MIND, BRAIN AND EDUCATION AT ERICE: TEN YEARS

EDITORS

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PREFACE

Science is friendship

Ten years of collaboration at the International School on Mind, Brain and Education, Ettore Majorana Foundation and Centre for Scientific Culture.

Antonio M. Battro

A brief history

What more felicity can fall to creature than to enjoy delight with liberty
Edmund Spenser (1552-1599)

I would like to reflect upon the spirit of the International School on Mind, Brain and Education at the Ettore Majorana Foundation and Centre for Scientific Culture at Erice in its tenth's anniversary. It all started in 2002 at the Harvard Graduate School of Education when I was teaching as visiting professor with Kurt W. Fischer a course on the "Educated Brain". At that time Kurt was also teaching with our friend Howard Gardner a very influential course on "Mind, Brain and Education", MBE, the first of this kind in a School of Education. The same year, my *annus mirabilis*, I was nominated at the Pontifical Academy of Sciences PAS and I went to Rome to become an academician in November. It was a great event in my life. We were received by Pope John Paul II and the session of the self–presentations of the new members was unforgettable in many senses. I was humbled among so many prestigious colleagues, several Nobel laureates and two cardinals, eminent scholars, Carlo M. Martini and Joseph Ratzinger, who was elected Pope Benedict XVI in 2005. I still keep my notes of the various conversations with fellow academicians, in particular with Pierre Léna, astrophysicist and co–founder of LAMAP, *La main à la pâte* in Paris, an expanding international program of inquiry–based science education. I was impressed by his achievements and ideas. And we became friends.

The story of our MBE School at Erice began to unfold when we decided with Pierre to organize a working group at the Academy in November 2003 on *Mind, Brain and Education* MBE and we invited Kurt to co–chair this meeting with us. The meeting was a success and elicited a series of working groups at PAS on the MBE topics in the following years. At that meeting we announced with Kurt, and one of our former Harvard students Juliana Paré–Blagoev, the launch of IMBES, the *International Mind Brain and Education Society*. Kurt became the first President of this new association and the Editor of its official journal *Mind, Brain and Education* whose first volume was published in March 2007, with David B. Daniel as Managing Editor. Since then the journal became a most appropriate platform for the publication of many of the papers presented or inspired in our meetings at Erice.

That year 2003 our Academy was celebrating the 400th anniversary of its foundation as *Accademia dei Lincei*, the oldest of the world. Many presidents of academies of sciences were also present. In the session commemorating this anniversary our colleague Antonino Zichichi, physicist and founder of the Ettore Majorana Foundation and Centre for Scientific Culture at Erice presented a topic close to his heart "Galilei, Divine Man" that became a source of inspiration for many of us who were working to build a new scientific field in "neuroeducation". And, most challenging, he generously offered us the opportunity to create an International School on MBE at Erice and invited me to visit the place. I went to Erice in 2004 with Marta Oyhanarte where we were hosted by Fiorella Ruggiu, the most efficient and friendly director of the Centre. We discovered that Erice was a unique site in Sicily where incomparable beauty, a millenary history and the most advanced sciences meet. I returned home fully convinced that this was *the* place for a MBE School. Fiorella became the key person in the organization of our meetings.

As a result of this trip we decided with Kurt to create and co–direct the new MBE School and in July 2005 we held our first meeting at Erice on the "educated brain", which was a success. Pierre and many dear colleagues from different nations came to this meeting. We invited a former student of Kurt, María Lourdes Majdalani (Lula), to become the Program Officer of the MBE School at Erice. I was also mentor of Lula at Harvard where we became close friends. We both live in Argentina. Now Lula co–edits this book, which is also the result of her friendly support and professional effort during a decade.

We were proud that the proceedings of our meeting on MBE at the Pontifical Academy in 2003 were published in a book: *The educated brain: Essays in neuroeducation* (1) and were translated into Chinese. The inclusion of China in the MBE movement was extremely important. I was invited in April 2004 to a meeting in Hangzhou for The Sino–French Symposium on "Learning by Doing" in collaboration with LAMAP, organized by Pierre and Wei Yu, former vice–minister of education of China. And there we went to share an unforgettable experience on the teaching of science in Chinese schools. And most important we started a collaboration with the Research Center for Learning Science of the Southeast University of Nanjing under the leadership of Wei Yu, and in another trip, this time in company with Kurt, with East China Normal University, Shanghai, organized by Jianxian Zhou, former Kurt's student at Harvard. We had the pleasure to receive Wei Yu at our first MBE School at Erice and in 2012 with her colleague Yanmei Zhu. Erice was also enriched by the significant contributions of Japan, in particular, those of our loyal friend Hideaki Koizumi, chief scientist of Hitachi, and his talented junior colleagues, who participated in every meeting of the MBE Schools since 2005.

In November 2004 Pierre organized with Edmond Malinvaud and Marcelo Sánchez Sorondo, Chancellor of the Academies, a joint meeting on “Globalization and Education” (2) at the Pontifical Academy of Sciences and the Pontifical Academy of Social Sciences in Rome, where I acted as chairperson of the session dedicated to the role of communication and information technologies. In this meeting, among many other remarkable contributions, Wei Yu presented a panorama of the education in China and my friend Nicholas Negroponte, director of the Media Lab of MIT, launched the “$ 100 Laptop” initiative that became in 2005 the seed of OLPC, the *One laptop per child Foundation*. I became the Chief Education Officer of this international program that have reached 47 nations and more than 2.7 million children and teachers. Today the *Global Literacy XPrize*, inspired by Negroponte, is promoting new technologies and pedagogies to educate children in remote places without schools. Our dear colleague Maryanne Wolf gives a presentation of her recent experience about that issue in this volume. It is based on the evidence that “children teach”. And the “teaching brain” is the topic of the celebration of the 10th MBE School at Erice coordinated by Sidney Strauss, whom I first met at Harvard thanks to Howard Gardner, and Elena Pasquinelli, a close collaborator of Pierre Léna at LAMAP. Our network of friends was quickly expanding.

Our ten Schools included a broad spectrum of topics, 2005: Summer School on mind, brain and education; 2007: Basic and applied topics on biological rhythms and learning; 2008: Neuroeducation: new perspectives in teaching and learning; 2009: Educational neurosciences and ethics; 2010: Learning, arts and the brain; 2011: Education in the digital era; 2012: Teaching: a new frontier of the neurocognitive sciences, education and culture; 2013: Science education in the digital era; 2014: Body, brain and personal identity and 2015: The teaching brain.

This is only a glimpse on how a remarkable international human network developed in the MBE field around Erice out of the friendly relationship of a small group of colleagues distributed in several continents. Many more actors enriched our Erice meetings in the following years and are listed in our website www.mbe-erice.org. Our School gathered participants from Argentina, Uruguay, Paraguay, Brazil, Mexico, United States, Canada, Spain, France, Italy, Germany, United Kingdom, Netherlands, Switzerland, Hungary, Austria, Sweden, Israel, Japan, China, Korea, Taiwan and South Africa. We are so grateful to all of them for their collaboration in this first decade of our Erice School, and we hope to continue to receive more participants in the following meetings. Science is friendship and Erice became a real home for all of us.

Fraterna Erycis

The magic of Erice was recognized since very ancient times. The top of mount San Giuliano, where Erice stays, was a sacred place of the Elymi native people. Virgil dedicated the Book V of his Aeneid to describe the mythical arrival of Aeneas to the beloved shores of Erice, his “fraterna Erycis”, with his fleet after the fall of Troy and his dramatic encounter with queen Dido of Carthage in his way to Rome. The description of the magnificent celebrations in memory of his father Anchises who was buried there is one of the pearls of the book. I always recommend its reading to our participants at Erice. The place became also famous because of the cult of Aphrodite, the Venus Ericina, the first of its kind in Sicily. The history of the successive occupations of Erice by Phoenicians, Greeks, Romans, Byzantines, Arabs and Normans has left many traces in the region. Medieval churches, monasteries and palaces, the Venus Castle in the old Acropolis, are still in place and splendid buildings of the time of the kingdom of Sicily have been well preserved. Erice is without doubt one of the jewels of Sicily.

The idea to create an international meeting place for advanced scientific studies in old Erice where senior scientists could discuss and exchange their views with junior researchers and students was the initiative of five physicists: John Bell, Patrick M.S. Blackett, Isidor I. Rabi, Victor Weisskopf and Antonino Zichichi. The Centre started in 1962 with The International School of Subnuclear Physics directed by Zichichi, who was also founder and director of the Centre. Since then more than 150 Schools have been implemented by prestigious scientists in their fields. More than a hundred Nobel laureates and thousands of participants from 140 nations have joined the Erice’s Schools and ten thousand scientists the world over signed the *Erice Statement* about the peaceful use of scientific knowledge, an initiative that was taken in Erice by Paul A.M Dirac, Piotr Kapitza and Antonino Zichichi in 1982, during the Cold War. Pope John Paul II visited the Centre in 1993 and greatly supported the “Spirit of Erice”.

Three of the old Erice’s monasteries have been incorporated to the Ettore Majorana Foundation and Centre for Scientific Culture since its inception in 1962. The San

Francesco Monastery (former Viceroy's residence) became the Eugene P. Wigner Institute with the Enrico Fermi Lecture Hall, the San Domenico is now the Patrick M.S. Blackett Institute with the magnificent Paul A.M. Dirac Lecture Hall and the San Rocco Monastery has been transformed in the Isidor I. Rabi Institute with the inspiring Richard P. Feynman Lecture Hall and the Secretariat of the Centre. And, most remarkable, these historical buildings provide today very convenient living quarters for the participants of the different Schools that take place during the whole year at the Centre. It is important to mention that the Centre has been named after an outstanding student of Enrico Fermi, the young and remarkable Sicilian physicist, Ettore Majorana, born in Catania in 1906, who disappeared in the sea in 1938 during the crossing from Palermo to Naples. This dramatic event was described by the Sicilian writer Leonardo Sciascia in his famous book "La scomparsa di Majorana" (1975). Majorana's legacy is still a source of inspiration for many of us in Erice.

It must be stressed that the Ettore Majorana Centre encourages in every School an intensive dialog between senior and junior participants, a friendly characteristic that is very much appreciated by young and old scientists and many times stimulates new fruitful and unexpected collaborations. And, of course, this exchange continues after the scientific sessions in the beautiful restaurants, gardens and bars of Erice. And most important, during our MBE Schools we always dedicate a whole journey to visit the spectacular historical places of the region, the Greek ruins of Segesta and Selinunte, the Monreale Cathedral and… the beautiful beaches. Our website www.mbe-erice.org gives a vivid account and photos of these trips and gatherings.

The butterflies of the soul

I was invited in 2003 by my friend Courtney Ross, a strong supporter of the Mind, Brain and Education initiative, to become a Scholar in Residence at the school that she has founded, the Ross School in East Hampton, NY, a most advanced institution of education. During my stay I worked on a project on a metaphor about the neurons as "butterflies of the soul". The inspiring idea came from Santiago Ramón y Cajal, the celebrated Spanish neuroanatomist (1852–1934) who in his memoirs, first published in 1923, wrote:

> *As the entomologist chasing butterflies of bright colors, my attention was seeking in the garden of gray matter, those cells of delicate and elegant forms, the mysterious butterflies of the soul, whose fluttering wings would someday —who knows?— enlighten the secret of mental life.*

The result was a wonderful video on the fluttering growth–cone of a neuronal axon superposed to a flying butterfly, a piece of art produced by Bronwyn Roe, a brilliant student of the Ross School, then 15 years old. I presented this video at the meeting that we organized with Kurt Fischer and Pierre Léna on "Mind, Brain and Education" at the Pontifical Academy of Sciences in the Casina Pio IV in the Vatican gardens in 2003. Courtney Ross attended this meeting and came to our first MBE School in Erice in 2005.

We incorporated the image of the butterfly in the cover of our first book on the educated brain and it became also the icon of our MBE–Erice website. We also proposed to award a work of art as an annual prize to recognize an outstanding presentation by a junior participant. The laureates in the different years were: Maki Koyama (twice), Kazuo Jano, Zachary Stein, Soraya Umewaka, Cecilia Alcalá, Vanessa Rodriguez, Yusuke Seki, Felix Schirmann and Anna–Lisa Vollmer. The Erice award 2015 was a painting of a butterfly. The artist, my student and friend Nico, is a right–hemispherectomized remarkable young man and this work of art reveals a feat of human neuroplasticity and a hope for education (3). Erice is certainly a privileged observatory to study Cajal's "butterflies of the soul" in a friendly environment of learning and teaching. And, most important, when we teach we learn, *docendo discimus*!

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INTRODUCTION

New perspectives on Mind, Brain and Education

Elena Pasquinelli

Introduction

Until quite recently, cognitive science steered clear of education, while the sciences of education tended to ignore cognitive science. Things have changed over the last few years, and there is now quite a lot of interaction between the two fields. Between 2009 and 2010, and coherently with it's editor in chief's claim that "policy–making needs science" (Alberts, 2010), the prestigious journal Science has dedicated three special issues to science–informed education. Just before that, in 2007, were born the *International Mind, Brain, and Education Society* IMBES and its journal (Fischer, et al. 2007); during the 2000 decade, while the international Organization for Economic Cooperation and Development and the Centre for Educational Research and Innovation OECD–CERI was achieving two programs on education and the brain, with relative publications (OECD, 2002, 2007), the Teaching and Learning Research Program TLRP and the Royal Society were producing reports on neuroeducation for the UK (TLRP, 2008; Frith & Blakemore, 2005; Royal Society, 2010). Also in Europe the Pontifical Academy of Sciences organized several working groups on the same subject (PAS, 2008, 2011, 2014) and in the last two years, the European Association for Research on Learning and Instruction, EARLI has given birth to a Special Interest Group SIG on Neuroeducation, and a new journal on neuroscience and education has seen the light (*Trends in neuroscience and education*). Meanwhile, teaching and research activities have been developed in the USA, UK, Japan, China, Germany, France and recently in Latin America (LA School: Latin American school for education, cognitive and neural studies). Education, cognitive science and neuroscience have thus become active arenas for the encounter of science and society (Brabeck, 2008, The International School on Mind, Brain and Education 2005–2015: Centro Ettore Majorana for Scientific Culture, Erice, Italy).

The accent has been put in particular on brain studies, as suggested by the spreading of neuro–labels: neuroeducation, education and neuroscience, educational neuroscience. These labels remind us how trendy neuroscience is, in our days —they are indeed in the good company of neuroeconomy, neuromarketing, neurolaw, and many other neuro–manias (Legrenzi and Umiltà, 2010). As a matter of fact, the field is larger than that, and the studies about the mind and its behavioral correlates have interfaced with education at several points of their history.

In 1899, William James addressed a talk to the teachers about psychology, claiming that the science of the mind ought to help teachers by giving them confidence in the methods they practice —when the theory is established— and by providing a “stereoscopic view” of pupils: at the same time intuitive and analytic. Also, that psychology has a positive value for research in education, since holding a theory about how the mind works “narrows the path for experiments and trials” (James, 1925). James’ terms were not too optimistic, though, since he feared that teachers might be misled into placing too big hopes in science:

> *Psychology ought certainly to give the teacher radical help. And yet I confess that, acquainted as I am with the height of some of your expectations, I feel a little anxious lest, at the end of these simple talks of mine, not a few of you may experience some disappointment at the net results. In other words, I am not sure that you may not be indulging fancies that are just a shade exaggerated.*
> **James, 1925**

James’ skepticism had two reasons. First, he doubted that there might be something really new in the psychology of his time, but the “old psychology, which began in Locke’s time, plus a little physiology of the brain and senses and the theory of evolution” (James, 1925). James was one of the first —together with Darwin himself— to acknowledge the potential of the theory of evolution for the understanding of the mind; but, at that time, both evolutionary biology and the science of the brain were far from having brought the revolutions they have caused in the understanding of the mind today. Second, according to James, psychology is a science, and sciences do not generate school programs or other applications straightforwardly: an intermediary is required in the form of “invention” or design.

> *I say moreover that you make a great, a very great mistake, if you think that psychology, being the science of the mind’s laws, is something from which you can deduce definite programs and schemes and methods of instruction for immediate schoolroom use. Psychology is a science, and teaching is an art; and sciences never generate arts directly out of themselves. An intermediary inventive mind must make the application, by using its originality.*
> **James, 1925**

Few years later, Edward Thorndike —whose research on animal learning paved the way to behaviorism— was proposing that the science of the mind and brain ought to back education, just as botany and chemistry back agriculture:

> *Just as the science and art of agriculture depend upon chemistry and botany, so the art of education depends upon physiology and psychology.*
> **Thorndike, 1910 p. 6**

Eighty years later the equation will be re–proposed and will include biology and medicine on the one side, cognitive science and education on the other (see Bruner, 1993; also: Fischer et al., 2007). According to Thorndike, however, the contribution of psychology to education is twofold. In the first instance, psychology unveils the unlearned tendencies of the human mind, and produces knowledge about the human mind and its natural propensities; this knowledge is meaningful for informing educational choices because it provides educators with an understanding of what can be learnt and what cannot, and about what should be taught because it cannot be learnt naturally.

> *Psychology contributes to a better understanding of the aims of education by defining them, making them clearer; by limiting them, showing us what can be done and what can not; and by suggesting new features that should be made parts of them.*
> **Thorndike, 1910, p. 5**

Secondly, the role of psychology is not restricted to providing knowledge and informing decisions in education through its general principles, because psychology is an experimental science, which has developed methods for measuring behavior. Through these methods, it is possible to test and verify whether educational interventions maintain what they promise, by measuring the students' performances in terms of behavior:

> *…in all cases psychology, by its methods of measuring knowledge and skill, may suggest means to test and verify or refute the claims of any method.*
> **Thorndike, 1910, p. 7**

In summary, the sciences of the mind and brain provide both a theoretical framework for understanding the limits and opportunities of education —based on the limits and capacities of the human mind— and a method for proving the validity of instructional methods by putting them to the test. Meanwhile, Thorndike was aware of the potential contributions that the association between psychology and education can provide to psychology itself:

> *Experts in education studying the responses to school situations for the sake of practical control will advance knowledge not only of the mind as a learner under school conditions but also of the mind for every point of view.*
> **Thorndike, 1910, p. 12**

By providing in–vivo settings for the study of learning processes, education offers a unique occasion for advancing the understanding of the mind–brain. Thorndike anticipated in this way the idea that it is necessary that we build a two–way road to connect education and the sciences of the mind and brain, a new field of applied research that will serve both practical and theoretical interests. Thorndike concludes where we've started —by placing the relation between education and the sciences of the mind and brain in the more general context of science as a guide for practice:

> *I hope that it is obvious and needless, that the relation between psychology and education is not, in the mind of any competent thinker, in any way an exception to the general case that action in the world should be guided by the truth about the world; and that any truth about it will directly or indirectly, soon or late, benefit action.*
> **Thorndike 1910, p. 12**

The idea of science at the service of practice will inform the behaviorist plan, as exemplified by John B. Watson, of establishing psychology on truly scientific —that is: experimental— grounds and of addressing problems that invest domains of social interest —such as education, justice, economy.

> *If psychology would follow the plan I suggest, the educator, the physician, the jurist and the business man could utilize our data in a practical way, as soon as we are able, experimentally, to obtain them. Those who have occasion to apply psychological principles practically would find no need to complain as they do at the present time. Ask any physician or jurist today whether scientific psychology plays a practical part in his daily routine and you will hear him deny that the psychology of the laboratories finds a place in his scheme of work. I think the criticism is extremely just.*
> **Watson, 1913**

Whether the sciences of the mind and brain have reached the maturity that is necessary in order to provide a meaningful contribution to the processes of education is still controversial. In 1974, the physicist Richard Feynman was still taking the sciences of the mind and the sciences of education as exemplary cases of "cargo–cult science": disciplines that have the appearance of scientific enterprises, i.e. an apparatus for providing experimental data, but lack the necessary methodological constraints that make the difference between science and pseudo–science (Feynman, 1985). Nonetheless, the theory of evolution and physiology have meaningfully contributed to psychology since the time of James' worried talk to the teachers, and both theoretical knowledge and methods for studying the mind and brain have evolved after Thorndike expressed his wishes. A cognitive revolution (September 1956, MIT Symposium on Information Theory) has hit the field in the mid–fifties of the last century, with the purpose of revealing the mechanisms and operations that are accomplished by the mind and underpinned by the brain —in opposition to the behaviorist view, but endorsing the scientific objective of the behaviorist plan. The last twenty years have brought huge contributions in the form of new knowledge about how the brain works and evolves —at the scale of the individual and of the species (1969 Society for Neuroscience; 1979, cognitive neurosciences; 1990, Decade Of the Brain). Some consider these contributions as being as meaningful for the design of education as biology and molecular biology revolutions have been for medicine:

> *Just as the revolution in molecular biology changed the whole face of medicine by providing both new understanding of physiological processes and new means of intervention when the processes are out of kilter, so the revolution in the study of the mind, usually called the cognitive revolution, is allowing us to enter a new era of human learning and teaching. This era does not reject the practical knowledge that has built up over millennia but greatly improves and enriches it. Good teachers and good learners may be born, but they cannot reach their potential, or anything close to it, without a deep understanding of the learning processes and how to enhance them. We are becoming more and more able to provide that understanding.*
> **Simon 2000, p. 116**

In what follows, I will address the following questions: How can available knowledge be used? How can new, useful, applicable knowledge be produced? I will adopt the point of view expressed by Thorndike that the study of mind, brain, and behavior contributes to education with both knowledge (namely, in terms of a better understanding of learning processes, but also of the teaching brain and the extended mind) and methods. I will also defend the idea that the encounter between educations and mind–brain–behavior sciences can profit to the latter at least as much as it does to the first. The bulk of the paper is however dedicated to develop James' reasons for skepticism and Watson's preoccupation with solid scientific foundations. It will become apparent that the road that links education with science contains many slippery slopes, and that —in order to establish a long–lasting, prolific relationship that will profit both— we should acknowledge and face the risks of a bad marriage.

