuous support towards our work.

The opinions expressed with absolute freedom in our meeting represent only the points of views of the participants. The Academy endorsed the following final statement:

The rapid development of neurosciences, the advances in psychology and education research, and interdisciplinary cooperation between these fields of investigation lead to a better understanding of learning, cognition, emotions, consciousness. Education of children, and in some respects of adults, often practiced with traditional methods, should not ignore this progress, even though it is in an early stage. Education is an art which needs to integrate scientific knowledge on brain and mind as well as other social, political and ethical aspects, in order to deal with its highly complex goal: namely, raising the child to full adult stature as a conscientious and educated person. Considering the deep societal changes throughout a globalized world and the impact of information technologies on human life, appropriate changes in education can enrich the lives of millions. The workshop on *Mind, Brain, and Education* addressed many facets of the immense challenges for education related to brain development, neural plasticity, developmental psychology, learning language and reading, dynamic modelling of learning and of development. The discussions in the Workshop converged on the following conclusions:

1. The promises of neuro- and cognitive sciences for a better understanding of the underlying basis of learning are developing rapidly. Cross-disciplinary research should involve educators and deal with real educational practices.
2. Given the complexity of the matter, care should be exercised to avoid hasty conclusions on education, driven by superficial implications of recent findings, such as uncritical statements about "Brain-based schools."
3. There are nevertheless areas where knowledge appears sufficiently solid to support conclusions impacting learning (e.g. sleep needs, arithmetic, reading abilities and bilingualism) and should be seriously considered. Relationships between brain, mind, consciousness and the self must be explored respectfully on an ethical basis in order to preserve human dignity and to promote equity. This can offer a rich opportunity to broaden the representation that men and women have today of themselves, of their states of individual development and of their achievement potential.

We are grateful also for the great help of many colleagues and friends in the editing of this book: To the vision and generosity of Sarah Caro, responsible for the several books published by Cambridge University Press dedicated to the new field of mind, brain, and education, including

The Educated Brain. To her successor in this difficult job Andrew Peart and his staff. To our collaborators Mary Kiesling in Cambridge, Massachusetts, and Percival J. Denham in Buenos Aires, Argentina who made easier the heavy traffic of emails and documents between America and Europe and provided much needed editing and computer skills to produce a satisfactory final version of this book. To the *Mind, Brain, and Education* initiative at the Harvard Graduate School of Education, to our Harvard students in the course *The Educated Brain* (Battro & Fischer, 2002–2003), who gave the title to this book and helped us to prepare the workshop at the Pontifical Academy of Sciences. Funds to support preparation of this book were provided by the Pontifical Academy of Sciences and the Harvard Graduate School of Education.

Finally we thank also IMBES, *The International, Mind, Brain, and Education Society*, launched at the Vatican meeting, the *Ettore Majorana Centre for Scientific Culture* at Erice (Sicily) and its president Antonino Zichichi, where we had the pleasure to invite several of the authors of this book to give a course also called *The Educated Brain* (July, 2005). The promising young scholars who attended the conference at Erice point the way to the exciting future that is growing from connecting biology and cognitive science with education to further knowledge and improve educational practice.

A. M. Battro, K. W. Fischer, and P. J. Léna

Foreword: Towards a new pedagogical and didactic approach

Rita Levi-Montalcini

The remarkable scientific developments of these last centuries, and particularly those from the Renaissance until our day, did not always contribute to a substantial change in the educational system, which constantly needs to be updated. In past centuries the total lack of knowledge about the cerebral structures and functions underlying cognitive capacities in the post-natal period has influenced in a negative way the adoption of more pertinent educational practices. In the twentieth century two events of fundamental importance have occurred: the understanding, however incomplete, of the activity of the cerebral organ and most recently the formidable development of computer systems that have imposed a total transformation of individual life in contemporary society.

At the beginning of the third millennium the changes in life styles at a global level require a revision of pedagogical and didactic systems. This radical revision is imperative in education from infancy through puberty and adolescence in order for students to be adequately included in computer science. The individual of tomorrow is the result of the formative attitude of today's child.

Current educational systems are still greatly influenced by the Victorian attitude based upon the principle that the child can be an object of reward or punishment, as is the case with a puppy. In what way does the brain of a child differ from that of a puppy? In both cases the brain has developed the paleo-cortical component known as the limbic system in ways that are not substantially different; this system underlies the emotional, affective, and aggressive functions of behavioral processes that have remained invariant for millions of years, from the appearance of mammals to *Homo sapiens*.

Human children differ from those of other mammals in the slowness of their brain development. This is why they become more dependent on parents or educators during the long maturational period extending from birth to puberty and beyond. Even if the slow maturation of brain faculties favors the development of such a stupendous and complex device as the brain of *Homo sapiens*, the protracted dependency on parents, or on

those who act as parents, leaves a permanent mark on the nervous structures that guide the individual's behavior when growing out of childhood to become part of human society.

It is important to give a child, in the first years, information that can so heavily influence his or her relations towards the world. It is in this stage that adults exercise a fundamental influence upon the young child through the religious/political belief system of the tribe or social group to which he or she belongs. Hate for the "different" instilled at a tender age, whatever the definition of this term might be, produces the tragic consequences of genocides and wars, which today still bloody the whole globe. Education imposed by these beliefs in the first years of life strongly influences the character and behavior of the adult of tomorrow. Totally different is the cognitive development of the child that has its origin in the neocortical component of the brain. The neocortex, in contrast with the paleo-cortex or limbic system, reaches a remarkable elaboration with the folding of the cortical lamina, which in turn makes possible an increase and reorganization of neural networks.