Reasons

At first, I will briefly put forward two considerations that justify the (renewed) interest of education for mind, brain, and behavioral studies.

Learning is natural, and learning as a cultural product

The first, general consideration is that learning is a pervasive cognitive function: humans (and other animals) learn without formal instruction because learning is in many respects and in many cases a natural activity: e.g. learning to walk, talk, recognize objects, interpret others' minds. Nonetheless, several authors point at the uniqueness of human learning, as compared to the rest of the animal reign (Boyd & Richerson, 2005; Csibra, 2007; Gariépy et al. 2014; Nielsen et al. 2012; Sterelny, 2012; Tomasello, 1999). This is not just because humans can reach a higher degree of abstraction and acquire a larger range of complex skills. Humans have in fact created a technology —special cultural institutions, tools, methods— for cultural learning. Even if learning is in itself a natural process, various forms of education provide the conditions for learning things that do not come natural to the human mind, namely: the ever–evolving body of knowledge and skills that humans have discovered and invented through history, such as reading, algebra or the scientific method. It follows that the better we understand the human mind and brain, the better we can design educational interventions that mesh with the *nature* of the human mind and brain while being inspired by the unique *cultural* development of the human species.

> *Learning is a basic, adaptive function of humans. More than any other species, people are designed to be flexible learners and active agents in acquiring knowledge and skills. Much of what people learn occurs without formal instruction, but highly systematic and organized information systems*

> *—reading, mathematics, the sciences, literature, and the history of a society—require formal training, usually in schools.*
> **Bransford et al., 2000**

Let's see how this general consideration can impact the reflection upon education, its aims and strategies. It is often asserted that something is going deeply wrong with school, and many reasons are indicated —not necessarily the same ones for different countries and educational systems, as we might expect; one general concern exists, however, and is represented by students' motivation and the school's capacity of mobilizing the interest, curiosity, engagement of the learners, and to avoid school drop–out. So, why do children do not like school, while they like playing? Why do children do not spontaneously engage in learning algebra, while they are so naturally engaged in learning to walk, talk and socialize? Since learning is a natural function —runs the often–repeated argument— children should learn without even noticing they are learning, say, algebra, as they do for other natural functions. If they don't, and learning algebra is effortful or even painful, then something must be wrong with *school*. The problem with this argument is that the comparison between schooling and playing, or between algebra and walking–talking–socializing, is deeply unfair. Walking, talking, and socializing depend on the maturation of specific regions of the brain in normal environmental conditions (conditions that are normally present in the physical and social environment of the child); it is sufficient for the young human being to be immersed in a social environment for developing them. Learning algebra certainly requires brain and environmental pre–conditions, too, but this is still not enough, because algebra is a cultural achievement of the human species and not a natural cognitive function of the human mind —we are wired in a way that makes algebra possible, but we are not wired for algebra. Similarly, knowledge about history is not simply activated by the maturation of parts of the human brain – even in the presence of the right environmental conditions —but requires an effort of memory, classification, thought upon a kind of content the human mind and brain has not received evolutionary pressure to treat. The learning of science requires the effort of putting under control intuitive explanations about how the natural world works, daily observations, and cognitive biases and heuristics that lead us to see patterns, correlations and even causation where there's none. The fact that natural human learning has limits (certain acquisitions come naturally to our mind, provided the right social context, while others require our context to include specific cultural factors) is related to another tenant of contemporary cognitive studies: that the human mind–brain is not a blank slate, and nothing like an Ipad —a system for travelling from one information to another. Quite at the opposite, knowledge is embedded in the very structure of the brain, even before birth, and specific pre–wired mechanisms and circuits take care of specific functions and constrain further acquisitions. This view has meaningful consequences for our conception of education.

> *Education is neither writing on a blank slate nor allowing a child's nobility to flower. Rather education is a technology that tries to make up for what the human mind is innately bad at. Children don't have to go to school to learn to walk, talk, recognize objects, or remember the personalities of their friends even though these tasks are much harder than reading, adding, or remembering dates in history… Because much of the content of education is not cognitively natural, the process of mastering it may not always be easy or pleasant, notwithstanding the mantra that learning is fun… they are not necessarily motivated in their cognitive faculties to unnatural tasks like formal mathematics.*
> **Pinker, 2002, p. 222**

In summary, a first reason for favoring the encounter between education and the mind–brain sciences is related to the fact that how the human mind–brain works count for deciding *what* can be modified by learning, *how*, and *how difficult* it will be. In this framework, mind and brain studies contribute to education by providing *knowledge* about the different learning *mechanisms, capacities, limits, constraints that are specific to the human mind*, and a *theory* about why certain forms of learning come naturally while others require greater effort and formal settings. It is important to underline that the content of learning matters, as well as age, and it is probable that a mature science of learning will differentiate into several specialized sub–domains.

Extensions to the human mind and to the learning brain

Another field of research that can be expected to further develop and to contribute to education concerns the *study* of various forms of artifacts and technologies —from reading and writing to mathematical symbols, diagrams, and other forms of visual representation, to information and communication technologies— and their impact on the brain, on learning, on education. While technologies are widely present in education, the understanding of their impact requires both empirical studies and a better understanding of the cognitive mechanisms that are solicited and support their use (Hirsh–Pasek et al., 2015). The so–called new wave in cognitive studies dealing with "extended" and "distributed" cognition

—socially distributed cognition, off–loaded cognitive processes (Hollan et al., 2001; Hutchins, 1995; Pasquinelli, Salomon, 1997)— has much to lend to the construction of a theoretical framework for interpreting empirical research. The same is true for the researches that aims at a better understanding of diagrammatic reasoning, and, more generally, at understanding how visual, spatial, and other cognitive, possibly low–level capacities, are exploited and mobilized by the use of visual representations, graphs, videos, with or without interactivity (Giardino, 2015; Kuhl, 2010; Tversky, 2011; Zack et al., 2009). Finally, a promising line of research is constituted by the study of scaffoldings and learning environments in teaching. "Scaffolding" is neither a form of direct instruction, neither a form of discovery instruction, but looks at the kind of helps, hints, simplifications, guides, environments that can help learners deal more efficiently with information, understanding, and memorizing (Paas et al., 2004). Scaffolds can include a variety of strategies, and of technologies, and scaffolds embedded into technological applications. Scaffolds and learning environments can then be inspired by learning principles as those put forward by the Science of Learning field of research (Bransford et al., 2000; Hirsh–Pasek et al., 2015; Sawyer, 2006). Scaffolding and the preparation of learning environments have their biological and evolutionary roots (and possibly their neuro–cognitive underpinnings) in specific aspects of social learning, as studied in human and non–human animals, namely: facilitation or enhancement —local and object enhancement being considered as forms of teaching that have the effect of facilitating learning with or without imitation, and having been described in a variety of species, e.g., some fishes, rats (*Rattus norvegicus*)— and encouragement as described in chimpanzees and gorillas (Brown & Laland, 2003; Galef, 2002; Galef & Laland, 2005; Gariépy et al. 2014; Boesch, 1991; Whiten, 1999, 2008). This leads us to another contribution to education that might be expected from cognitive studies at large: the understanding of the mechanisms that underpin the capacity of learners of learning from others (e.g. imitation), and of teachers of teaching to learners, through a variety of strategies —in addition to facilitation, tolerance of imitation, gestural and verbal aids to imitation, direct explicit teaching through demonstration and/or verbal explanations (Kline, 2014).

The teaching brain

Recently, evolutionary psychology, anthropology, ethnology, developmental psychology, cognitive archeology, and education research have started to glimpse into the teacher's mind (Battro, 2010, 2013; Battro et al., 2013; Chazan, 2012; Kline, 2014; Hewlett et al., 2001; Holper et al., 2013; Kline et al., 2013; Lancy, 2015; Mevorach & Strauss, 2012; Morgan et al. 2015; Rodriguez, 2012; Skerry et al. 2013; Strauss, 2005; Strauss & Ziv, 2012; Strauss, 2014; Strauss et al., 2014). It is advanced by some that humans have special learning abilities that they do not share with their primate cousins —that are possibly the key to their "cognitive" advantage upon other species— and that these abilities are set in social cognition. Contrarily to other primates, humans learn from adults how to deal with tools and complex actions, the aim a tool or an action is meant for. This is because they can understand the intentional aims of other's just like they do with their own intentions (Tomasello, 1999), and because they can imitate with fidelity (Boyd & Richerson, 2005). However, this receptive capacity is not the sole modification of the human brain. On the productive side, humans are uniquely teaching primates who intentionally instruct others so as to fill their knowledge gap (Gergely & Csibra, 2007). They do this universally by displaying a multifarious but limited set of teaching behaviors. They teach what cannot be extracted neither by observation and experience of the environment, nor through emulation or the imitation of behaviors, such as: tool use and production, history, science —that is, culture. So, even if other primates pass information socially, humans are unique in their capacity of passing information culturally. The teaching capacity is naturally wired: it is a natural cognitive function shared by all human beings, with specific skills and interrelated functions.

An alternative view of teaching describes this ability as being shared among several species (thus opposing the species–specificity clause), under different forms, possibly in virtue of different neuro–cognitive underpinnings – teaching with a theory of mind being thus not the only possible form of teaching. Teaching is seen —especially in the domain of animal studies— as a solution that nature has selected for in specific environmental conditions, namely in the service of kin selection and in cooperative breeding animal societies (Caro & Hauser, 1992; Fogarty et al., 2011; Hoppitt, 2008; Thornton & Raihani, 2010).

A promising line of studies that might help filling the gap between the two (apparently) opposed approaches, consists in developing researches that pursue the identification of the *cognitive primitives of teaching, and their neural underpinnings*. That is, to focus on the cognitive processes that make teaching possible (rather than on the visible outcomes of teaching), or on the *precursors* of teaching, and explore the idea that complex cognitive processes —such as teaching— can and should be described at the level of their *building blocks*: fundamental components that can combine differently in different species, that possibly have an ancient evolutionary history, have specific neural underpinnings, and can become the object of cultural training. As with every complex cognitive ability, in fact, teaching must be rooted on neuro–cognitive building blocks that can integrate different mechanisms, be present in different species, eventually with different outcomes, that have an evolutionary history, and can eventually be shaped by culture. These same components can be present without ever producing overt teaching. Furthermore, teaching behaviors might be reached through different evolutionary lines, with the support of different cognitive building blocks (De Waal & Ferrari, 2010). An example of such an endeavor, and of its success, is represented by the primacy research about numeracy has given, during the last two decades, to the identification of cognitive precursors of numerical abilities: pre–symbolic cognitive components of numerical abilities that are common to human babies, non–numerical cultures, and different species (Dehaene 1997).

The understanding of the teacher's mind and brain is moving its first steps, but is certainly one of the most interesting lines of research at the convergence of mind–brain–behavior studies and education. It will help us understanding how to train teachers so as to tap on the natural potential of teaching skills, and to develop these natural capacities into professional skills.

Methods and a view

A further general consideration is related to our capacity of taking good decisions, e.g. in response to the societal transformations that seem to pose problem to education, on the grounds of personal intuition or experiential wisdom. The so–called "information revolution" has changed in many ways the way we work, do research, communicate; it opens new opportunities for creation (the creation of information objects, or programming) but also for learning and education (new potential tools for education: computer simulations, e–learning); some consider that the transformation of the industrial society and economy into the knowledge society requires new forms of education, and new technologies to come in. But how? In the absence of past experience, tradition, and habits some ground is needed to take decisions about how to transform education and how to introduce "new technologies". Education is not a natural science: it is a form of design, possibly grounded on relevant knowledge. We do not study education only for gaining a better understanding about how the peoples of the Earth educate their youth, or about the evolution of social institutions.

> *Everyone designs who devises courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient… The natural sciences are concerned with how things are…. Design, on the other hand, is concerned with how things ought to be, with devising artifacts to attain goals.*
> **Simon, 1969, p. 130**

As anticipated by Thorndike, the study of the mind can contribute with tools for studying the mind at work and the behavioral effects —thus, the efficacy in terms of expected changes— of educational interventions and technologies. These methods can contribute to establish what really works; integrated to the theoretical framework described above, they can help understanding why what works works, therefore foreseeing what might work and fairly test it. But this is not all. The sciences of the mind and brain are also uniquely suited for helping teachers, educators an policy makers in general in the hard task of becoming aware of our limits in decision making and of understanding when and how to trust our intuitions. We've seen that we are wired both for learning and for teaching and we certainly possess a know–how of both that derives from practice. It is important that we come to a better understanding of our natural skills and of the contents of practical knowledge, e.g. knowledge that is gained by teachers through their professional practice. Nonetheless, this is not enough for fostering learning that goes beyond the kind of teaching and learning that happens in nature. The problem is that when it comes to complex situations we are not necessarily very good at using experience, unaided observation and intuition to take good decisions in things that matter: our observations are confounded by many factors, and our reasoning is heavily biased by available information and experience, we are prone to illusions and to the irresistible tendency to confirm our opinions; moreover, our experience limited and the knowledge of experts is soon outdated, even if we tend to overestimate both (Chabris & Simons, 2010; Kahnemann, 2011). Again, the study of human cognition reveals in fact limits of our mind in a way that makes the case for an informed use of science and of rigorous methods for fairly evaluating the outcomes of our actions. In this way, mind–brain–behavior sciences do more than providing contents and tools for grounding better decisions: they put forward a view of education as an applied science, a form of design grounded on natural skills scaffolded and eventually corrected by scientifically produced knowledge.

In summary, the reasons for favoring the encounter between education and the sciences of the mind and brain lays in the very nature of our mind, which makes that policy making really needs science in order to provide solid information for grounding decisions. However, even if the outlined contributions are a sufficient rationale for promoting an applied science of education that integrates the contributions of behavioral, mind, and brain studies, it is well advised to take into account, in advance, the several slippery slopes: potential risks, drawbacks, misunderstandings and errors that hide behind good intentions and enthusiasms. Things can go wrong in many ways. In what follows I will go through some of them.

Risks

We seem to need a good conceptualization of a path going from theory to practice in ecological settings and backward. A crucial step in this path is represented by the production of relevant knowledge and of proofs of effectiveness and causality, that is, proof that a certain intervention —based on sound scientific principles— works and that the positive effects can be reliably attributed to the intervention (and not to other confounding factors). In other words, knowledge produced by cognitive science and neuroscience can be useful for education; e.g. it provides a vision of the mind, of learning, learning processes, timing, reasons for difficulties. Such a vision can help avoiding big mistakes; e.g. thinking that learning algebra is not different from learning to walk. But a vision is not enough for informing programs, and it can also be risky.

Understanding the risks is crucial for favoring a good encounter between the sciences of the mind and education. Risks concern at the same time a. the corpus of knowledge and how it is used, b. the evidence that serves as an empirical basis for proving or disproving the efficacy of interventions, c. the meaningfulness of the contributions of mind–brain–behavioral studies for education, d. the kind of collaboration that is established between science and education.

a. Misuses of the corpus of knowledge

1. In the first place, education might not get the science right —a bad start for the enterprise of providing education with more scientific soundness. The emerging field of neuroeducation —or mind, brain, and education— has been paralleled (and preoccupied) by the spreading of so–called “neuromyths” (Pasquinelli, 2012; Geake, 2008; OECD, 2002). Neuromyths flourish in a climate of neurophilia

—the interest for neuroscience news and discoveries— and are nourished by both inadequate scientific communication and biases of our mind; they are inspired by scientific knowledge, which is oversimplified, misinterpreted, or misused. E.g., the excessive simplification of knowledge about differences between the left and right hemispheres can lead to the myth that one is rather left or right brained (one of the hemispheres is in command and dominates the other) if one is rather logical or creative, rational or emotional, verbal or artistic–minded. But the current myth of a creative and artistic right hemisphere is undermined by cases of a right hemispherectomy that preserves outstanding painting skills (Battro, 2014). Thus, one can try to give prestige to preconceptions about the mind thank to the reference to brain sciences or to the brain tout–court. Scientific results can be misunderstood or overestimated or unduly extended to other domains. In the case of the Mozart effect, one study on adults reporting results at short term on spatial tasks has been used in order to justify a mass of commercial products aimed at babies, fetuses, bananas and sake, pretending that listening some minutes of Mozart music per day would bring about extraordinary effects on intelligence and development (including of good taste). Scientific results can be cherry picked in order to justify decisions, such as the one of giving privilege to early education (before three years of age): only results that cope with the decisions are retained, even if they belong to cognitive capacities that are significantly different from the ones at stake, or if they are old and have been updated meanwhile. Sometimes, "brain based" approaches to education are just based on pseudo–scientific claims that clash with current knowledge in biology and psychology. It is the case of one of the major commercial brain based programs: Brain GymTM, which proposes gym exercises for equilibrating the different parts of the brain, describes brain buttons for pushing the blood towards the brain, and suggests drinking water for keeping the brain hydrated.

2. A second risk connected with the (mis)use of the corpus of knowledge consists in being persuaded by the neuroscientific jargon and by brain images that we have a good explanation for a phenomenon, while all what we have is a description, a localization, or a trivial, circular restatement of the problem. Weisberg (2008) and Weisberg and colleagues (2008), as well as McCabe and Castel (2003) have described this phenomenon as "the seductive allure of neuroscientific images and jargon: in three separated experiments they have shown that the indication of the cerebral location is often (wrongly) taken as an explication of a mental phenomenon; that circular explanations that contain brain jargon are more often positively evaluated as being good explanations, in comparison with circular explanations with no reference to the brain; that this phenomenon is not limited

to naïve readers, but is still present in students in psychology (but not in experts, such as researchers and teachers in the neurosciences); that morphological images of brain activation make a text more convincing than diagrams of brain activation or no image at all. The "seductive allure" is not necessarily bound to the brain hype, and can be a concern for other sciences as well; we know that longer explanations have a persuasive effect independently from their content, too. Nonetheless, these considerations evoke ethical concerns that should be actively addressed each time sciences and society interact.

3. A third risk is represented by wrongly taking scientific knowledge as prescriptive. In the domain of epistemology this mistake has a name: the "normative fallacy". Let us help us with an example. It is possible that boys and girls (and maybe mostly the latter) learn better when they are separated in gender classes. It appeared to be so following a study published in 2010 by Sullivan, Joshi, Leonard; it does not appear to be so no more in 2011, according to a literature analysis conducted by Halpern and colleagues. This kind of sudden turn deserves further attention, but is not the topic of the normative fallacy, which consists in believing that science can take decisions at our place. While science can inform choices about the design of interventions once the goals of interventions have been established, science cannot tell policy makers that school should adopt gender classes. In fact, this kind of choice is submitted to other values and goals than good grades, such as: having girls and boys growing friendship at school and learning to collaborate together, etc. In the same way, the discovery that the mind has innate features and that different people can have different structures does not justify discrimination. But science is purely descriptive: it does not justify separating or discriminating sexes, it does not take decisions about what to value and the contents of education. In other words, knowledge about the human mind can inform the design of educational actions, without prescribing any choice.

> *Nature does not dictate what we should accept or how we should live our lives.*
> **Pinker 1997, p. 52**

At the same time, the practical objective of making education better should not make researchers blind in respect to how nature really is and tempt us to promote views of the human mind because they fit with a certain view of education (how should nature be so that education can be better). A secondary risk of taking science as prescriptive is in fact to mute science when it reveals things about nature that we would not like to put in the political agenda; e.g. one who believes that men and women should be given equal opportunities, might be tempted to mute science when it reveals fundamental differences between the sexes, their biology and brain. We can name this mistake the "moralistic fallacy" (Pinker 1997).

4. Thinking that theoretical knowledge about the mind and brain is straightforwardly and immediately relevant for education is a form of misuse of scientific knowledge, and an illusion: the illusion of direct transfer. Philosopher John Bruer has expressed a worry relative to what he calls the "neuroscience and education argument" (Bruer 1997). The "neuroscience and education argument" described by Bruer consists in the claim that the development of knowledge in neuroscience can revolutionize the educational practice. According to Bruer the step from neuroscience to education cannot be direct: they are a bridge too far and making this step without a solid bridge can be catastrophic. The bridge is represented by cognitive psychology, which mediates between knowledge at the cellular level and knowledge at the behavioral level. Willingham (2008) makes a strong point on the lack of interest of theoretical research: Not only useful knowledge must be specific and new, so as to really inspire applications and not just attitudes, but it has to provide evidence that it makes a difference (and a positive one) in the classroom. In other words, knowledge is not enough for an applicative domain like education without proofs of causality and proofs of efficacy (Willingham 2008). E.g. what is the outcome, in terms of education, of the discovery that repetition is good for memorizing? One could imagine that given the fact that repetition is good for memorizing, then repetition should become a standard method for learning; however, in the ecological setting of the classroom, repetition might clash with motivation and produce lower involvement, possibly lower performances. By this example I do not mean that studies about memory are not relevant for education, but that a scientific hypothesis, even when duly confirmed, is one step in the direction of an educational application, not a final product. In vitro–studies are preparatory to in–vivo ones that are ideally realized in the classroom, with real learners and teachers, in ecological conditions, and – above all – in relationship with the kind of tasks and learning contents that are aimed at in real learning conditions. Between in–vitro and in–vivo studies, a crucial step is thus represented by a form of pedagogical engineering for designing interventions inspired by science and readily testable in more ecological conditions (Hinton & Fischer, 2008).

b. Bad use of evidence

5. It seems trivial to say that a science of education must be grounded on evidence. However, producing duly controlled evidence is not an easy achievement in

the domain of education: randomization and blindness clash with practical, ecological, and ethical requirements; Hawthorne and Pygmalion effects are a major threat, very difficult to eliminate when teachers with different levels of motivation, different capacities and working conditions are made responsible for the experimentation. Pursuing the gold standard can then be frustrating, and even impoverishing unless we are ready to accept, and duly acknowledge, a certain degree of incertitude. Evidence–based medicine has developed a system for pragmatically dealing with the inevitable existence of different types of evidence: a classification into levels. First comes the gold standard of meta–analyses of randomized, double–blind, controlled tests; last comes "expert opinion without explicit critical appraisal, or based on physiology, bench research or 'first principles'" (OCEBM, 2011).

While the gold standard is recognized as the most reliable, the intermediate levels, and the last level too, are not rejected, though: available evidence is pragmatically used as it is. But those who use it are aware of its level of reliability, and alerted to the flaws of the evidence upon which they are grounding their decisions.

> *What are we to do when the irresistible force of the need to offer clinical advice meets with the immovable object of flawed evidence? All we can do is our best: give the advice, but alert the advisees to the flaws in the evidence on which it is based. The Centre for evidence–based medicine CEBM 'Levels of Evidence' document sets out one approach to systematizing this process for different question types.*
> **OCEBM, 2011**

Empirical pointillism

6. While theoretical knowledge is too general —because its consequences have not been proved in controlled settings— controlled and rigorous evidence can be too narrow —because one cannot anticipate whether the evidence will still hold for different settings. In fact, it is the property of randomized controlled trials (RCT) to create the special conditions in which any other factor but the one which efficacy is being tested are under observational control. This is what warrants the self–validity of RCT and distinguishes them e.g. from longitudinal correlational studies with confounded factors. This property of RCT is very useful: it allows researchers (both in in–vitro and in in–vivo situations) to isolate one variable and identify it as having a causal link with another variable, namely when assessing the value of new treatments (in medicine) and interventions (in

education). Nonetheless, once we try to translate the results of RCTs to ecological conditions, many other variables can impact upon the final result, in addition to the one that has been isolated in controlled conditions. This fact shades a doubt about the capacity of RCT of predicting effectiveness in situations that differ from the original controlled condition, even when RCTs are conducted in in–vivo situations (Cartwright, 2009). Further steps or strategies are then required. One consists in multiplying the variability of the populations that are submitted to the tests, as well as the tests in ecological conditions with different variables. Another consists in having good reasons for thinking that the same results will project elsewhere because there are no major influencing factors that can affect the result or because the conditions are very similar to the ones realized during the test. Whenever these conditions change, the capacity of predictability diminishes. For instance, special respiratory maneuvers are presumably effective in a wide range of cases, because the human body has a predictable structure and no other major factors can influence the efficacy of these maneuvers; nonetheless, in patients with special anatomical lesions, the effect of the maneuvers become unpredictable (Cartwright, 2011). In order to achieve generalizability and gain predictability power, in–vitro and in–vivo studies must be part of a broader view: a theoretical model that includes a general model of the functioning of the human mind and brain, and more and more detailed models and subsequent hypotheses relative to the specific cognitive functions at stake in the intervention, the nature of the obstacles to learning, the instructional situation and material. Again, theoretical models, knowledge produced in the controlled situation of the laboratory and evidence gathered in ecological settings must all be mobilized together.

The knowledge resulting from fundamental research on mind, brain, behavior conducted in cognitive science laboratories has a further role to play in preparing in–vitro studies —a role that has been anticipated by both James and Thorndike: narrowing the space of the possible tests to be realized in in–vivo conditions. As well described in the domain of translational medicine (Marincola 2004; Mankoff, et al. 2004; Lean, et al., 2008), in–vivo tests are as necessary as they are expensive in terms of costs and time. It is crucial that a rational choice is operated that selects interventions inspired by solid science and consistent, predictive models; but this in not enough. As in the case of translational medicine, the challenge consists in being able to identify the contents of knowledge that can make the object of interventions that have a chance of working better than the ones that exist and of being concretely adopted in education (Wehling, 2010). The teaching of translational medicine is that this capacity can hardly belong to researchers in fundamental science alone, in the absence of knowledge about the needs and ecological conditions of the specific applications at stake, as well as of the social and economic context, namely, of education.

The picture that emerges from these considerations is one in which cognitive scientists are just one link in a chain that goes from "the bench" to "the bedside" and back, and includes researches in domains apparently as far as neuroscience, psychology, evolutionary psychology, social sciences, history, and economics. The "missing link" between research and practice (and back) being represented by a form of design or engineering that can mobilize models and interventions validated by trials at the service of pedagogical engineering.

c. Irrelevant knowledge

7. Since education is not a theoretical science, but an applied one, and since the preoccupation with education is connected to design, knowledge must be useful. There are many ways in which knowledge can be irrelevant for education, even if we get the science right. Too often, "brain based" approaches to education are at best loose citations of scientific facts about the brain, general principles that are invoked in order to justify old adagios or general principles inadequate to inspire educational interventions (at best, they provide us with general vision about the mind and learning). Such principles do not need to be false, but are unusable for narrowing the infinite possibilities of designing applications in the domain of education. The risk is that of doing more harm than good to education, and that of confusing educators and policy makers to the point of convincing them to turn away from science and stick to intuitions, traditions, personal experience.

8. Or knowledge can be too far from the real preoccupations of educators; there's nothing surprising in this: the preoccupations of cognitive scientists doing pure science are not the same as the preoccupations of professionals facing specific concrete problems during their daily practice.

> *Psychologists who study scientific thinking seek answers to questions such as, "What is thinking?" and "How does knowledge develop?" Teachers and educational developers seek answers to questions such as, "How should we teach (a particular aspect of) science?" and "Do some teaching methods work better than others?" The former questions – in pursuit of fundamental understanding of human cognition —are characteristic of basic research in the science laboratory. The latter questions —aiming towards usability*

> *and efficacy— are characteristic of an engineering design, aimed at solving real–world problems.*
> **(Li & Klahr, 2006).**

It would be wrong to ask scientists to produce only knowledge that is useful for some application, but it is fine to ask some of them to collaborate with professionals to the development of applied research fields, such as a research field in cognition and education.

Knowledge can also be produced that is relevant and valid but is never adopted. Several reasons for the lack of adoption of evidence–based interventions have been addressed in the last 20 years in the domain of medicine (ex.: Oxman et al, 1995; Davies & Taylor–Vaisey, 1997; Lenfant, 2003, McCaughey & Bruning, 2010). First, knowledge is not made available, that is, accessible to those it might inspire; second, the internal and external conditions for adoption are not taken into account in the very design and development of research (Dearing, 2006; Dede et al., 2008). Evidence–based medicine has exemplarily addressed the first issue with the creation of the Cochrane international collaboration: 28000 people of 100 different countries preparing and making reviews accessible via a web site, so as to answer specific problems relevant for medical practice by the means of large meta–analyses of data. Similar efforts exist in the domain of education but are not often led at an international level (Slavin, 2002, 2008). They represent a telling example of how much digital technologies can help education, not necessarily in the way that is predominantly portrayed. Translational medicine (defined as the effort to close evidence–practice gaps) has addressed the second issue by dealing with external validity: how much interventions that are shown to be valid in the laboratory or are successfully implemented at one spot, generalize across populations, settings, times, and modes of implementation, (as addressed in the risk of *pointillisme*) —and external conditions for adoption— namely, by taking into account the diversity of the populations, the economical and social factors involved, the history and administrative contexts of the institutions involved, as well as the nature of communication and change. Translational medicine thus purports to integrate RCT trials that are at the core of evidence–based medicine with basic science and social, human, and economical sciences; obesity and diabetes being often cited as exemplary cases of the importance of being aware of social and psychological factors in order to plan preventive and anticipate drop–outs from cures (Fleming et al., 2008). Also, to take into serious account the problem of communication of results and of their diffusion among practitioners —not in the sense of communicating more and more or even better, but in the sense of understanding the social and psychological mechanisms of the resistance to change (Dearing, 2006). Medicine lends a lesson that education should study carefully: it seems necessary to acknowledge that a purely straightforward, logical, rational, top–down process might not lead to adoption because they do not apply to the real conditions of use (Pasquinelli, in preparation). This is why social sciences cannot be forgotten when planning a good encounter between the study of cognition and education. Still, the social context is not the only obstacle; that is, "internal" barriers should be equally evaluated. With "internal barriers" I refer to the very cognitive mechanisms that hinder adoption: a) the difficulties that hinder the transformation of declarative knowledge into procedural forms and the generalization of knowledge from one domain to another (Green & Seifert, 2004; Gick & Holyoak, 1980); b) the effect of heuristics and biases in the understanding of statistics and probabilities, such as on risk perception and decisions related to action (Feufel, et al, 2011; Gaissmaier & Gigerenzer, 2011; Wegwarth & Gigerenzer, 2011; Gigerenzer et al., 2010; Gigerenzer, et al. 2007; Kahnemann, 2011; Kahnemann, et al., 1982); c) the various forms of optimistic illusions and biases that tend to confirm us in our opinions —in particular, but not only: the confirmation bias and the various phenomena described as illusions of knowledge, fluency, understanding— and the evolutionary bases of self–deception (for a quick overview: Simons & Chabris, 2010; Gilovich, Griffin, Kahnemann, 2002; for a discussion of the optimistic illusions in an evolutionary perspective: McKay & Dennett, 2009; Trivers, 2000; Van Veelen & Nowak, 2011; for an overview of the confirmation bias and of the illusion of knowledge: Nickerson, 1988; Rozenblit & Keil, 2002; on intuitions about intuitions: Inbar, Cone & Gilovich, 2010). This is an often ignored form of contribution that research in cognitive science can bring into education, and more generally into translational research: reveal the unconscious mechanisms that are part of understanding and decision–making and thus contribute to the design of evidence–based interventions, teaching and communication tools that help to fill the evidence–practice gap.

d. Disciplinary chauvinism

9. Another risk that threatens recent attempts to build a new research field is disciplinary chauvinism. On the one side, neuroscience risks to be artificially singled out from the family of disciplinary fields that, as a complex, produce new knowledge about how the mind–brain works – neuroscience, cognitive psychology,

behavioral sciences and evolutionary, developmental, social psychology, artificial intelligence… This risk is connected to a major tradition in philosophy of the mind, and to a powerful attractor of our mind: mind–brain dualism.

The "brain revolution" has certainly had among other effects that of reviving the interest of education for the sciences that address the functioning of the mind. However, none of these sciences can be singled out and sent to a privileged encounter with education; at different levels of analysis and granularity, through different tools and methods, they all foster our knowledge of one and the same object: learning and teaching as cognitive abilities. The same need for multidisciplinary cooperation has been called for as a sine qua non for the success of the venture of understanding memory —a crucial function for learning and education. (Dudai, Roediger III, Tulving, 2003).

> *A new science of memory is being shaped in front of our very eyes. It rises on the shoulders of giants: psychology, neurobiology and brain research, computational science, philosophy. Each of these parental disciplines contributes a distinctive vocabulary of terms and acronyms, all embedded to some degree or another in zeitgeists and conceptual frameworks. For the practitioners of the science of memory to be able properly to exploit, and benefit from, the rich multi–disciplinarity of methods and findings, they must understand the language and modus operandi of their colleagues in other sub–disciplines. Such understanding is a sine qua non of the success of the venture.*
> **Dudai, Roediger III, Tulving, 2003, p. 1**

However, the new science of education presents a specificity: the giants on which shoulders it rises are not limited to the family of the sciences of mind, brain, and cognition, but encompass pedagogical research, as well as the history, sociology and economy of education, as well as research on didactics.

10. Disciplinary chauvinism can take another aspect: thinking that the new research field could be a one–way road from the cognitive research to education. For many of the reasons listed above, this isn't so. Education provides an ideal setting for in–vivo studies for integrating and completing the corpus of knowledge that the sciences of the mind–brain–behavior traditionally produce in in–vitro settings. For example, the study of scientific thinking in in–vitro conditions has revealed the existence of number of resistances and reasoning biases; however these findings can be objected on the ground that cognitive experiments are

conduced with novice subjects, that have no domain knowledge, and that experts might not be prone to the same mistakes. The combination of in–vitro, controlled experiments with in–vivo, ecological observations and experimental research can help reveal the processes that are at stake while learning new scientific concepts, or while teaching them, thus providing insights into scientific thinking itself. It also helps to reach external validity for the results of experimental research and ecological relevance for education —without giving up the possibility of singling out influent (?) variables in controlled experiments or the opportunity of generating powerful predictive models.

> *A key feature of the in vivo/in vitro method is that we can investigate a question in a naturalistic situation and then go back into the psychological laboratory and conduct controlled experiments on what has been identified in the naturalistic settings. … Thus, by using the in vivo approach it is possible to increase the likelihood that important real–world cognitive phenomena are investigated.*
> **Dunbar, 2001, p. 118**

But this is not the end of the story. How the mind works in the framework of education is a source of observations and of topics for future research in cognitive science laboratories. In fact, education reveals constraints to learning and limits of cognition, skills, and attitudes that do not show equally well in laboratory research. This is the case when it comes to the difficulties that educators have pointed to in teaching science —the so–called domain of conceptual change and preconceptions. These have inspired research in developmental psychology as well as in cognitive neuroscience, searching for the effects of previously acquired or innate knowledge on further acquisitions and on the brain (Petitto & Dunbar, 2004).

We have then to recognize that the encounter between education and mind–brain–behavior sciences does not profit education exclusively, but mutually. It is possible that this same encounter could help solve the first type of disciplinary chauvinism by pushing the sciences of the mind, brain, and behavior to find a new and truly multi–disciplinary configuration.

Conclusions

Mind–brain–behavior studies add to the practical knowledge that educators have accumulated in millennia a deep, scientific understanding of learning processes

—unavailable to James, Thorndike and Watson. Developments in the cognitive neurosciences of learning have definitively disproved the image of the infant mind as a blank slate: how the brain is wired —because of past experience or evolution— counts for further acquisitions and the limits of the human brain constrain what comes naturally to the human mind, and what does not, thus making the case for education but also for the contribution of mind–brain–behavioral studies to education itself. The same considerations apply to teaching considered as a natural capacity.

No matter how desirable, the marriage between science and education still raises objections, and misplaced hopes and fears. We should avoid to feed them, for example by being fully aware of the risks of such an enterprise: those related to getting the science wrong, but also of misusing scientific knowledge or of producing knowledge that is not meaningful for the problems faced by education.

Cautionary notes should not overcome the objective —and the possibility— of forging a new way of thinking about education. It is thus useful to summarize what has appeared above —that is, that behavioral, mind and brain studies can supply education with different types of contributions: a) a corpus of knowledge about learning processes, mechanisms, constraints, and related cognitive functions; b) models for interpreting the evidence, anticipating what *might work*; c) methods for verifying whether it is the case; d) a study of the biases and mechanisms that restrain or rather favor the adoption of innovations; finally, e) that from these sciences emerges a vision of education as neither filling–in a blank slate nor letting innate capacities flourish.

These contributions graft at different levels on the process of education: some have an impact on decision–making, others on educational research, and finally on educational practice. This means that in order to favor a good marriage between the sciences of cognition and education one should put in place different strategies each encompassing different, complementary objectives.

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SECTION 1

Acknowledgments and Souvenirs

The first decade of the International School on Mind, Brain and Education at the Ettore Majorana Foundation and Centre for Scientific Culture, Erice-Sicily

Kurt W. Fischer

My dear friend and colleague Antonio Battro and I created the Erice School to encourage discussion in different areas of research related to the emerging interdisciplinary field of mind, brain and education. He is right to celebrate that when science and friendship come together, as they have in Erice, the confluence often enables rich and rare conversations and collaborations. We intentionally designed the conference to include both senior and junior researchers from neuroscience, education, cognitive science, psychology, philosophy, and related fields. We have been gratified to find so many colleagues who were generally happy to see themselves as participants in the establishment of the new discipline of mind, brain and education. Some were already affiliated with one of the new centers for work in this field in the U.S. at HGSE, at Dartmouth College, at USC, at U. of Texas, or in the U.K. at Oxford University. However, the international representation of scholars at this meeting in Sicily each year was a hallmark of the work. Hoping that none were left out in my accounting, my review of the school's records across this decade indicates we have had participants from twenty–four countries representing five continents, with the strongest showing from the U.S. and Europe, but equal involvement of many scholars from Asia and the Middle East, North and South America, along with one colleague who joined us from South Africa.

In Erice, I particularly enjoyed the success we found in bringing so many diverse voices to engage in this meeting of minds. This success is in large part due to the efforts of many fruitful partners in the convening of scholars, among whom Hideaki Koizumi continues as most essential to Antonio and I. In fact, given Hideaki's participation in all ten of the decade's Schools, and the participation of at least thirty Japanese scholars across the years, we may justly attribute to him an equal partnership in the school's organization and hosting responsibilities. In addition, we are grateful for the partnership with prominent colleagues who contributed over multiple years by bringing their own work and in nominating junior scholars to present, particularly Usha Goswami, Paul Van Geert, Daniel Cardinali, Pierre Lena, Wei Yu, Candelaria Ramírez, Fernando Vidal, Sidney Strauss, Susan Magsamen, Bruno Della Chiesa, and Franz Riffert. We also want to extend our special thanks to our program officer across the decade, our Lula, (María Lourdes Majdalani) for her tireless efforts in maintaining good order among the communication and organizational details required to ensure the program's success.

My own journey at the start of the field of mind, brain and education began with a basic insight that the form of growth curves in development was key to figuring out what kind of changes were occurring in the functioning of the brain. Since those early years I have been highly gratified and stimulated to see all the directions that others have carried this work linking learning and the brain. The exchanges at Erice established a general referent, to help all of us in creating more productive representations of interdisciplinary work.

The variety in fruitful outgrowths from the first decade of the Erice discussions has been fulfilling for me personally, but has also contributed to the development of the field in multiple ways, including by enhancing the quality and scope of papers submitted to the new Mind, Brain and Education journal. In Erice, we had the opportunity to explore a wide range of topics, from the implications of brain research for teaching, educator preparation, and our understanding of personal identity, to ethical issues at the intersection of neurosciences and education, and how the brain and learning are affected by diurnal patterns of night and day.

The journal's founding in 2007 corresponded with the second year of the School's convening., The overlapping interactions between friends and scholars involved in both ventures, along with increasing participation in the international association (IMBES), have proven mutually beneficial to each pillar in the growing edifice of the new discipline. At least of a third of the journal's editorial advisory board were in Erice one or more years for the MBE School. In addition, the number of direct correlations between topics of discussion and papers which were first presented at the annual MBE School, and later published in the journal, is a testament to the richness of these exchanges. The journal presented issues focused on the topics of biological or circadian rhythms (Volume 2(1), on ethics in neuroscience(Vol 4,issues 2 and 3) , and the neuroscience of learning and the arts (Vol 5(1), all topics which were featured first at the MBE School in Erice (in 2007, 2009, and 2010, respectively). Likewise, there are topics from the journal which appeared later at the MBE School in Italy, such as Mary Anne Wolf's focus on connecting neuroscience with the classroom, seen in the journal (Volume 3(2), in 2009, and then in Erice in 2012, and the concept of the teaching brain, introduced by Antonio in the journal (Volume 4(1)) in 2010, and then recurring as a theme in Erice in 2015.