During childhood in primary school, children learn the first rules of social relations, and in a few months they travel the paths traveled for tens of thousand of years by their ancestors, from the time these remote predecessors discovered those formidable symbolic communication tools that make up spoken and written language. With this discovery, the possibility of exchanging messages between individuals, between the individual and the masses, between those who belong to generations past and those living today, between those today and the generations to come, has multiplied a hundredfold in our species.

It has recently been discovered that cognitive capacities are already at work in the child's brain and that they are far greater than recognized in the past. What is the basis of this statement? For one thing, those who belong to the new generation show a totally unexpected and natural tendency towards the use of information systems such as computers from the early years, using a formal-logical approach.

The evolution of information technologies has revealed the enormous and unbelievable capacity of the child and the pre-adolescent not only to receive information, which was considered in the past to be the privilege of the mature brain, but also to use it immediately and thus even to surpass adults, surprisingly. The skill and enthusiasm shown by children when using the computer is amazing. The average age of the first contact with these technologies is tending to decrease continuously.

Today the necessary task in educational and didactic systems is not to indoctrinate the child and the pre-adolescent by transmission of knowledge through traditional textbooks but to make them aware of their own

capabilities and to help them use these capabilities to progress from the passive condition of "loading" information into memory to the active condition of learning by direct experience. This last property of active learning comes from the neocortical circuits which develop luxuriantly from birth and are stimulated by messages from the external environment.

Seymour Papert, a renowned supporter of novel pedagogic-didactic theory, affirms that the child needs to be recognized in his or her role as "active producer" and not as "passive consumer" of learning (Papert, 1992). How is it possible to reach a revolution that implies such a total revision of the pedagogic-didactic systems?

I argue that the use of the computer in the first stages of the individual's development stimulates the creative capacity of the young user. The learning of mathematics, generally considered as a distasteful discipline in the first years of schooling, becomes a tool of active thinking via the computer. Mathematics as taught by traditional methods is in my judgment not only difficult to learn but completely useless because of the lack of direct application to the events young people are observing.

Participating with the child in the creation of computer programs, such as videogames or computer control programs, and not vice versa, Papert has created a program called LOGO that allows the child using the computer to develop creative activities in music, the arts, games, and other areas (Papert, 1980). It has been shown that with this kind of practice children learn better and faster in comparison with traditional school methods.

A typical example of learning precocity is confirmed by the results obtained at the *Diana* elementary school in Reggio Emilia in Italy, which is not only widely recognized in Europe but is described as a model program by Harvard University's Project Zero in the essay *Making learning visible*, which describes the methodology and techniques involved and the resulting autonomous learning by the children, in conjunction with care from the teachers (Project Zero, 2001). It is the teacher's duty to support the child and to help him/her to develop as an individual. She guides him/her, and at the same time they learn new things together.

Thanks to the computer and this kind of new pedagogy it is possible to have this experience, as expressed by various authors. While learning acquired from the reading of textbooks decays with time as the knowledge is forgotten and only retrieved from time to time, the knowledge acquired from the use of computers and active learning can be remembered better.

The new didactic system should not be based on a triangle – teacher-textbook-student – but instead should be built on the professional ability

to generate creative learning based on an educational project developed in an open environment, as is proposed by Paolo Manzelli, president of CreaNET (see *Laboratory for Educational Research, Florence University*).

We need to think about a new school, a different school. We need not only replace current study programs but also change teaching methods. This change is already at work in the United States and is producing relevant results. The "interactivity" of a new educational and didactic system connecting school, research centers, and society is the keystone to reaching community objectives corresponding to European social demands.

This cultural revolution will evoke reactions of support and opposition. It is interesting to observe, as has the mathematician and teacher Papert, that the use of information technologies in arenas such as education has been accepted and applied more easily in the so-called developing countries than in many of those of a more advanced level, which have been characterized by conservative trends (Papert, 1996). Moreover, the developing process of new technologies is irreversible, and change is urgent: The goal is to see members of the new generation become actors and not spectators in the world arena of life.

References

Papert, S. (1979). *Mindstorms: Children, Computers and Powerful Ideas*. New York: Basic Books.

(1992). *The Children's Machine: Rethinking School in the Age of the Computer*. New York: Basic Books.

(1996). *The Connected Family: Bridging the Digital Generation Gap*. New York: Basic Books. www.ConnectedFamily.com/

Project Zero and Reggio Children (2001). *Making Learning Visible: Children as Individual and Group Learners*. Contributors: Claudia Giudici; Carla Rinaldi; Mara Krechevsky; Paola Barchi; Howard Gardner; Tiziana Filippini; Paola Strozzi; Laura Rubizzi; Amelia Gambetti; Paola Cagliari; Vea Vecchi; Giovanni Piazza; Angela Barozzi; Ben Mardell; Steve Seidel. Cambridge, MA: Reggio Emilia, Italy: Reggio Children, International Center for the Defense and Promotion of the Rights and Potential of all Children www.pz.harvard.edu/Research/MLV.htm

creaNet *Laboratory for Educational Research. Florence University EGO-CreaNet Association, Telematic Network*. www.thinkquest.it/egocreanet/stating.html