On this mountain overlooking the Mediterranean, the confluence of scholars, and sharing of ideas among previously unacquainted fields of study, in the unique medieval and ancient city was a winning recipe. Holding our annual meetings in Erice fostered this dialogue in a setting which complemented the uniqueness of our endeavor. The rooms at the Ettore Majorana Centre, the unforgettable view to the mountains and the shore of the Mediterrean from the balcony room in the Paul A.M. Dirac Lecture Hall, and all the beauty of Erice's courtyards, medieval streets, and ancient monastery buildings provide what we agree is an appropriate setting for "high intellectual endeavor", as the Centre's website claims.

As Antonio points out in his essay in this volume, the strength of this School derives from the foundation of friendship which enhanced the networking and invitations to junior scholars, from dialogue among senior MBE researchers, and from the diversity of participants and of core topics addressed. This book celebrates the first decade of the Erice School; however, it is my hope that Antonio, Hideaki, and others to come will maintain this worthwhile endeavor in decades to come.

A school with a view

John Higgins

Rock–ribbed Mount Cofano, like an ancient stone hand–ax planted in the Tyrrhenian Sea, looms in my memories of Erice.

The afternoon I arrived in Sicily for the Eighth International School on Mind, Brain and Education, Antonio Battro delighted in showing me around. We climbed the path through the park toward the Norman Castle, turned a corner and suddenly Cofano appeared in the distance, rinsed in the warm afternoon light.

The view was more spectacular at dawn, even when it vanished one morning behind the sea mists that raced up the flanks of Mount Erice and rolled over the castle's walls.

But it's the view of the sunbaked Cofano massif framed by the open fourth wall of the upper room at San Domenico I'll remember most. It was here that Antonio and Kurt Fischer formally announced a new line of inquiry within the field of Mind, Brain and Education: the scientific study of teaching itself.

As a journalist and the only non–scientist among some of the leading scholars in the field, it was thrilling to witness what felt like the launch of an exciting venture into one of the fundamental mysteries of humanity: what is teaching precisely and how does it work on the developing brain?

I am grateful to reflect now, two years later, on how the Mind, Brain and Education summer school contributed to my ongoing effort to synthesize research from a variety of fields to tell the story of teaching to a broad audience.

It's a story I've been researching since reading Antonio Battro's provocative 2010 article "The Teaching Brain" in Mind, Brain and Education —a quest that led me to Cambridge in 2012 for the Knight Science Journalism Fellowship at MIT.

My timing couldn't have been better. Vanessa Rodriguez, a dynamic former middle school teacher in the MBE program at Harvard, edited a series of articles that year about the teaching brain from a variety of perspectives.

I initially cast a wide net for research on teaching in humans, other animals and machines. I was surprised to find so many people thinking about this basic question on so many levels: from animal teachers and the teaching potential of early stone–tool makers to five–year–old–teachers and teachable computer agents such as "Betty's Brain" that turn learners into teachers.

Our Erice summer school focused on advances in the teaching of science in the computer age when many of the interactions between teachers and students leave a digital trace, providing researchers unique data sets and research opportunities.

These laboratories can be as vast as an entire country, as Magela Fuzatti explained in her presentation on Uruguay's Plan Ceibal. They can provide alternative worlds where students —and teachers and researchers— can explore cause–and–effect relationships and reasoning, as described in Tina Grotzer's presentation on virtual, immersive ecosystems. Or they can be portals within a museum that enable exploration of something as complex as the tree of life with a multi–touch tabletop, as Chia Chen explained in her presentation on the Life on Earth Project.

While I enjoyed all the presentations and formal discussions, I especially valued the informal conversations over a fine Sicilian meal or on the day trips to the nearby ruins and beaches. As a journalist, I mostly listened, but I appreciated the opportunity to think out loud about subjects far outside the usual scope of typical newspaper journalism.

These conversations gave me confidence that this emerging field is more than merely an academic curiosity or worse, another educational fad long on hype but short on evidence. For just those reasons, caution is warranted – often it is the media that races ahead of the science in its search for easy answers to the unprecedented challenge of educating all of the world's children.

Skepticism shouldn't lead to paralysis waiting for all questions to be resolved, however. A science of teaching is emerging with many more questions than answers. But we will never reach the goal of universal literacy and mathematical fluency without the basic research that has informed every other complex undertaking in the modern world from medicine to energy to the Internet.

My fellowship year away from the deadlines and demands of daily newspapers concluded with the Erice summer school, where I was invited to share my perspective as a journalist learning to tell the story of human teaching —a story much deeper and broader than the typical discourse on education policy.

After Erice, I was hired by the Seattle Times to contribute to a grant–funded project called Education Lab, which applies the rigor of traditional watchdog journalism in deeply reported stories about promising practices backed by research and a track record of success.

My most recent stories have explored the science behind teacher–student interactions measured by the Classroom Assessment Scoring System developed by Robert Pianta and colleagues at the University of Virginia and the RULER approach to social and emotional learning developed by Marc Brackett and colleagues at Yale University.

I've also written about important work at the University of Washington, including brain imaging research on reading and writing disabilities by Virginia Berninger and Todd Richards and groundbreaking studies on infant and toddler brain development by Patricia Kuhl and Andrew Meltzoff. I was even able to interview Vanessa Rodriguez for a short piece about her new book, *The Teaching Brain*.

I'm fortunate that much of my newspaper work also serves the interests of my book, though the demands of the job leave less time for the bigger project than I would prefer.

Still, whenever I reflect on my brief time in Erice, I renew my confidence that I am witnessing the emergence of a science of teaching, a story that I am eager to tell.

Erice and the sciences

Pierre Léna

Learning Latin at school as a child, I was reading pieces of the Aeneid. The story of the old Anchises being carried on the shoulders of Aeneas, in the midst of the devastation of Troy, left on me a profound impression. Here was an admirable example of filial behavior!

I would never have thought that, many years later, I would go to the *vicina astris Erycino in vertice sedes*, where over three thousand years ago the body of Anchises had been buried. This magnificent mountain, facing Africa at the western tip of Sicily, remained unknown to me until 1977, where a remarkable meeting gathered there the astrophysicists joyfully embarked in the discovery of a new sky, the infrared sky —my main job at the time.

It would be nearly three decades for me to come again to Erice. I was then devoting some of my time to *La main à la pâte*, created by Georges Charpak in Paris to change science education in primary schools, and had met Antonino Zichichi at the Pontifical Academy of Sciences in the Vatican, at the occasion of a Workshop on this subject. He showed much enthusiasm and invited me to hold a meeting in Erice. So did I in 2005, with a handful of scientists and teachers willing to disseminate, as grains of pollen, our engagement for children: this was my return to the beauty of the streets, the flowers, the land and seascape of Erice.

Such a return could not be the last one. The next miracle was the will of Antonio Battro, a great supporter of *La main à la pâte* who became a real friend, to organize a yearly session on Mind, Brain and Education (MBE). Eminent scholars were mastering this subject, of which I was totally ignorant. But, after all, it was science, and science can always be learned. In addition, we were all interested to understand better what happens when a child learns. And Erice offered superb learning occasions with people such as Bruno Della Chiesa, Hideaki Koizumi, Kurt Fischer, Wei Yu, Maryanne Wolf, so many others… and naturally Antonio. I attended two MBE sessions (2008 and 2012), but several of my colleagues, generously welcomed, did come in 2011 and 2013.

It is difficult to say exactly how Erice meetings impacted our strategy and actions in science education. For sure, their spirit penetrated us. And I can outline two wonderful consequences: our young colleague Elena Pasquinelli (MBE, Erice, 2012) published in 2014 a remarkable book, for the moment in French, showing how cognitive understanding can help the teachers embarked in science education. I am sure this book, and the ideas it contains, have a great future.

The second consequence is really a hope of mine. Ten years of MBE Erice School demonstrate for me the value of a regular meeting, gathering the best thinkers worldwide on a given subject, in a place where beauty and good wines provide a natural creativity! Hence, after International Schools in physics, cosmology, chemistry, and so many other topics, I hope we shall be able to accept the proposal of Antonino Zichichi, in order to establish an International School of Science Education. Why not dedicate this school to Ascanius, the son of Aeneas?

My path in studying "how the brain learns and how it fails to learn"

Maki S. Koyama

It was 2005 that I first attended the International School on Mind, Brain and Education (MBE) at the Ettore Majorana Foundation and Centre for Scientific Culture in Erice. At that time, I was a PhD student at the University of Oxford in UK, and Dr. Koizumi (Hitachi Ltd, Japan) invited me to the meeting. My PhD work delineated differences in behavioral and brain–based mechanisms of word reading ability across different scripts (e.g., Japanese logographic and phonographic words, English alphabetic words). At the meting, I presented a poster, showing some preliminary findings from my first PhD work: I highlighted that different sensory and cognitive skills were associated with reading development in logographic Kanji and syllabic Kana words, which share the sounds and meanings but are dramatically different in the visual forms (e.g., long–term visual memory makes stronger contributions to learning logographic Kanji symbols that are visually complex, relative to learning syllabic Kana symbols). The educational implication from this finding is that a child's reading problem and remediation strategies for reading should be considered in the context of the script in which he/she is learning to read. This poster was my first public presentation in my academic career, and I won the MBE poster award, which enormously encouraged and motivated me to pursue neuroscientific research on reading disabilities (i.e., dyslexia).

I was again invited to the meeting in Erice in 2008, just before I started my first postdoc fellowship at New York University (NYU) Child Study Center. The topic of the meeting in 2008 was "Basic and applied topics in biological rhythms and learning", and I gave a talk about one of my PhD studies regarding second language (L2) reading. My research question addressed potential differences in the brain activity during word reading in L2, by comparing two groups of L2 leaners, whose first language (L1) had different levels of letter–sound relationship. Using functional magnetic resonance imaging (fMRI), my study revealed that reading English as L2 induced stronger activation in brain regions involved for phonological processing in Japanese adults, relative to reading English as L1 in English adults. This finding indicates the increased cognitive loads associated with the greater phonological demands for reading L2 English that has an irregular letter–sound relationship, relative to reading L1 Japanese Kana that has an extremely regular relationship. The educational implication from this finding is that existing phonological training for English dyslexia has great potential to improve English reading in L2 learners. Overall, the attendance of the 2008 MBE School helped me to shape my research interest in language–based learning disabilities, just before I started my first postdoctoral training.

In 2011, I was again invited to the meeting, which focused on "Education in the Digital Era". One focus of this meeting was the possibility of interventions using digital tools for children with learning disabilities. For example, I learned the ongoing "One Laptop per Child" initiative in South American countries, which can potentially transform the education system there. The experience in attending this meeting allowed me to broaden my perspectives about education and neuroscience, expanding my research interest into exploring the value of digital tools in improving children's academic performance. At this meeting, I gave a talk about the preliminary results from my dyslexia study. I applied task–free resting–state fMRI (R–fMRI) to children with dyslexia, showing aberrant intrinsic functional connectivity patterns associated with dyslexia and behavioral remediation (i.e., improved reading skills) in children with dyslexia. One of my finding highlights persistent atypicality in the functional connectivity within the attention network in children with a history of dyslexia, even in those whose reading problems were remediated via phonology–based or multisensory–based training. This finding, together with the knowledge that I gained from the meeting, emphasizes the importance of research to investigate effects of attention–based remediation strategies, as well as those of the use of digital tools that assist children in learning, on reading performance in struggling readers.

I am currently working as a research scientist, using multiple neuroimaging techniques, such as fMRI and electroencephalography (EEG), at the Child Mind Institute, a non–profitable organization devoted to children with psychiatric disorders and their families. I investigate how the brain learns (e.g., to read, to calculate), and more importantly, how the brain fails to learn. My overarching research goal is to improve the identification of early behavioral and brain–based markers to predict risks and prognosis of learning disabilities and psychiatric disorders. I have been grateful that the MBE School inspired my passion for research and increased my motivation to attempt to narrow remaining gaps between neuroscience and education. After reflecting on all my experiences in Erice, I truly hope to contribute my research to improving children's physical and emotional health, as well as their educational prospects.

The power of the Arts

Susan Magsamen

I think back to the arts and learning convening held in Erice with great fondness. The opportunity for such rich and deep immersion in to the arts, creativity, curiosity and learning from research to practice came together in a beautiful alchemy, creating something that didn't exist before and forging my belief in the arts as a way to live, teach and grow.

Since our meeting I have founded an arts integrated evidence based company called Curiosityville for young children 3–8 years old. Last year I sold this project to Houghton Mifflin Harcourt. It has been an extraordinary year. Curiosityville is now firmly imbedded as an integral part of HMH Early Learning. We are working to providing Curiosityville to young children, families, educators and the community. Most importantly I am learning how to scale arts integrated products around the world.

As I reflect on the past year what profoundly stands out is how Curiosityville embodies the essence of creativity and innovation. Curiosityville has a strong clear voice forged from powerful creative problem solving in its development. This voice was born out of the arts and playful learning. From the time I could remember I was always drawing, dancing, writing poetry and singing (badly but singing)! I believe that everyone involved in the creative development of Curiosityville also forged their skills through the arts —as a participant or a patron. The arts help develop our ability to share our feelings and thoughts and our capacity to receive information and ideas from others. In part, this is what makes us human and what builds an insightful person, family, community, nation and world.

The riot and unrest in Baltimore over the last month have brought the critical role of the arts in to focus even more for me. JHU's Bloomberg School of Public Health held an Engage Baltimore event that included a number of city school students sharing their voices through dance, music and slam poetry. I was so moved by the expression of pain, hope, joy and potential in every single piece and I don't think I could have deeply understood this complex feeling through any other medium.

Here is the link to the event: www.youtube.com/watch?v=YvE1WeZTTCo. Please take a moment and scroll to The Dream Piece by Martina Lynch at 18:10 minutes in the video. It is simply amazing!

The dynamic and visionary work that was discussed in Erice continues to help me define and grow my work and I am eternally grateful.

A blessing from above

María Lourdes Majdalani

The car that took me to Erice late one night in July arrived up to one point where it could not continue. “Now you must walk Miss”, said the driver. I was so tired I could hardly concentrate on the irregular cobblestones I was stepping on. The next morning I woke up in one of the most beautiful places I have ever known.

It all began in Harvard Graduate School of Education, in 2002, when destiny gifted me, a simple Graduate student, with the best mentor ever: Antonio Battro, an Argentinian, as myself, who had come a long way in Science and Education. I knew his name because I used to read his articles on the newspaper. I still remember I told a friend of mine that one day I would get to know him better. Well, that day finally arrived, and Antonio was very surprised to hear I had come all the way from Argentina!

Once back in our country, Antonio asked me to be his Program Officer for the new school he was founding together with Kurt Fischer: the International Mind, Brain and Education School. I was very happy to accept the challenge. But I could never imagine that I would be the School´s Program Officer for the following ten years: a real privilege!

I am the responsible of every detail concerning the School: arranging the Program, organizing the web page of each year, supervising the accommodation in Erice, giving suggestions on trip, clothing, etc. Once there, we usually have a welcome dinner where participants present themselves. And something participants never forget: our trip to the historical places of Segesta and Selinunte. Each meeting is special in a different way, thanks to the heterogeneity of our participants that come from all over the world. I have learned a lot from each one of them.

I remember one moment in which Daniel Cardinali, one of our participants and once the organizer of one of the Schools dedicated to Chronoeducation, devoted a whole conversation on my doctoral thesis together with Antonio Battro. We were watching the magnificent view and they both offered so good advice on how I had to proceed with the matter that they clearly made a difference in my career.

I also had the chance of presenting my own research on moral education more than once. It was really challenging to interact with the School´s participants who proposed new ways of addressing moral education in schools and homes. I remember Bruno della Chiesa´s feedback who, after carefully listening to my work, proposed the theme of the following School to be held in 2009: *Educational Neurosciences and Ethics*. During 2011's School, *Education in the Digital Era*, I had the chance to present the Moral Development on–line Course for Teachers (MODE).

I am so grateful to my dear mentor and friend, Antonio Battro, for the possibility he gave me of being his Program Officer in our Mind, Brain and Education School. Ten years have already gone by, and I still feel each new School as a blessing. During these years I have learnt so much from the people who have been a part of it: Fiorella, our Secretary at the Ettore Majorana Foundation and Centre for Scientific Culture, Alessandro and Pino, offering their help there as well, Giovanni, Domenico, Francesco at San Rocco Café… and all the participants with whom we shared so many precious chats and meals in one of the most marveling surroundings of the Mediterranean Sea, Erice.

Coding for a Better Life

Cecilia Rodríguez Alcalá

I feel a thrill when I have an impact on other people's lives. Success is no longer tied to my personal story, it is more closely related to the story of my country. As of 2015, Paraguay has a population of 6.8 million with about 28.5% below the age of 15 and 65.4% between the ages of 15–65. Paraguay's digital divide and lack of educational opportunities are a contributing factor to its high poverty levels: 35% of the population lives below the poverty line.[1] Moreover, according to the Global Competitiveness Report of the World Economic Forum, Paraguay is ranked 140 out of 144 in terms of education quality.[2]

In this context, we created Paraguay Educa, a non–profit organization founded by a group of entrepreneurs who had the vision of promoting a creative and knowledge based society by transforming the education of Paraguay's majority youth population. As a technology–based knowledge center, Paraguay Educa is dedicated to educational and social inclusion programs through ICT innovation and community development.

> *"In a world where digital fluency is a competitive advantage, we believe that children provided with quality education and technology will become active citizens for change. Our* ***mission*** *is to become an excellence center for education and innovation centered on digital fluency and social inclusion. Our* ***vision*** *is that every child in Paraguay develops life skills and digital competences."*[3]

The organization's initial strategy consisted of establishing public–private partnerships to create Paraguay's first digital city in the country through the One

1. www.usaid.gov/frontiers/2014/publication/section-1-paraguays-poverty-spotlight-focusing-women-and-markets-innovation

2. reports.weforum.org/global-competitiveness-report-2014-2015/economies/#economy=PRY

3. Paraguay Educa, www.paraguayeduca.org

Laptop Per Child (www.laptop.org) program and based on the results, influence policy makers to expand the experience nationwide to 900,000 children in elementary schools. The objective of this pilot experience was to demonstrate that providing children with technology based learning platforms would allow them to develop life skills and become global citizens ready to face the interconnected challenges of the 21st century.

After seven years of work, Paraguay Educa has turned into one of the most influential NGOs in the country. We were able to create the first Digital City in Caacupé, providing laptops, connectivity and training to 10,000 impoverished children and teachers. Caacupé was selected due to its high migration rate and poverty levels: 60% of children have at least one parent living abroad and three out of five children are street workers. After four years and a USD 4.5 million investment, three external evaluations demonstrate that the OLPC program engages students in a "learning by constructing" collaborative platform resulting in creativity, critical thinking, collaboration and active citizenship skills while reducing dropout rates by 30% annually.

Paraguay Educa bases its educational paradigm on the “constructionist” theory of Seymour Papert and other “constructivists” inspired by Jean Piaget. Paraguay Educa has coined the term ICKDT Information, Communication, and Knowledge Development Technologies (from the Spanish acronym 'TICCC') because it firmly believes that computers in education are not just a means to store and transfer information, but rather are tools to develop capabilities in a new virtual space. Thus, “learning to learn” is the educational approach we use for student’s cognitive and creative development.

Furthermore, children become agents of change by involving their families in extracurricular activities oriented towards providing solutions to community problems and promoting participation in democratic processes. Children are working inside and outside of the classroom setting, teaching their parents how to use the internet, creating animations, sending pictures to their family members abroad, fixing their own hardware problems and programming their interests into the learning software Sugar (www.sugarlabs.org). This list becomes endless when you visit Caacupé where the creativity gap no longer exists.

Teachers are also catalyzing change in their communities, donating their vacations for training and teaching not only their classrooms but also the parents, aunts, uncles, grandparents and neighbors that want to become part of the newly formed digital society. Parents are also engaged in this virtuous cycle: they have formed working groups to remodel schools, establish electrical outlets in classrooms, build tables and chairs among other related initiatives.

In 2011, I had the privilege of participating in the Sixth International Conference organized by the School On Mind, Brain and Education in 2011 at Erice to speak about my work in Paraguay Educa. The theme, "Education in the Digital Era", introduced powerful ideas about computational thinking in the digital environment and the many possibilities that opened in this new ecosystem ranging from social inclusion to new opportunities for children with disabilities. I thank Antonio Battro for the invitation and coordination of an unforgettable event in one of the most beautiful places I have ever experienced inspired by conversations with visionary experts from all over the world.

More recently, I contributed to the design of Paraguay Educa´s Centro Tecnológico Serranía (CTS) in Caacupé, created in 2014 to promote research, innovation, education and knowledge transfer activities. Through CTS, Paraguay Educa's aim is to become a world leader in the generation of pedagogical models and community–based strategies for the adequate implementation of technology in underprivileged populations. The courses offered at CTS promote critical thinking and inquiry–based learning and the teachers provide ongoing support to the participants and the community.

CTS directly addresses the issue of a community thirsty for knowledge and access to the digital world. Adults, having seen their children grow and connect with the rest of the world through the OLPC program, also want to gain the skills necessary to understand and thrive in the globalized world we live in today. In this context, CTS gathers community members, from teachers and directors of local schools to parents and students of all ages, to come to the center not only to learn valuable technological and 21st century skills, but also to work together to use these new skills for the benefit of their community. Community action and empowerment are at the center of every class.

CTS incorporates the Samsung Smart School solution, which allows community members to learn using technology in fun, creative and interactive ways4. CTS provides courses in a diverse variety of fields, from Financial Literacy to

4. www.samsung.com/es/business/solutions-services/mobile-solutions/education/samsung-school

Programming to Graphic and Web Design, among many others. The interactive learning environment, together with global collaboration available through the technology used at the center, allow for increased student engagement and performance. In 2014, CTS beneficiaries totaled 800, whereas in the first semester of 2015 CTS has already benefited 700 participants

Currently, Paraguay Educa´s strategy consists of not only on site work in Caacupé but also transferring knowledge for the deployment of other IT learning initiatives at a national level working alongside the Ministry of Education. Through public awareness and lobby efforts to include the Presidency, Ministry of Education, Congressmen and key opinion leaders in a country–wide education crusade, Paraguay Educa helped design a National ICT Master Plan for technology platforms at all levels of society (e–government, e–commerce, and e–citizenship, among other public services). In order to fund the ICT National Plan, Paraguay Educa articulated alliances with other NGOs in a media campaign to assign Itaipu's (Paraguay's national hydroelectric) energy revenues to a ten–year trust fund promoting education investments and research and development initiatives through the FONACIDE law. Consequently, from 2012–2023, Congress will assign an additional annual fund of 180 million dollars as part of the most important education bill in the history of the country, where 40% of the resources are destined to develop technology based learning solutions.

A quixotic path lies ahead for Paraguay. I now realize that while I was trying to give back to Paraguay, I found my true passion: "If you want truly to understand something, try to change it." (Kurt Lewin).

Erice and The Ross School

Courtney Sale Ross

Ross Institute has partnered with MBE since its nascent stages and applauds its success at every milestone. We have worked closely with leaders in the MBE group, even inviting several as scholars-in-residence or visiting scholars at our laboratory Ross School, to advance the research benefiting educators and diverse learners worldwide. Erice 2005 stands out for both its idyllic setting and its inaugural convening of world-class scholars focusing their academic talent on educational matters. I recall fondly the first conference as being a tremendous moment of triumph for the organization. I am pleased that the roots firmly planted a decade ago continue to flourish by inspiring new research and application. Ross Institute remains committed to MBE and desires its ongoing success and our mutual interaction for decades to come.

SECTION 2

Personhood and Brainhood

A circle of brilliant minds: Reflections on Erice

Michael Chazan

At Erice I faced not a wall of blank staring eyes but a circle of alert faces and brilliant minds. When I learned that at the end of each session at Erice we would be asked to sit in a circle to engage in discussion I will admit that I was a bit skeptical that this would amount to very much, but soon found myself enmeshed in lively discussion, and if matters ever flagged then Yadin Dudai was ready to goad participants into a reaction!

Figure 1: The blank stares of mounted trophies including springbok and gemsbok, and a wild cat from the farm where I stay during my fieldwork in South Africa and where I began this article, a far cry from the circle of attentive minds I encountered at Erice.

That the experience at Erice was stimulating and enjoyable goes without saying but it is more difficult to arrive at a clear sense of how our discussions have shaped the direction of my research. I am a prehistoric archaeologist and the experience at Erice did sharpen my interest in using archaeology to study the evolution of human cognition. I was given an opportunity to write a paper on this topic for *Mind, Brain, and Education*, but efforts to develop a research program that grows directly out of an interest in the direct relationship between archaeology and cognition has been less successful. Much of my effort over recent years has focused on developing my field project at Wonderwerk Cave and the sites of the Kathu Complex, South Africa, where we continue to have success and face many challenges, particularly from the increased pace of development. However, I can trace three ways in which the Erice conference has had a continued impact not only on my research but also on my teaching.

> *Teaching active minds*. In our discussions on the evolution of teaching there was a consistent critique of the model of the student as an empty vessel to be filled with knowledge. For educators this point is perhaps obvious but for me this point continues to raise questions about how I teach archaeology at the University of Toronto.
>
> *Finding intellectual connections*. At Erice I was impressed by the way in which researchers were able to situate their research in a broad intellectual context. As an archaeologist I often feel pushed to focus on the technical aspects of my research and the experience at Erice was a welcome reminder that archaeology touches on fundamental issues of broad relevance. In recent years I have turned towards exploring the nature of artifacts from an archaeological perspective.
>
> *Social engagement*. It was not a great surprise to find at Erice a group of intellectually engaged researchers, given the interdisciplinary structure of the meeting this was to be expected. What I did not expect was to find researchers heavily engaged in the social inequalities that are a central aspect of the contemporary world. At Erice I learned for the first time of the project to provide computers for children around the world and about Maryanne Wolf's work with children with dyslexia.

I would like to discuss each of these points —education, intellectual engagement, and what I can only call engagement with the real world.

Teaching Archaeology and Aggasiz' Fish

It is fairly easy to get students interested in archaeology but it is another matter altogether to teach archaeology. I have recently published an article in which I allude to the method used by Louis Aggasiz, the zoologist who founded the Museum of Comparative Zoology at Harvard, to teach his new students (Riddle and Chazan 2014). Aggasiz is said to have presented his students with a fish and then left them to their own devices for a week. My own experience becoming an archaeologist did not involve any fish but did resemble this scenario. As a first year student at Tel Aviv University I was left in a room of pottery sherds for hours on end and during the breaks in the school year I went off to excavate. I loved it. It was through the combination of class work and such immersion that I became an archaeologist. Archaeology is not only intellectual, it is also highly tactile and I have spent hundreds of hours drawing artifacts, not with particular skill but this process forced me to engage with artifacts with my hands as well as my eyes. However as a teacher I find that the challenge of taking the 'Aggasiz approach' is not simply the logistics of arranging for hands–on contact with artifacts and fieldwork opportunities. Rather I find that the key challenge is that immersion is often unstructured and wends its way, this way and that. Everybody engages with their fish in their own way! But teaching at a very large university does not easily allow for winding pathways and we erect rigid structures (and modes of assessment) to herd our students through their education. A further challenge is that one cannot force students to be motivated and engaged. Faced with Aggasiz fish many of my students would turn on their phone and start scrolling through their Facebook. I wish I could say that Erice provided me with an answer of how to teach but in a sense it only heightened my sense of the limitations of my teaching practice. However, I do have students with me in South Africa and when I hit points where I question 'what am I teaching them?' as the research stretches through its many mundane stages and navigates unexpected twists and turns I am able to remind myself that they are learning even though, or maybe even particularly when, I am not formally teaching.

Intellectual Connections: The Artifact Enigma.

The session I participated in at Erice was on the evolution of teaching and this topic fit well with my sense that archaeology has the potential to provide insight into the evolution of human cognition. Since Erice I have become drawn into thinking about a slightly different issue, the nature of artifacts as objects. In a sense I have come to the conclusion that by leaping directly from archaeology to cognition we are ignoring a fundamental issue, the identity of those objects that not only the products of cognition and action but also an external material reality. As material culture studies develops as a discipline there is a growing awareness of the importance of artifacts but I see a more fundamental issue: understanding the essential nature of artifacts.

Experimental psychologists have investigated the emergence of concepts in ontogeny, often employing toys and other artifacts in their experimental design. This is sound experimental procedure but it leaves unaddressed the question of how artifacts came into existence. In my article for *Mind, Brain, and Education* I began to explore the co–evolutionary relationship between hominins and artifacts. For millions of years the landscape of human evolution has been a landscape of artifacts. At Erice I spoke about our discovery of traces of fire at Wonderwerk Cave in a level dated to one million years ago, the earliest secure evidence for fire on an archaeological site. Since that time I have been engaged with the Wonderwerk Cave Research team in improving the empirical data and seeing whether we can identify even earlier evidence of fire, perhaps as far back as two million years ago. At the same time I have been thinking about the role of fire in human evolution and have come to the conclusion that we might have fallen into a trap of reconstructing human evolution as a series of heroic discoveries rather than a long and complex process. Fire is a natural phenomenon and traces of fire in the geological record date back to the Devonian. What is significant in human evolution is the way that hominins have engaged with fire, shifting it out of its status as a natural phenomenon and coaxing it into a web of technology, social relations, and beliefs. I now argue that there is not an 'origin' of fire but rather a process of shifting interactions that can be traced for a period of over a

Figure 2: Cleaned surface from 2013. The arrow indicates the position of the object shown in Figure 3.

million years. Fire emerges in human society as a natural phenomenon but also as something else. When we light a candle of memorial and encase it in glass we cannot understand this act purely in terms of the physics of combustion; at that point fire is in some sense artifactual.

I have begun work on a book looking at the reality of artifacts from the perspective of the archaeology of human evolution. This is an exciting undertaking as I have an opportunity to pull together disparate strands of thought that I have pursued in recent years. Holding this project together is a definition of artifacts that departs from the traditional emphasis on the role of human manufacture as the defining characteristic of artifacts. One turning point for me in this regard came from my teaching, when a first year student made a beautiful presentation on her rock collection. In going through her jewelry box she found a drawer of rocks that she did not remember collecting. She asked her mother about her unexpected find and her mother immediately recalled how these were the rocks they used to collect together in the playground. The student then recounted how her mother sent her off to university with a polished rock as a keepsake. Where do we draw the line between artifact and non–artifact in this story? It seemed to me that all of these objects were clearly artifacts, whether they bore traces of manufacture (as is true of the polished rock) or not (as in the case of the rocks in the jewelry box). My response is to define artifacts not in terms of any physical properties but rather by our engagement with these objects. I argue that artifacts are best understood as objects that are integrated into human temporality, a temporality in which there is a recollection of the past, experience of the present, and anticipation of the future.

Figure 3: The handaxe with traces of flake removals during the process of manufacture approximately one million years ago.

One implication of this redefinition of artifacts is the implication that objects can go in and out of their life as artifacts. One million years ago a Homo erectus made and used a handaxe, an artifact that was then discarded at Wonderwerk Cave. I would argue that when it was discarded this object ceased to be an artifact and became simply a part of the physical world. In 2013 we restarted the excavation at Wonderwerk Cave. In the course of excavation I cleaned a surface with a large unpromising looking rock (Figure 2). Once the surface had been cleaned and photographed I turned the rock over and saw the traces of chipping that had formed a crude but real handaxe (Figure 3). A million years separates the discard from discovery, a million years during which the handaxe lay inert in the ground. As I turned this object it was not simply a process of discovery but also an act of creation. For this was now an archaeological artifact, an artifact with a new purpose, no longer an instrument for transmitting energy from the body to the external world but evidence for reconstructing our human past.

Social Engagement: My, that is a Big Baby

Earlier this summer I sat in Wonderwerk Cave watching three talented, athletic male actors bring evolution to life in a wonderful play. As one actor leaned down to help along the birth of a Homo sapiens baby, the largest of the actors tumbled out to be greeted by the exclamation: “My, that is a Big Baby”. Big baby indeed! But in the context of the play very useful for demonstrating the evolution of differences in skin color, quite a significant topic in modern South Africa. At that point I had to wonder how I came not only to be watching this show but actually to be sponsoring the visit of the Walking Tall theatre group to the Northern Cape. The night before we had (with some trepidation) mounted the same show in a Baptist Church and the night before we were at a community center. How does this fit with the work of a scientist?

The idea of the social responsibility of scientists is hardly unique to archaeology and within archaeology is today viewed as an integral part of ethical practice. Yet in practice it can be jarring to be witnessing the birthing of a healthy 6 foot baby in the midst of a busy field season. I am absolutely convinced of the importance of the partnership with Walking Tall and will work to further develop this relationship in the coming years. I feel similarly confident about the value of the field course we were able to offer for students from the Sol Plaatje University in Kimberley, one of the first universities founded since the end of Apartheid. But, still… a six foot baby?

At Erice I was surprised to learn of the involvement of several participants with the One Laptop per Child project. I was inspired to see that a neuroscientist can see the potential of digital education to have a positive effect on the lives of children around the globe. I was impressed to learn that Maryanne Wolfe's work on dyslexia is fueled by the fact that she cares about children who have to suffer through inappropriate educational structures. I came to see that part of the value of engagement is that it actually can push research forward.

My research in South Africa largely focuses on remote periods of time that mean little to local communities. The brilliance of Walking Tall is precisely that they are working to find a way to communicate the excitement and relevance of this heritage. I am under no illusion that my engagement will have anything like the impact of providing computers for tens of thousands of children or protecting dyslexic students from the unintentional cruelty inflicted by traditional pedagogy. Yet there is something to this work that feels right, and that somehow helps push our research efforts forward. The best I can do to articulate the value of this aspect of our work is to say that it encourages a sense of attentiveness, of listening to the world around us. In a country scarred by a legacy of colonial violence, of imposing scientific categories with no regard to the pain this caused, I find such an attitude of attentiveness to be appropriate.

The Lesson of Erice: Science is Messy but You Can Meet Interesting People

So what took place high up on the hill of Erice? For me little was resolved, I did not solve problems I had struggled with, and the initiatives that I took to follow up directly on our discussions have yet to bear fruit. But I learned a great deal and I was able to gain a model of scientific practice in which teaching, research, and engagement are all intertwined. Sitting around a circle turned out to be a very effective use of our time.

Brain and person: A minimal sketch

Fernando Vidal

Body, brain, and personal identity: re–examining the connections between these three entities at the level of concepts and practices may be central at a time when scholars variously engaged in bringing about a "neuroscientific turn" in the medical and human sciences assume that the neurosciences are having and will have a revolutionary impact on the individual and society, while others critically examine such assumption and demonstrate its empirical and conceptual limits (Feuerhahn and Mandressi 2011, Littlefield and Johnson 2012, Ortega and Vidal 2011). Both sides implicitly raise questions about the nature of knowledge, scientific methods and epistemic hierarchies and, beyond them, about different ways of thinking about the human person.[1]

"Personhood" is the state of being a person, but the attributes that define a person (e.g. self–consciousness) are disputed, and differ across cultures and historical periods. "Personal identity" refers to self–sameness and continuity over time. A crucial question in connection with these concepts and the entities they might refer to concerns the relationship between body and person. In the Western world, debates about that relationship have taken place at the crossroads of philosophy, theology, the natural sciences, and the sciences of body and mind. What kind of body and which parts of body do we need to be the persons we are? "The brain" has been a widespread answer. But such an answer can be understood in various

1. This "minimal sketch" uses parts of my introductory lecture to the Ninth International Summer School on Mind, Brain and Education at the Ettore Majorana Foundation and Centre for Scientific Culture, in Erice (Sicily). I take the occasion to thank the School's directors, Antonio Battro and Kurt Fischer, for their invitation to organize the event, which took place on July 31-August 3, 2014 with the title "Body, Brain, and Personal Identity: Historical and Contemporary Perspectives." The present text discusses topics that I have treated in more detail in previous publications.

ways, from the almost figurative to the literally reductionist, and moreover it represents only a moment in a long history of discussions about what constitutes personhood.

Indeed, the rise of the modern, preeminently psychological and cerebral definition of the human person belongs in the history of attitudes to body and personhood as they evolved in the Christian Western world. Its globalization results from broader processes, and has to be examined in connection with them. But such a definition also has to be relativized. On the one hand, sociological studies suggest that the neuroscientific view of the self has only a moderate impact on lay understandings and practices of personhood. On the other hand, not only do people have different views of themselves as they are and would like to be, but cultures differ in the attributes (such as individualism or autonomy) they use to characterize personhood, as well as to identify different entities as "persons" and determine the beginning and the end of a person's life.

It is fit to begin examining the connections between body, brain and personal identity with the contemporary situation to which it fundamentally speaks (see for example Rose and Abi–Rached 2013). Since the 1990s, we have become used to hearing that we are essentially our brains. Many people, inside and outside science, believe that such a view of the human results from neuroscientific advances. In 1994, DNA co–discoverer Francis Crick published a book entitled *The Astonishing Hypothesis*, and subtitled, *The Scientific Search For The Soul*. Crick wrote that,

> *"You," your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules… This hypothesis is so alien to the ideas of most people today that it can truly be called astonishing.*
> **Crick 1994, 3**

Crick and many others have worked to make this belief no longer "astonishing," and to turn it into a late 20th–century commonplace.

Brain transplantations are not yet possible, but they have long been a favorite thought experiment in Anglo–American philosophy. We may be inclined to think that the "person" is where the brain is, and that it is therefore more appropriate to speak of a full body transplant for the brain's owner than of a brain transplant for that of the body. Yet what makes the experiment challenging to philosophers is precisely that such a seemingly spontaneous view about who is donor and who the recipient is by no means obvious. Brain scientists, however, appear to waver less. Michael Gazzaniga (2005, 31), one of leading neuroscientists of the second half of the 20th century, commented on the common way of understanding the brain–transplant fiction with the statement, “This simple fact makes it clear that you are your brain.”

Gazzaniga and many others convey the view that humans may be considered as “cerebral subjects” characterized by “brainhood” —that is to say, by the property of *being* rather than merely *having* a brain (Vidal 2009). In this view, the brain is the only part of the body we need in order to be ourselves. As mentioned, the notion that we are essentially our brains can be understood more or less literally and more or less reductionistically. But there has been a tendency to express it concisely, as in philosopher Roland Puccetti’s (1969, 70) famous, “Where goes a brain, there goes a person” (Puccetti 1969, 70). What this crisp aphorism says is more complex than it seems. Puccetti did not intend to claim that we are our brains, but that since the brain is the biological foundation of personal identity, brain and person are inseparable – in ways that themselves remain open to inquiry and conceptualization.

Sociology and history have thrown valuable light on how people might “be” brains and on the very notion of the “cerebral subject.” From the sociological point of view, the very existence of many articles, books and websites criticizing what they call *neurohype*, *neurocentrism* or *neuroessentialism* suggests the existence of a phenomenon that seems as widespread as it is contested. In June 2013, a *New York Times* cultural commentator wrote, “The brain is not the mind.” This is a rather mild assertion, but it was seen as expressing an obsolete dualism and was countered with the claim that “The mind is what the brain does” (Brooks 2013, Marcus 2013, Waldman 2013). Are we, or are we not *cerebral subjects*, and in what sense yes or no?

Instead of trying to answer this question directly, it is more productive to take “cerebral subject” as the name of a notion of the human, and ask two questions: first, are there any real, concrete cerebral subjects? And, second, which weight does the brainhood ideology actually have in contemporary society? In first approximation, there is one answer to both questions, and it is: It depends. Indeed, some real people see themselves as cerebral subjects and do things accordingly – but not necessarily all the time. At the level of groups and individuals, the weight of the ideology depends on contexts and situations. In other words, the label cerebral subject cannot be affixed permanently to anyone. It serves to designate notions and practices that are operative part of the time. We can compare it to the idea of "genetic self." It makes sense when people's life and self–concept are largely defined by genetic conditions, or by genetic testing, screening and treatment. When the genetic makeup becomes the focus of attention, and when persons see themselves or are seen chiefly through the lens of their genome, they embody genetic subjects.

By the late 1990s, the brain seemed to have largely supplanted the genome as source of foundational explanations for human features and behaviors. These explanations do not dictate views of subjectivity always and absolutely, but they so in particular circumstances, and sometimes at a very large scale. Sociologist Nikolas Rose's example for what he calls "neurochemical selves" is the well–documented fact that millions of people around the world perceive sadness "as a condition called 'depression' caused by a chemical imbalance in the brain and amenable to treatment by drugs that would 'rebalance' these chemicals" (Rose 2003, 46). In real life, however, we shift registers in our ways of acting, experiencing and interacting, as well as thinking and speaking about ourselves and others.

When a phenomenon or area of knowledge is neurologized, it does not inescapably cease to be understood in different ways. In a medical context, individuals may share a condition, but not its interpretation. For example, in her study of bipolar disorder patients groups, anthropologist Emily Martin (2007) described the clash between a dominant reductionist model, and participants who challenged the idea that mood disorders can be reduced to brain dysfunction. In this case as in many others, grassroots diversity coexists with an apparently more homogenous specialist discourse.

Though significant at many levels, the view of the human associated with notions such as *cerebral subject* or *neurochemical self* does not automatically give rise to public consent or transform individual experience. Sociologists working with different populations, including children, adolescents, doctors and a range of patients and persons with psychiatric diagnoses, have shown that individuals adopt a neuroscientific vocabulary mainly after some kind of neurological event, for example a brain hemorrhage. But they still do not attribute to neuroscience an absolute capacity to account for them. Rather, they assimilate and appeal to neuroscientific concepts only insofar as these concepts seem to support ideas they already have. The observation of such a pragmatic relationship to “neuro” idioms demonstrates that “claims that neurosci¬ence will dramatically alter people’s relations with their selves, others and the world are overstated. In many cases, neuroscientific ideas have assimilated in ways that perpetuate rather than challenge existing modes of understanding” (O’Connor and Joffe 2013, 262).

For all their undeniable value to relativize the impact of ideas about the brain on views and practices of personhood, sociological studies are based on asking people what they think. But such impact may happen independently of self–conceptions or one’s explicit opinions. Much of psychiatry, including scientists at the head of major national mental health agencies, explain that there are no mental diseases, only brain diseases. The consequences that could follow from translating such position into public health policy would affect people regardless of their individual opinions about mental illness in general and their condition in particular. A public policy dictated by such redefinition of mental illness implicitly takes humans as cerebral subjects.

Here is where the historical point of view is valuable because it suggests the contemporary prominence of the brain in Western contexts and the debates that surround it belong in an equally Western history of discussions about the relationship between personhood and the body. We perceive that best by turning to the *longue durée*, to long–term processes and slowly evolving structures. The focus on the present and the recent past generates many insights, but also some misconceptions. For example, Nikolas Rose and Joelle Abi–Rached (2013, 22) observe that late 20th century Western societies witnessed the rise of what they call a “‘somatic ethic’” in which people identify with the states of their bodies. In their view, this somatic ethic gradually extended “from the body to the embodied mind” —and *that*, they claim, is what brought the brain to its contemporary prominence.

Such a description applies to the proximal roots of the turn to the “neuro.” But the importance of the brain may be connected to a deeper undercurrent. Narratives focused on the recent past document leave open the question, Why the brain? Rose and Abi–Rached appeal to the extension of a late 20th century “somatic ethic” to the mind embodied in the brain. A simpler and more common answer consists of saying that the brain is so obviously relevant for personal identity that recent neuroscientific advances have given it the place it deserves. This looks plausible for the recent past, but in fact the brain became associated with the self not because it was better understood but because, at a certain point, the self was redefined in terms of functions that were associated with processes located inside the head, and hence, somehow, in the brain. To understand the radical nature of such a process we must look toward broad contexts and the distant past.

According to Christian anthropology, persons have an intrinsically corporeal existence. Through debates in the first centuries of Christianity emerged the dogma according to which Jesus was God made flesh, simultaneously fully divine and fully corporeal. Christianity is based on believing in the carnal nature of Christ, and that belief gave the flesh a fundamental ontological function. Jesus resurrected with his own body of flesh, and his resurrection became the paradigm of the resurrection of humanity at the end of time. In the early centuries of Christianity, debates about resurrected bodies and persons constituted one of the main spaces where the notions of personhood and personal identity were invented (Vidal 2002). The discussions contributed to fashion the three interrelated questions that became integral to those notions: What are the necessary and sufficient attributes that define a person – a person's essence? What differentiates one person from another? – the problem of individuation. What are the qualities, features or properties that make me be the same person over time in spite of considerable physical and psychological change –the problem of re–identification. (For an overview, see for example Olson 2010). In the Latin Christian tradition, the answers to these three questions always included the body – not particular body parts, but somehow, in spite of many difficulties about what exactly that meant, one's own integral material body. In this perspective, brainhood was unthinkable.

When it did become thinkable in the late 17th century, it was unrelated to advances in knowledge about the brain and its links to the mind or the self. Rather, brainhood resulted from a combination of John Locke's theory of personal identity and the corpuscular theory of matter – in other words, from a mutation in the concepts of matter and person, and in the ways of understanding their connection.

On the one hand, the so–called corpuscular theory of matter explained natural phenomena by the size, local motion, shape and interactions of microscopic material particles. Differences among physical bodies no longer originated in the nature of their substance, and things did not have to be made of any particular kind of matter to be what they were, nor did they have to remain composed of the same substance in order to be the same. Material continuity thus lost its significance, and Locke extended this to persons and to the very definition of personhood. He did so in 1694, in the second edition of his *Essay Concerning Human Understanding* (Book 2, chapter 27). First, he separated substance and personal identity, the "man" (as he put it) and the person. While the "man" is the biological organism, the person is "a thinking being, that has reason and reflection, and can consider itself as itself, the same thinking thing, in different times and places" (§ 9).

In Locke's view, personal identity requires the capacity to recognize one's actions and accept responsibility for them. In turn, this capacity implies a continuity of memory and consciousness, such that, he wrote, "as far as this consciousness can be extended backwards to any past action or thought, so far reaches the identity of that person" (§ 9). Locke thus made personal identity depend on self–consciousness, regardless of the substances to which it is attached. That is why he argued that if my consciousness were located in my little finger, and this finger cut of my hand, "it is evident the little finger would be the person, the same person; and self then would have nothing to do with the rest of the body" (§ 17).

The dematerialization and psychologization of personal identity led to the first formulations of brainhood immediately after Locke. Insofar as the person was now defined by functions traditionally connected to the brain, the brain became the only organ we need in order to be persons in general, and the individual persons we actually are. In the 18th century, several authors asserted as much. For example, in his *Analytical Essay on the Faculties of the Soul* (1760, § 771), the Genevan naturalist and philosopher Charles Bonnet wrote that "[i]f a Huron's soul could have inherited Montesquieu's brain, Montesquieu would still create." To apply Puccetti: Where Montesquieu's brain goes, there goes Montesquieu. The body that is relevant for personhood amounts to the brain. This is an extraordinary claim, but one that did not follow from knowledge about the brain itself.

Since then, brain research has lent legitimacy to such a claim, reinforced the view of the human it conveys, and gave new contents to the contemporary forms of "neuroessentialism" (Reiner 2011). A number of late 19th and early 20th– century scientists proclaimed the future primacy of neurobiology among the sciences of the human. Since the mid–1990s, in large measure thanks to the use of neuroimaging technologies to study topics that used to be associated primarily with the human sciences, their prophecies seem to be moving toward their accomplishment. Nevertheless, as the historical sketch above suggests, neuroessentialism has only recently been connected to brain research as to a crucial source of evidence in its favor. It expresses a metaphysics and an ontology that neuroscience only seems to authorize and to make plausible.

The historical points in this connection are: first, Personhood was not always defined in exclusively psychological terms; and second, As long as the psychological redescription of personhood had not happened, brainhood was not imaginable. In other words, the articulation of body, brain and personal identity as it emerged in Western modernity is, in its origins, a geographically localized, ideologically bound and historically contingent phenomenon. The historical perspective thus coincide with that of anthropologists when they conclude, “Producing persons is an inherently social project” and emphasize that “personhood is not an innate or natural quality but a cultural attribute” (Kaufman and Morgan 2005, 320–321).

Does it then make sense to speak of *personhood* and the *person* in a transcultural perspective? Some thinkers, especially in bioethics, propose to get rid of these notions. For example, philosopher Bert Gordijn (1999, 357) has argued that instead of discussing whether or not particular beings, such as nonhuman animals, fetuses or patients in a vegetative state qualify as persons, we should shift the focus “to the morally relevant attributes of beings and their role as conditions for certain kinds of moral status, without the intervention of the troublesome concept of the person.” However, since listing those attributes amounts to defining person, simply giving up the word is not a solution to the problem of selecting the relevant features for declaring someone dead, alive, or deserving of respect. When not taken normatively, the notion of personhood may facilitate cross–cultural comparison. Surely some languages lack words corresponding exactly to “person.” But that is why keeping “person” center stage may sustain the search for its functional equivalents at the level of concepts and practices in history and across cultures.

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Going to the brain gym

Francisco Ortega

During the past few decades, the brain has ceased to be merely an organ to become a social actor. The spectacular progresses of the neurosciences, as well as the intense process of popularization by the media of images and information that associate cerebral activity with practically every aspect of life, have reinforced a growing perception of the brain as the site and agent of all the properties and actions that define us as human beings. The brain is increasingly seen as responsible for everything we used to consider attributes of a person, an individual, a human subject. The expression "cerebral subject" adequately subsumes the reduction of the human being to its brain, in other words, the belief that the essence of every human individual is to be found in his or her brain (Vidal and Ortega, Forthcoming).

One of the developments that characterize the expanding universe of contemporary neurocultures is the development of a cerebral self–help industry, and more generally what I have called "neuroascesis" —disciplines of the self aimed at the brain (Ortega, 2011). This world includes a number of best–selling books which promise to help their readers develop chosen brain areas for a variety of purposes, from enhancing memory and reasoning performance, through fighting depression, anxiety, addictions, and manifold other compulsions, to improving sexual performance, reaching personal happiness, and even establishing a direct contact with God (Capacchione, 2001; Chafetz, 1992; Ehrenwald, 1984; Goldberg, 2001; Goldman, Klatz et Berger, 1991 ; Mark et Mark, 1991; Spotts and Atkins, 1999; Wells, 1989; Winter et Winter, 1987). Many of these publications follow the right hemisphere rehabilitation trend. The rationalism and technicism of Western society, with its emphasis on logic and language, are identified with a predominance of the left hemisphere, and are said to have repressed the holistic and mystical dispositions of the right one, which are supposedly more akin to Eastern ways of being.

In the domain of education, for example, a fad that began in the late 1960's has been promoting the countless advantages that training the "right brain" offers for schoolwork, while criticizing the "traditional" educational system founded on left hemisphere aptitudes (Edwards, 1979; Gainer and Gainer, 1977; Hermann, 1981; Hunter, 1976). These neuroeducators pursue a "hemispheric balance in the curriculum" that would compensate for the excesses of left–brain–biased educational methods, and avoid their didactic failures. These projects bring back to life the pedagogical crusade and many of the assumptions defended by the French physiologist and neuropathologist Charles–Edouard Brown–Séquard (1817–1894). Brown–Séquard did not believe that brain functional differences were due to innate, structural differences in the hemispheres, but, rather, that they resulted from a failure of the educational system. As he explained, "We find that it is owing to that defect in our education that one–half of our brain is developed for certain things, while the other half of the brain is developed for other things (Brown–Séquard, 1874a, 1874b). For him, the issue was clear–cut, "If we have two brains, why not educate both of them?" (1874b, p. 1). His neuroeducational project therefore aimed to develop both hemispheres. "If children were thus trained," he wrote, "we would have a sturdier race, both mentally and physically" (Brown–Séquard, 1874a, p. 333 These ideas were further developed by John Jackson, among others. In 1903, Jackson, a grammar school professor in Belfast, founded The "British Ambidextral Culture Society" (Harrington, 1987; Harris, 1980, 1985). In his book *Ambidexterity or, Two–handedness and Two–brainedness: An Argument for Natural Development and Rational Education*, published in 1905, he proposed a neuroeducational system that would take in due consideration the development of both hemispheres. He declared that future generations "must utilize to the utmost every cubical line of brain substance," and that "this can only be done by a system of education which enforces an equal pre–eminence to both sides of the brain in all intellectual operations" (Jackson, 1905, pp. 103–104). As a result, brainpower would be duplicated, and the brain would be able to perform independent activities simultaneously. "If required, one hand shall be writing an original letter and the other shall be playing the piano; one hand shall be engaged in writing phonography, and the other into making a pen–and–ink sketch" (Jackson, 1905, p. 225).

Today, the self–help market is flooded by titles that connect the right hemisphere to the most bizarre phenomena, from the careers of artists, musicians, politicians or dictators as determined by their cerebral "orientation," to tantric sexuality, mediumnistic capacities, and other paranormal activities supposedly made possible by the 'right brain' (Blakeslee, 1980; Capacchione, 2001; Ehrenwald, 1984; Spotts and Atkins, 1999; Wells, 1989). This literature amalgamates the most diverse genres, including rather serious studies by neuroscientists, cognitive psychologists, and well–known psychiatrists who, declaring to base themselves on the newest neuroscientific findings, offer exercise programs aimed at enhancing brainpower, and thereby preventing mental decay and the pathological conditions of the aging brain. Skills such as perception, short– and long–term memory, logical, verbal, and visual and spatial abilities can be supposedly developed with the help of neuroascetical procedures (Goldberg, 2001; Chafetz, 1992; Winter and Winter, 1987; Mark and Mark, 1991).

Books written by self–help authors who merely capitalize on the neurocultural ideology perhaps reach an even larger audience, and certainly advertise an even larger range of results as their more "scientific" counterparts. Indeed, the promised results may include the capacity to identify hidden meanings in people's conversation, to absorb facts like sponges and reproduce them verbatim years later, to read and understand a book in thirty minutes, or to record in memory facts, images, and even complete books. Some of these publications, those most in tune with New Age movements, use a scientific vocabulary and technical jargon, but their promises seem to cover what looks like an infinite spectrum. After all, if quantum mechanics demonstrates that reality is an illusion created by our brains, then "the universe is the mind and the mind is the universe" (Spotts & Atkins, 1999, p. 80). The exercises proposed in this segment of the literature are guaranteed to promote altered states of consciousness through which to connect one's brain to the forces of the Universe and a superior intelligence, the Cosmic Mind or the Divine Mind.

It is particularly fascinating to notice how these latter–day best–sellers reproduce just about every topic and topos of traditional self–help literature while updating its scientific appearance. We may mention, among others, the emphasis on creativity as a means to engender reality; the idea of an "internal self" that can be cultivated and promoted by acting directly on the brain; and the insistence upon autonomy, responsibility, and self–control of one's own destiny and reality itself, all now attainable thanks to neuroascetical practices. Cerebral self–help discourses tend to rank individual responsibility and autonomy as supreme values; and these values are in turn sustained by an emphasis on self–control, and both often go hand in hand with the idea that reality can be molded by thought, or even created by it.

Neuroascesis thus brings about a sui generis form of solipsism (as regards the cerebral autonomy of the self) and idealism (as regards the ontological consistency of the world). In tune with these features, cerebral self–help proceeds as if only the cerebral self existed, to the exclusion of other people and social and cultural environments. While traditional self–help made the mind the defining center of the subject, and claimed that the power of the mind could change life, fulfill one's desires and monitor one's performance, now the physical brain is enthroned in the very same place once occupied by the mind. The old slogan, "You are what your mind is" has been superseded by the postulate of the cerebral subject, "You are what your brain is."

Contemporary best–sellers reproduce older ones not merely in their general outlook, suitably updated, but even in the details of their prescriptions for cerebral exercises, as well as in their remarks on the importance of physical training, a balanced diet, and the effect of alcohol, drugs, and other toxins on the brain. We find the very same recommendations and observations in much earlier self–help health publications, such as John Harvey Kellog's *First Book in Physiology and Hygiene* (1887). Of course, the socio–cultural contexts are different. Kellog's program related to the perception of a weakening of social rules and moral order —a perception according to which the physical, social and political bodies were all out of control, and could be reclaimed only by individual strength of will (Gunsfield, 1992). Brain fitness aimed at retrieving moral rectitude and guaranteeing the return of a socio–moral order thought to be eroded by the loss of traditional authority and legitimacy.

In contrast, today's ideology of the cerebral subject has no intention of restoring or legitimating traditional forms of authority; it rather aims at responding to the demands of a culture obsessed by the maximization of bodily performance. It may seem that the "cult of the body" is contrary to the ideology of the cerebral subject. Nevertheless, although the exercises and programs prescribed by the self–help authors mentioned here are aimed at the brain, the programs themselves include diets, physical exercise and recommendations for a generally healthy way of life. In short, the practice of cerebral self–help actually involve the entire body. "The idea is that by taking care of your body, your brain also benefits" (Brownlee, 2006a. See also Brownlee, 2006b; Cotman and Berchtold, 2002, Singer, 2005). This highlights the intrinsic ambivalence of neuroascesis. On the one hand, contemporary cerebral self–help instantiates the recurrent tendency in the history of neuroascesis to adopt a certain kind of *neurosolipsism* that reduces the whole to one of its parts —the person and/or the body to the brain. On the other hand, concrete neuroascetical recommendations call for the physical training of the body, while at the same time claiming that their real target in the brain.

The widespread use of metaphors and analogies from bodily fitness is an eloquent sign of the ambivalence that inhabits neuroascesis, and demonstrates its connections to the somatic culture of biosociality (Rabinow, 1996). The very idea of "brain fitness" or "neurobics" present in the titles of many such books (Cohen & Goldsmith, 2002; Dennison & Dennison, 1989, 1994; Eiffert, 1999; Goldman, Klatz & Berger, 1991; Mark & Mark, 1991; Winter & Winter, 1987) leads the readers to thinking analogically. Thus, "Just as weight lifting repetitions in the gym or jogging strengthen certain muscle groups, mental exercises appear to strengthen and enhance cognitive functions over time" (Tannen, undated). Several books and programs speak of a "Brain Gym" where one could do "mental weight lifting" (CBS, 2006). The "cerebral muscles" (Goldberg, 2001, p. 255) are supposed to be trained, but without any excesses to avoid "brain cramps" (Chafetz, 1992, p. 72). Similarly, "brain stretches" will help us "burn some synaptic calories," prevent us from becoming "mental couch potatoes" (Parlette, 1997, p. 16), and allow the mental muscles to enjoy television, a true "bubble–gum for the brain" (ib., pp. 152–53).

Most of the books reviewed here set up distinctions among levels of brain accomplishment or mental prowess, for "you do not have to attain the brain equivalents of Steffi Graf's or Michael Jordan's level of physical fitness to be quicker in conversation, better at solving problems, have richer memories, and livelier associations" (Chafetz, 1992, p. 23). For readers "who wish to exercise [their] brain systematically as an athlete would exercise various muscle groups" (ib., p. 213), authors propose programs to train different cerebral muscles alternately and in a balanced way. To accomplish this it is of course important to hire a cerebral "marathon trainer" and to keep "brain workout diaries" (ib., pp. 213–14). As these examples suggest, the cerebral subject ideology has actually transposed the bodily fitness vocabulary to the brain itself. In the somatic culture, bodily and cerebral fitness go hand in hand, and self–help health products, similar on numerous points to those marketed in the 19th–century, are presented in new guises that combine body–building language and images with supposedly up–to–date neuroscience.

None of this can be explained by invoking neuroscientific advances, not even those connected to cerebral plasticity, which have come to play such a central role in contemporary neuroascetical discourse. Rather, the genealogy of neuroascesis is best seen in an ontological perspective, as having to do with the development of views about the human and forms of sociality and subjectification that involve notions and practices of the self and its relationships with one's own body and other people. In short, neuroascetical practices are tools whereby persons constitute themselves as cerebral subjects, and that is why to do their genealogy amounts to doing that of a particular form of being human.

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Reflections on Personhood

Mirko Daniel Garasic

I had the pleasure and honour to participate to the 9th Erice International School on Mind, Brain and Education, and during my experience, I found the topic and approach of the *Body, Brain and Personal Identity: Historical and Contemporary Perspectives* extremely timely and stimulating. Many interesting presentations were given and I roughly divided them into three groups. The "Anthropological", the "Body(Brain)/Mind" and the "[Personal] Identity" are approximate definitions that I used to categorize most of the talks –although aware that such restriction does not pay sufficient tribute to the work of the colleagues.

The "Anthropological" group of presentations focused on a number of traditions from all over the globe: from the contrast between Eastern and Western traditions, to more specific aspect of the Asian, Amazonian or Judeo–Christian culture, innovative ways of analysing their interaction with our ways of processing developments in neuroethics were brought forward. Among others, I found Fernando Vidal's acknowledgement of brain death connection with the notion of personhood (highlighting the difference between the Western tradition and other traditions where the term "person" does not even exist) really interesting and capable to integrate the needed global perspective epitomizing our times. The separation theme was also touched upon by others: for example, Vanessa Elisa Grotti stressed the separation between nature and culture (as well as human versus non–human), with a final consideration on the rise of individualism in Christian societies. Through an analysis of autism and the diversity movement, Francisco Ortega instead brought forward the definition of "neurocultures". Michael Barilan used the Judeo–Christian tradition to speculate over the admissibility of moral bioenhancement.

The "Body (Brain)/Mind" group of presentations had a strong presence of philosophical approach that allowed some valuable and necessary speculation to come into the discussion. For example, Eric Olson focused the attention on the part versus whole contraposition, while Sky Gross —through the use of some of the outcomes of her studies— explained how most brain tumour patients will define in parallel that a) the brain is yet another organ and that b) the brain is the location of the illness and, thus, unique. From a non–Western tradition instead, I found fascinating the work of Shuenn–Der Yu, who highlighted how meditation represents a form of "deconstruction" of personhood in individual terms, but it represents nonetheless a necessary step.

The "Personal Identity" group of presentations was perhaps the most uniformed set of talks, and —in a sense— it included a number of presentation that were able to interact more directly between each other. For example, Michele Farisco asked if —due to the technological advancements that we have had— we can say to have a new form of personal identity. For him, the creation of potential new "forms of bodies" (the combination of "old" bodies and new technologies), could present us with such a scenario. Somehow in response to that Ronit Yoeli–Tlalim underlined (again) that the Tibetan conceptualisation of personhood differs from that of the Western tradition. Yet, alternative models are increasingly considered also in the West. However, the reading of the anatomy remains Eurocentric for example. Still in relation to this East–West dialogue, Alessandro Lazzarelli explained how personhood is more of a social, objectivizing definition, while self is more focused on the experience of the individual —especially relevant in relation to bodily experiences.

Since summer 2014, I can proudly say that I have been quite productive in terms of publications and talks —in many occasions connected with the themes of discussion at the 9th Erice International School on Mind, Brain and Education. Among other achievements, I have been invited as a speaker at the *Hunger Strikes: Ethical and Political Perspectives International Conference* where I presented 'To Force–Feed or Not To Force–Feed: That is the Question' on 30 December 2014, at Tel Aviv University. Subsequently, I presented a similar talk —'Force–Feeding Hunger Strikers: Humane or Inhumane Treatment?'— at the 10th *World Conference on Bioethics, Medical Ethics and Health Law*, UNESCO Chair in Bioethics on 6 January 2015 in Jerusalem, Israel. On 6 May 2015 I will continue this series of presentations on force–feeding and hunger strikes by giving a talk as an invited speaker at the Health Systems Management Departmental Seminars at Ben Gurion University of the Negev, Beersheba, Israel. The title of my talk is 'On force–feeding hunger strikers in Guantanamo'. Finally, Next June 2015, I will instead present some of my work on cognitive enhancement —'Why should I say out loud if I've cognitively enhanced myself?'— at the Zagreb Applied Ethics Conference 2015, taking place from 29 June to 1 July 2015, at the University of Zagreb —Center for Croatian Studies, Zagreb, Croatia.

Concerning my publications, I have contributed with the chapter 'Torture' in Springer's *Encyclopedia of Global Bioethics*, Springer, edited by Henk ten Have. While I co–authored with Andrea Lavazza two articles published by two prominent journals relevant to the topics touched upon in Erice. The first article, is an open peer commentary appeared on the American Journal of Bioethics–Neuroscience and the title is: 'The neuronal excuse: one can lack motivation and want to be helped with it, while remaining a moral perfectionist'.

The second article —'Performance enhancement in the workplace: why and when healthy individuals should disclose their reliance on pharmaceutical cognitive enhancers'— was published by Frontiers in Systems Neuroscience and it is available online. Finally, —although still in need of some minor changes— my first manuscript —'Guantanamo and Other Cases of Enforced Medical Treatment – A Biopolitical Analysis'— is currently under contract with Springer and it very likely to be published by the end of the summer.

In line with the approach seen and lived in Erice, I try to keep an open mind towards research and I believe that the goals achieved during these past months have shown that. Spreading through a number of topics, I have tried to implement —even— if not directly the interdisciplinary and valuable experience that I have gained during my time with such a variegated group of scholars. Fostering such an enterprise and allowing junior scholars such as myself to participate can only deserve my gratitude, as it certainly constitutes a very important milestone in my academic path.

Can one still speak meaningfully of personhood today? Challenging Farah and Heberlein's argument

Bernard Baertschi

Introduction

The concept of 'personhood' or of 'what it means to be a person' has been a central tenet in the question of moral status for a long time. A person, Boethius claimed in the 5th century, is an individual endowed with reason (or rationality). Aquinas, Locke and Kant adopted this definition. A view I will name 'personism', following Jean–Yves Goffi (2007). Recently, some neuroethicists have levelled a charge against it. In a paper entitled 'Personhood and Neuroscience: Naturalizing or Nihilating?' published in 2007, Martha Farah and Andrea Heberlein argued that this concept should be dispensed with. They think that its neural basis consists of an automatic response from an innate brain module that is dedicated to face recognition and therefore is alien to morality (and often even to reality —they speak of an 'illusion').

I will examine their argument here.

Farah and Heberlein's argument

For Farah and Heberlein, if being a person is so important to us, it is because face recognition is innate and very soon into play. To buttress their claim, they mention the case of a boy 'who sustained visual cortical damage, including damage to the fusiform face area, in his first day of postnatal life. Despite his relatively preserved ability to recognize non–face objects, he never acquired the ability to recognize faces. In other words, a certain region of cortex is destined for face recognition as early as age 1 day, and other regions, which are capable of recognizing inanimate objects, cannot take over this function.' (2007: 43)

Of course, this observation does not prove anything: the boy does not recognize faces, but he knows that he is before persons. However, Farah and Heberlein think that cases like this allow us to conclude that it is on the basis of our capacity to recognise faces that we have built our view of moral status. Briefly said, we are so wired that we separate spontaneously and naturally persons from non–persons.

What should we think of this natural tendency ethically speaking? A personist will not be very happy with that: every human being possesses a face, but every human being is not a person, because every human being is not endowed with rationality —think of anencenphalic babies. Moreover, every genetically human being does not possess a face —think of embryos— and non–human beings who are persons could exist, as Boethius already said (he mentioned angels and God). Farah and Heberlein also deem that this natural tendency can lead us astray when they state: 'The human face is a powerful trigger cue that activates the whole person network, and this may be what makes it hard for many of us to dismiss the personhood of a vegetative patient or a fetus' (2007: 45). Our innate capacity to recognise faces is obviously a source of confusion because it compels us to grant the moral status of a person to everyone possessing a face, and this is not an appropriate criterion.

Farah and Heberlein extend the critique against personism as such. They think that believing that the world is divided between persons and non–persons is an illusion from a moral point of view. Consequently, ethics should not be built on such a foundation.

Are they right? In order to answer this question, I should examine more thoroughly their objection. It consists of a threefold charge: the concept of a person rests on an illusion, it is arbitrary and it is a categorical concept, ill suited to the gradual character of our psychological and moral life. They do not deny the existence of persons in the sense of beings endowed with rational psychological states, but they deny the relevance for ethics of a moral status named 'person' or 'personhood'.

The charge of illusion

Our brain divides the world in a manner it is not truly divided. Consequently, concerning personhood, 'like visual illusions, it is the result of brain mechanisms that represent the world nonveridically under certain circumstances.' (2007: 45) Of course, there exist clear cases of persons, but others are not, and their number is growing with the progress of medicine (embryos, fœtuses, comatose persons, psychopaths, etc.). Therefore, to believe that the world is tightly divided between persons and non–persons is a mistake.

Is the charge convincing? We could already doubt that the illusory character of the distinction could be an argument against personism, in the sense that the illusion is not that there exist persons, but that the divide is sharp. But that is only one aspect of the illusion that I will discuss later (it is the third charge); another one is that we extend personhood to beings that are not able (or not able anymore) to have interests, like some comatose individuals, granting them moral status they should not have.

I could reply in biting the bullet: why not grant them this status and consider, like the Law, all born human beings as persons? Pragmatically, it could be a wise stance to adopt, protecting vulnerable people, allowing abortion and embryo research. But most personists would be dissatisfied with this reply, some because they believe that human beings without a face are also persons and some others because they separate personhood and humanity since rationality is not necessarily linked with the latter. Consequently, another reply will be preferable. My answer is that personhood could well be anchored in a brain module for face recognition, but that this link is only contingent and has for long been severed by moral philosophers adopting personism.

We value persons for their rationality, not for the fact they have a face; or we distinguish persons *because* we value rationality, and not because we value human faces. It is possible that the psychological origin of this process resides in our sensibility to faces, but this fact has no essential relation with our moral judgment, it is only contingent, and often misleading because the class of individuals with a human face and the class of individuals endowed with reason are not the same, even though they overlap.

The charge of arbitrariness

Conceptually, personhood could be the marker of moral status. But is it an adequate one? Farah and Heberlein do not think it is because it is arbitrary: rationality covers a large number of different properties and that it is arbitrary to pick one instead of another.

Should we possess conscience, consciousness, critical interests, capacity for language or ability to choose on the basis of reasons in order to be a person? All these properties can be put under the umbrella of reason or rationality, but it seems possible to have one without having the others. Traditionally, reason has been put forward in contradistinction to sentience, rationality being the mark of human beings and sentience the mark of animals. But we know today that some animals possess some rational capacities listed above.

This difficulty is often raised against personism. Nevertheless, I think that it is not fatal at all, because it is grounded in a double mistake. First, many concepts have no necessary and sufficient conditions, without any consequence for the existence of their referent. Second and more importantly, in ethics, we do not need a definition of what a person is, that is a necessary and sufficient condition of personhood, we do not even need a necessary condition, but only a sufficient one, that is a criterion. And we have many, including the list of mental properties put forward by philosophers from Boethius on. Practically, this means that we will require that a being possesses at least one of the rational properties on the list in order to be granted the status of a person.

The charge of graduality

A person must possess at least one of the rational properties on the list. But these properties are gradual; therefore, which amount of it? Where is the threshold? It seems impossible to set it non–arbitrarily and resorting to neuroscience does not solve the problem, as Farah and Heberlein acknowledge: ‘Relevant clinical observations and neural network modeling indicate that the change in psychological capabilities would be gradual and would in general lack the kinds of qualitative transition points that could be used as non–arbitrary places to draw a line between persons and non–persons’ (2007: 40).

The difficulty of graduality stems from the requirements of ethics. If the psychological discourse lives very well with gradual properties, it is not the case with the normative one: we must know if an individual is a person or not in order to know how we should treat her and if she possesses rights. Or course, it is possible to set a threshold, but it will necessarily be arbitrary. On this point, Farah and Heberlein are right.

However, is it damaging for personism? It is not very surprising that normative distinctions and psychological ones do not completely match. Their requirements are not the same and we know that it is not possible to pass easily from facts to norms. ‘Person’ could be a gradual concept in itself, but its function in ethics prevents that we use it as a gradual one. It is a problem if we want to anchor ethics in our human reality.

Nevertheless, these observations would compel us to give up personism only if we had a better option. Farah and Heberlein think that they have one, stating that ‘rather than ask whether someone or something is a person, we should ask how much capacity exists for enjoying the kinds of psychological traits previously discussed (e.g., intelligence, self–awareness) and what are the consequent interests of that being’ (2007: 46). But this proposal is essentially the same as the proposal of the personists, and Farah and Heberlein acknowledge it in the end.

Conclusion

Why, then, all this fuss about personhood? Farah and Heberlein think that personhood is a veil that prevents us from seeing many normative relevant points, and they hope that the language of interests will not. I think that they are partially right, in the sense that their arguments strike not personism as such, but a kind of ‘mystical’ one.

Some personists claim that the status ‘of “being a person” should not depend on whether one has or does not have certain capacities (e.g., intellectual capacities)’ (Gastmans and De Lepeleire, 2010: 81). So, on what should it depend? The ‘mystical’ personists speak as if they believed that it depended on nothing (we should respect persons ‘just as they are’). This is a view very near the one depicted by Farah and Heberlein. However, if they are right to think that some personist theories are grounded in an unconscious and automatic brain module, the main personist tradition is not. As I said, the link between the human face and personhood has been largely loosened, even severed, for a long time in non–mystical personist ethics (Baertschi, 2014).

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SECTION 3

Neuroeducation: Past, Present and Future

A decade of my participation in the MBE-Erice: From Brain-Science-Based Education" to "Evolutionary Pedagogy"

Hideaki Koizumi

A decade at the MBE–Erice

As is widely known, the MBE–Erice: International School on Mind, Brain and Education at Erice, Italia, at the Ettore Majorana Foundation and Centre for Scientific Culture (EMFCSC) in Sicily, Italy, has been led by Professor Antonio Battro of the Pontifical Academy of Sciences, Vatican, and Professor Kurt Fischer of the Harvard Graduate School of Education (HGSE). Maria Lourdes Majdalani has served as the program officer for many years.

Reminiscent of the medieval era, Erice is a heavenly town, spread on a precipice at an elevation of 750 meters above the coastline. The research center, which is named after a genius physicist from Sicily, Ettore Majorana (1906~?; his whereabouts became unknown at a relatively young age), uses renovated old monastery buildings complex, and "international post–university activities" have been conducted since 1963 as "research on scientific culture." Many activities other than the MBE–Erice also have been held, covering physics, chemistry and physiology/medicine. As many as 85 researchers who participated in these activities in the last half century received the Nobel Prize after their participation (source: EMFCSC Web site).

The initial discussion format employed by the MBE–Erice is the most superior discussion style within my range of experience. With approximately 25 participants, each discussion session has about five senior researchers (such as Professors Pierre Lena and Jean–Pierre Changeux) with the balance consisting of core and junior researchers. Discussion is initiated by senior researchers' keynote lectures, which set the direction for discussion. Such lectures are delivered at the research center's famous hall, which used to be visited by Pope John Paul II. After the keynote lectures, the venue shifts to the research center's highest floor, where refreshments are served. Core and junior researchers present posters featuring the theme, followed by thorough discussion. Discussion takes place among participants sitting in a circle in a free and open atmosphere, in which senior or junior does not matter. With senior researchers serving alternately as the moderator, the venue is engulfed by heated discussion. The venue has an open space that links to a heavenly veranda with a commanding view of the blue Mediterranean Sea. Sometimes a white cloud flows above the roundtable discussion venue.

During the MBE–Erice session, which lasts about one week, major restaurants in Erice warmly welcome the MBE–Erice participants. Pick a favorite restaurant, show your ID badge and provide your signature, and enjoy a predetermined lunch or dinner. Discussion continues over meals among groups of five to 10 participants. I could not be more grateful for the organizers' generous consideration to always include three or four junior Japanese researchers as participants in the discussion sessions. To enhance the discussion sessions, I began to nominate junior Japanese researchers studying at the University of Oxford and Princeton University, who were used to expressing themselves. Many of the participants who have been awarded the best presentation prize were encouraged by the prize and continue to be vibrant in their respective fields.

I was invited to participate in the MBE–Erice every year for the past decade, which I largely owe to Professors Battro and Fischer. Attracted by the MBE–Erice activities, I did my best to manage my difficult schedule to participate in these meetings. Each of the former core and junior researchers who has participated in the MBE–Erice even once has made a significant advancement and become a full–fledged researcher. Asking myself if I had made a significant advancement, what I value most is the transition from my new approach to the field of education based on the noninvasive brain–function imaging method to an even newer approach to the educational field including preschool child care from the perspective of evolution.

Evolutionary Pedagogy Including Evolutionary Child Care

At the MBE–Erice in the summer of 2014, I submitted a short thesis "Evolutionary Pedagogy." In the fall of the same year, I published my complete research with full details (*Albert Einstein's Inverse Omega: Considering Education from the*

Perspective of Evolution: Evolutionary Pedagogy, Bungeishunju Ltd., 2014 [in Japanese]), in which I wrote only about proven facts without shifting to the next level to prevent giving the impression that the content might be a mere hypothesis, especially because evolutionary pedagogy was such a new field. In this paper, however, I would like to address my current concepts, commemorating the 10th anniversary of my participation in the MBE–Erice. Twenty years ago, a symposium titled "Frontier of Mind–Brain Science and Its Practical Applications" was held beyond the established industry–government–academia framework, for which we published the proceedings (Koizumi, H., ed., *The Trans–Disciplinary Symposium on the Frontier of Mind–Brain Science and Its Practical Applications: Search for Foundations of Science and Technology in the 21st Century*, Hitachi, Ltd., 1995). The timing was opportune with all the initial data in place on the functional MRI (fMRI) and magneto–encephalography, which were produced as prototypes at Hitachi, Ltd., and the initial data on optical topography (fNIRS) available. We discussed a predictable future of the medical, healthcare, information and communications (including brain–type computer/artificial intelligence), education and robotics fields, among others, based on applications of noninvasive brain function imaging. All these fields are currently flourishing, exactly as foretold in the proceedings I delivered 20 years ago.

Introduction of the Concept of Impedance Matching to the Theory of Evolution

The record time of Kirani James, the men's 400–meter track gold medal winner at the London 2012 Summer Olympics, was 43.94 seconds. On the other hand, concerning Oscar Pistorius, a Paralympic runner with two artificial legs, his record was 45.07 seconds in the same 400–meter category. The difference between the two records is nearly only one second, and a reversal could even occur in the future. Artificial blade legs do not use any external power. In terms of the source of internal power, which is leg muscle mass, Mr. Pistorius has less muscle mass because of his amputated body parts. Nevertheless, he can run highly efficiently with running blades, which is, I believe, attributable to the improvement in mechanical impedance matching (MIM). In observing various kinds of fossil remains on my hand, I believe that the emergence of avidly moving animal groups from the Ediacaran period of the Proterozoic era (635 to 541 million years ago) to the Cambrian period of the Paleozoic era (541 to 485 million years ago) was attributable to the improvement of the MIM.

Inherence of Animals

Aristotle roughly divided organisms into animals and plants based on the existence/nonexistence of senses and mobility. Carl von Linne added another perspective of the heterotrophic characteristic of animals and classified nature into the animal kingdom, or *Regnum animale*, and the kingdom of plants, or *Regnum vegetabile*. As the most basic characteristic of animals, animals are multicellular organisms with mobility and sensory organs. When an animal moves, the movement vector consists of direction and velocity. To determine the direction of movement, basically the velocity of the right side and that of the left side of the moving body need to be changed (the caterpillar direction shift principle). To accelerate the velocity, it is necessary to improve the MIM of the individual moving body and the environment (e.g., leg and ground). During evolution, I believe that the necessity to control the direction of a velocity vector resulted in the birth of a ladder–shaped nervous system and the need to improve the absolute value of the velocity vector led to the hardening of a partial body, which started in the Cambrian period. The human body's spine is a ladder–shaped nervous system and humans' right and left hemispheres of the brain on top of the spine are considered to have evolved as extensions of ladder–shaped nervous systems. In other words, humans' left brain hemisphere, which is strong in analytic processing (differential calculus), and humans' right brain hemisphere, which is good at comprehensive processing (integral calculus), are tightly connected by corpus callosum fibers.

Evolution of the Sensors of Organisms

On the other hand, for the acquisition of nutrition sources and avoidance of and escape from predators, which are necessary for survival, animals' sensory organs evolved from a sense of touch and olfactory receptor organs to include a visual sense. Although it is commonly believed that the development of vision was the major factor triggering the Cambrian explosion, we need more analysis before concluding so. It is true that the senses of touch and smell are effective for the acquisition of nutrition sources from a short distance, and vision is effective for the acquisition of distant nutrition sources and the avoidance of and escape from predators. However, both predators and prey need long–distance measurement after the acceleration of movements. In the early Cambrian period, many Trilobite species evolved but quite a few of them did not have eyes. Although the precision compound eyes of some Trilobite species are intriguing, I believe that the emergence of genes that build exoskeletons and legs from rigid crystal calcium carbonate gained from CO_2 and calcium in the sea was important for both the dramatic improvement of the MIM and the formation of compound eyes.

Ubiquity and Historicity of Evolution

As described above, there are many cases where the rough outline of evolution is determined by physical binding conditions, analogous to chemical reactions with slow reaction speeds, which take a while to reach a chemical equilibrium but eventually settle in a mechanism that follows the principles of chemistry. Although this process is not generally called natural selection, from the perspective of statistical mechanics, it is a stochastic process that eventually follows the laws of physics. In the kingdom of nature, however, things happen by chance without an apparent cause including genetic fluctuations and such a process determines the subsequent conditions of the system–so–called historicity. History does not allow a reproduction experiment and is outside the scope of the sciences. In–depth discussion about this perspective is necessary to address evolution as a science (Seizon and Life Sciences Symposium, Biological and Cultural Evolutions: Their Ubiquity and Historicity, Tokyo, Oct. 3, 2015 (announced)).

Similarities between Evolution and Development

With regard to the similarities between evolution and development with compressed time axes, many theories have been presented, first by Aristotle (384–322) and later by many others including the theory of embryonic developmental stages by Johann Meckel (1781–1833), embryology by Karl von Baer (1792–1876) and the recapitulation theory by Ernst Haeckel (1834–1919). Because evolution includes historicity, chance occurrences need to be considered, which generate exceptions. Within the ubiquity–based part of evolution, similarity is seen easily and the process of evolution gives many hints to help understand development. Concerning this point, many scholars and thinkers were influenced by Haeckel. Such influences were clearly indicated by Jean Piaget (1896–1980), Sigmund Freud (1856–1939), Carl Jung (1875–1961) and Friedrich Engels (1820–1895), among others. Because Haeckel's recapitulation theory was almost completely discredited in the field of biology, the major field in which the theory of evolution falls, the application of the theory of evolution to education did not come about although it was almost there.

Origin of Human Cognitive Evolution

Recently, the motor neocortex governing precision handling motions has received attention. We are learning that the neural system governing anthropoid apes' strong grasping motions of fingers when they move from one tree to another by grasping tree branches is different from the neural system governing humans' precise and dexterous grasping motions of fingers to use stone tools —the latter has one less synapse neuronal system to a muscle cell. When modern humans play, for instance, instruments such as the piano or the violin with fast and accurate finger movements, the motor and sensory areas of the neocortex located at the deeper areas of the central sulcus play an important role in rapid and precise motions. Humans' ability to use fingers, governed by the motor and sensory areas of the neocortex, to create and use precision tools dexterously might naturally have triggered or been linked to more complex thinking. I believe it is highly likely that from this process, the sophisticated cognitive ability of the modern human race was obtained.

Foundation of Learning

Because the developments of biological forms and associated functions are often similar to the process of evolution, the process of evolution provides many hints when developmental cognitive neuroscience, which is yet to be researched fully, is applied to learning and education. For example, with regard to the developmental order of cerebral areas and neural myelination, a myelination map was created by Paul Flechsig (1847–1929) more than 100 years ago, leading to the discovery of orderly developments from basic functions to sophisticated ones. In other words, myelination begins with somatic sensory and motor areas and is completed with the sophisticated association area, which accords with the order of evolution as well. However, grounds were insufficient for connecting the developmental order and an educational curriculum. However, recent animal experiments helped uncover that learning not only reinforces neural connections on the gray matter of the brain but also promotes the myelination of the white matter of the brain at the same time, leading to the potential that the order of myelination might be useful in formulating child–care and educational curricula.

Future of Evolutionary Child Care and Evolutionary Pedagogy

For the first time in its evolution, the modern human race has acquired symbols and languages. It is becoming clear that anthropoid apes were not able to possess languages with a hierarchical grammar. It is extremely difficult to express futuristic phenomena using body expression like mime (pantomime). I believe that a clear sense of the future was obtained only after a brain area for working memory was developed and language was acquired. From this perspective, it can be said that anthropoid apes are still the same as chimpanzees or other similar animals. Actually, it takes a while for infants to develop before they understand the concept of the future.

Further consideration of the future eventually reaches the imagination of death. Due to the uncertainty of the future, widespread imagination is possible. I would also like to mention the possibility that the acquisition of languages could lead to the emergence of neurosis and psychosis.

New Measurement Methodology via Language Dialogue with Artificial Intelligence (AI)

As a basic measurement methodology, if the subject for the measurement is of an open system, the internal information of the system is obtained from signals leaking to the outside, whereas if the subject is of a closed system, the internal information of the closed system is obtained by sending probes into the system and reading the perturbations (micro changes) that occur on the probes. For spectroscopic measurements, photons are generally used as probes. Taking noninvasive brain function imaging as an example, magneto–encephalography, by measuring the leaked magnetic fields generated by neural activities (open system) and solving the inverse problem, the location of the neural activity is identified. In the case of optical topography (fNIRS), by radiating photons from the end of a near–infrared short wavelength region into the brain (closed system), internal information is obtained by measuring light absorption and dispersion. The basic principle for measuring cognitive status is to introduce language into the intra–brain language area, detect the language sent out from the cerebral language area and read the reactions of the language area according to the meaning of the dispatched language, thereby measuring the response of the intra–brain cognitive system —a new cognitive status measurement method.

If AI is not used, I think a similar measurement already has been employed for some time. Freud initiated "psychoanalysis," a methodology to know patients' cognitive functions or emotional status via a dialogue. Furthermore, by giving feedback to the patient's brain through a dialogue, the status of the patient's brain can be transformed. The Socratic dialogue initiated by Socrates, a classical Greek philosopher, is a similar methodology.

The advantages of dialogue using AI are the availability of an enormous background of knowledge and data, the ability to make minor adjustments to perturbations (micro changes) quickly and the ability to provide delicate feedback during the next dialogue. Different from surmising the mind based on the activities of the cerebral functional areas, the methodology using language to an in–depth level is profound, which naturally requires careful consideration of the ethical issues beforehand.

The AI for dialogue or dialogue robots can be utilized for language acquisition. English can be learned as the lingua franca with such a *lingualoid* as a dialogue robot with AI. It also could be used as a potential method to preserve a number of language–related cultures of minority groups in the world.

In addition, AI allows evaluations in a learning process through dialogues. Furthermore, based on the evaluation results it becomes possible to give almost real–time feedback to learners' educational materials. Moreover, I hope that the use of AI for dialogue will make it possible to conduct new evaluations of various educational methods.

Of course, ethics should be the first priority to develop this kind of new AI technology.

What Should People Know About Science?

Deanna Kuhn

There is now substantial agreement among science educators and scientists that appreciation of the methods of science is the most important thing to convey to young people about science. Why for all ages from early elementary school through college are we still so uncertain about how to achieve this goal?

Columbia University has once again undertaken the process of reforming its required core course in science for non–science majors, thus revisiting the question of what students ought to know about science. Columbia undergraduates are a highly select and sophisticated group, destined to be leaders in their fields. The fact that Columbia faculty are still challenged in deciding what these elite students ought to know about science highlights just how challenging the question is for the much larger population of less elite students, including K–12 students, a great many of whom will never study science in college. Efforts to interest more young students, especially girls, in science have yet to show much effect.

It's become increasingly apparent that non–specialist students can be introduced to at most a smattering of current scientific knowledge. Most science educators have come to the view reflected in the newly published K–12 Next Generation Science Standards (NGSS) that the most important thing we can do is acquaint students of all ages with the *methods* of science – identifying questions, developing hypotheses, designing and conducting experiments, examining and interpreting data, and debating conclusions. What's more, this goal is thought best achieved by engaging students in some scientific activity as a means of experiencing these methods for themselves. *Achieve*, a group charged with developing curriculum and assessment tools for achieving NGSS goals, has published guidelines for activities such as one in which students access and study data that will allow them to identify effects of latitude, topography, ocean circulation patterns, and wind circulation patterns on mean temperatures and precipitation in several US cities.

Such activities are an improvement over earlier approaches to getting young students interested in science by showing them surprising phenomena —miniature erupting volcanoes and such— that elicit an "Oh, wow!" response but don't lead much of anywhere. On the other hand, after they've gone through all the prescribed steps of Achieve's weather variation exercise, it may turn out that they are left underwhelmed. They likely already know the weather is different in California and Minnesota and, moreover, that any details one might want are there to be found on the internet. They are not surprised that scientists have studied and know about these things. Hence the activity doesn't seem one particularly likely to inspire further exploration of what science has to offer.

In a recent article, John Rudolph, editor of the leading journal *Science Education*, reminds us of another approach to making science relevant to the uninitiated, one that goes back a century to the work of John Dewey. Dewey championed appreciation of the scientific method as the core objective of science education and furthermore as essential for citizenship. Citizens need to be able to distinguish the kinds of questions that are amenable to scientific investigation from those that are not. They need to know how such questions can be addressed scientifically and what stands to be gained from doing so. The problem, Rudolph claims, is not with these educational goals but with schools' seeming inability to devise workable school experiences to achieve them.

The data are dismal on how little of the traditional K–12 science curriculum sticks. We thus must continue to look for what might. An approach to addressing Dewey's goal of making students aware of what science can do that my students and I have explored is to draw on social science topics as an entry point. Such topics entail phenomena students likely already know something about. But they likely will not know that such topics are the stuff of science. What better way, then, to get them to see its power and relevance? Compared to traditional early science topics, which largely describe and explain, such topics have the further appeal of being readily framed by an authentic problem to be solved, which is known to be a powerful learning tool.

An example of such a topic that we have experimented with is juvenile delinquency. We tell middle–school students that social scientists have been studying the matter for some time and data are available on teen crime rates and on potentially predictive factors such as education, family income, and population density. We make available an authentic but simplified database for 60 localities across US states and some foreign countries, compiled from publicly available statistics, and ask students to investigate which factors are predictive of teen crime rates. They use a simple computer tool, InspireData, to examine the data, and they prepare a final report on their findings.

In addition to becoming aware that and how the scientific method can address important problems like these, the activity fosters students' awareness that real–world outcomes are most often the consequence not of a single cause but of multiple factors acting in concert. Other topics we've employed straddle physical and social science, such as the factors that contribute to life expectancy variation across countries. Another topic —the variables that contribute to body mass index— has proven a particularly rich one as students collect their own data (on respondents' calorie intake, exercise, age, and parents' BMIs) and enter them in a shared database.

The understandings we see develop are not ones that emerge quickly, and we therefore engage students in activity that is dense (at least two class periods per week) and extended over a semester. The results, however, are encouraging. On posttest assessments students are asked to address new forms of multivariable problems, as well as new content beyond the sets experienced during the intervention. The most common posttest response of participating students is to invoke multiple causal contributors to account for an outcome. In contrast, among a comparison, non–participating group – but one whose science teacher reported she frequently used inquiry methods – the most common response is to explain an outcome as produced by a single cause. If more than one cause is mentioned, these are invoked as alternative (rather than additive) causes.

In the course of such activities, our work shows, students also come to see how their (and others') pre–existing beliefs about a phenomenon like teen crime are amenable to influence by means of application of a scientific method. If a student makes this discovery for just a single topic, it likely will occur to him or her that the same could be true for other topics. This awareness of the powers of science is the essence of what Dewey believed citizens need. His vision in this regard takes us a long way toward addressing the pressing contemporary concern of getting students interested in and educated about science.

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Teaching challenges in chronobiology

Luiz Menna-Barreto

Introduction

Both graduate and undergraduate teaching of Chronobiology must overcome several difficulties, mostly due to previous notions on biology, where oscillations in organisms are hardly presented, discussed or even acknowledged. In elementary and high school teaching organisms are generally represented as fixed structures, and life cycles are mentioned but scarce reference to the seminal contributions of chronobiology are offered, organisms being described almost exclusively on spatial terms. The first time a young student is taught about life, he is generally shown a picture of a dead cell, a clear message that spatial dimension is essential, or that life is a constant, stable property of matter. When it comes to human physiology the difficulty is reflected in some form of resistance to the idea that changes rather than stability may reveal more about the functions of an organism —somehow a consequence of the popular notion of homeostasis. Normal values of body functions tend to be assumed as fixed values, such as temperature and blood pressure, oscillations being interpreted as noise resulting from external influences.

What is your normal state, awake or asleep? I have been asking this question to several audiences both in formal and informal situations involving people at all levels of education. After initial expressions of surprise, the majority answers "awake", a few choose "asleep", but I never hear "both". I then proceed to discuss why a single state should define a normal state of their bodies, asking those who chose "awake" whether they considered sleep abnormal, and vice–versa. I then propose the notion of change as essential in the study of life, after asking why did you feel compelled to choose one state —wouldn't it be because "your notion of normalcy does not allow for changes?". After many years of experience with this dialogue involving audiences of all ages, and convinced that a revision of prevailing concepts deserve closer attention. As a consequence, I realized that teaching chronobiology must be extended to all levels of education, both formal and informal, with special attention to very early education. Yes, I am talking about preschool education. Children generally react better of the notion of oscillations in my experiences, whereas adults tend to resist, a curious form of attachment to an abstract principle of a single–state normality. This reasoning helped us to understand that the main message to be conveyed by elementary and high school teachers is that changing is normal – bodies show changes along the day and these changes can easily be identified. As a secondary goal teachers should be invited to impart the idea of ontogenetic variations, showing that a changing body also changes along aging. Providing examples of changes actually happening in their daily routines, such as sleep/wake habits, may be of great value, of course adapted to distinct ages. We published a booklet, "O sono na sala de aula" (*Sleep in the Classroom*, Louzada and Menna–Barreto, 2007) aimed at parents and teachers, especially those trying to cope with adolescents' peculiar sleep habits (and changes).

In this article I first describe an ongoing program developed by our group in Brazil aimed at the diffusion of chronobiology in elementary and high schools throughout the country. Is the second part I offer some thoughts on the perspectives of chronobiology in the near future, especially its potential role in education.

Part I – The Tempo na Vida project

We started with the idea of creating a digitalized animation to be distributed in disks (dvds) and also available on line, in order to reach schools in most parts of our country. The original idea dates back to the beginning of the years 2000 when it was conceived in the format and size of a circus, with an outer pathway depicting a 24h day and an inner circle where scenes of daily life would be shown. The visitors would be invited to walk along the outer circle from the point where scenes of early morning were shown, then proceed exposed to scenes depicting the following hours of the day, going into the night until reaching the entrance point at early morning. Changing levels of illumination and noise were included to render the experience of walking along a day more realistic. The plan was proposed to a funding agency but unfortunately was not approved —in fact its cost went well beyond the budget of the agency. But we kept the idea and finally adopted a much cheaper and mobile alternative —a digital day in the format of an animation.

The project, now called "Tempo na Vida" (Time in the Life), was submitted in 2010 and approved by the Brazilian agency CNPq (Conselho Nacional de

Desenvolvimento Científico e Tecnológico —"National Counsel of Technological and Scientific Development"). The main purpose of the project was the organization of a Science Fair which took place at Universidade de São Paulo in 2012–2013. Elementary and high school students of fifteen states of our country participated of the Science Fair with projects of research in chronobiology. The students from each of the states were recruited after we contacted former graduate students of our lab; they organized workshops with local elementary and high school teachers. The outcomes of the workshops helped us both to understand local conditions and also identify general issues. These issues ranged from a great interest on the basic notions of chronobiology paired with an almost absolute lack of previous information on the theme. Most of the workshops involved public school teachers and where work conditions are in general very inadequate. There is also a remarkable contrast between actual poor teaching conditions and a formally advanced legislation, where, for instance, we read in a document issued by the federal education authorities in 1997, that basic concepts of biological rhythmicity should be imparted to students. Our workshops thus partially filled that gap between nice recommendations and poor realities, by offering teachers material and inspiration for classroom activities.

As part of the Tempo na Vida project[1] we designed an animation depicting daily activities of a family (*Família Dias*) along the 24h of what we considered representative of the routines of an urban Brazilian family of seven members: a baby, a boy, an adolescent, a mother and father, a grandmother and an uncle (night worker). The 24 hours are divided in two–hour segments, such as 8–10

1. www.temponavida.com

AM, each segment containing hypothetical scenes of the seven family members in their activities usually performed at that time of the day. Detailed information on four biological variables are available for each member of the family in each segment: heart rate, body temperature, cortisol concentration and brain activity (EEG). Values offered in the animation are also hypothetical, although supported by data from our lab (Marques and Menna–Barreto, 2003) and from current chronobiological literature (Moore–Ede, 1982). The animation is now available in two formats, dvd and online (www.temponavida.com). English and Spanish versions of the animation are available both in the dvd and site. Material with some basic concepts and suggestions for classroom activities are also available in the dvds and in the site (only in Portuguese at this moment). In the near future we intend to reach other parts of our country and establish a digital forum open for students and teachers with a focus on the use of time in the school.

Part II – Pedagogical principles and thoughts on contemporary chronobiology

In my talk at the Mind, Brain and Education School in Erice, ten years ago, I mentioned some guiding pedagogical principles which are present in our Tempo na Vida project, most clearly in the animation and propositions of classroom activities. The main source of inspiration for us are the ideas advanced by Paulo Freire (1998) and many others who followed Freire's inspiring thoughts on education. The first idea is that teaching activities are far more effective when the students identify themselves and their daily lives in the material offered by the teachers. The second but not less important is the active role proposed for students, present in questions and efforts to solve problems ideally present in their daily lives. The third principle helps us to determine the moment when abstract concepts may be introduced, that is when the students are ready to absorb scientific knowledge, because they show their need for a better explanation more than just accept their teacher's compulsion to convey qualified information. In my teaching experience the best evidence of success are evidences of the presence of what may be called an "inner dialog" of the student with the facts and concept —that ensures long life to lessons, enriched by personal experience.

A turning point in learning chronobiology is the moment when students begin to realize the limitations of what is vulgarly diffused as the principle of homeostasis. At that moment one can go back to the question of "what is your normal state, awake or asleep" proposed in this article as an initial teaser but now charged with theoretical issues, centered around the concept of the mean value of a variable (Reinberg, 1977). The notion of an Internal Temporal Organization may be at this moment presented and discussed, mostly with the help of evidences of the consequences of the disruption of that organization. In our life we frequently are submitted to what we have been calling Temporal Challenges, situations in which we are forced to change our routines and must adjust our habits to new temporal realities. Temporal Challenges are present in the rapid crossing of time zones or in irregular working hours, and now we are able to offer explanations of the associated signals and symptoms such as sleep disorders, mood changes, and attention deficits. Temporal challenges show more adverse effects when chronic, that is, when the discrepancy between the social clock and our biological rhythms remains unstable. In fact, acute changes followed by a rapid return to habitual routines, such as an eventual night–long activity of partying or studying, may show positive effects on mood with detectable anti–depressive quality (Hemmeter et al., 2010). Sometimes along our lives we build Temporal Traps, that is, we get involved —voluntarily or not— in situations where temporal challenges are present. Environmental time cues (called *zeitgebers*) relevant to the maintenance of a stable temporal organization comprise, besides the light/dark cycle, feeding times, timing of physical exercise and probably very relevantly, social interaction (Hastings et al., 1998). Contemporary society is full of such traps especially in the scenery of globalization (Crary, 2014), so it is not surprising that we witness today, for instance, a growing number of sleep complaints, tips of the iceberg of a disturbed temporal organization. To be able to understand and eventually help individuals in such disorders one must retrace the ways in the near and remote past of their lives so as to identify what may have become temporal traps for them. Temporal traps are not evident as the spatial traps, legs do not get stuck and one is able to move, in other words, try to live in the trap. Consequences are slow in this kind of trap, they wax and wane, the surface may be for instance sleep disorders, metabolic problems or hormonal dysfunctions, hardly noticed as consequences of the trap itself. This difficulty is obviously related to prevailing concepts of life, where diseases are thought as disorders in the body machinery. Metaphors like the eye as a camera, heart as a pump or brain as computer did make sense in the early 1900, now they must be disputed since they avert our understanding by ignoring change (oscillations) as a fundamental biological property.

Chronobiology may have come to open new paths of understanding and treating diseases —first signs of this mission may be found for instance in the already significant contribution of several authors in the area of cancer research, notably findings concerning time of chemo or radio therapies (Focan, 2014). Another relevant role for chronobiology was pointed out by Russell Foster in his address to the World Conference on Chronobiology in 2012, he predicted that the present decade will be known as a decade of important achievements of chronobiology in the area of psychiatry. Education is certainly an important field for applications of chronobiology, both in the design of school schedules, notably school start time (National Sleep Foundation, 2011) and readiness to learn along the day or night (Cardinali, 2014). There is an issue which I find intriguing: when asked about the reasons for the actual timing (duration) of vacations education directors (all levels) seem surprised and say something like ″it is tradition, I don′t know where this came from″. I have been concerned particularly with the extension of around three months of the summer vacation. My colleagues often complain of the enormous difficulty in engaging the students after that long vacation. The tradition, as far as I know, dates back to the Middle Ages, when students were recruited by their families to help in harvesting chores (Kerr, circa 1969).

Most of what has been published concerns students′ rhythms (sleep and performance), but little attention has been paid to teachers′ rhythms —especially in countries like Brazil where they often accumulate jobs in different schools and have long working hours. In this article I have tried to point out the importance of chronobiology for education, both in the classroom and in planning of school activities. There is indeed much room for future research in those areas.

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The Development of Neuroeducation in China: the Past and the Future

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The rapid development of science and technology, particularly the recent progress in noninvasive brain function imaging techniques and molecular biology, has provided the tools with which we might solve some of life's greatest puzzles about our mind. In the last decade or so, the accumulated knowledge of human brain has exceeded that acquired during thousands of years' civilization. Therefore, neuroeducation, as a trans–disciplinary research field, had been emerging and developing during the last decade [1][2]. The emergence of neuroeducation had a great impact on the development of early education in China and provided a wonderful opportunity for education research innovation in China. It also produced a great influence on Chinese government policy decision makers, resulting in the change of education policies as well as classroom practices [3]. In the outline of national plan for medium and long–term education reform and development (2010–2020), the Chinese government had made the important initiative of early child development [4].

In 2002, a research institute named research center for learning science (RCLS) was founded by Prof. Yu Wei at Southeast University, aiming to conduct translational research on child development and learning science. It was the first research institute of China for doing neuroeducation research. Four years later, a key laboratory of ministry of education was also founded by Prof. Yu Wei at southeast university. This laboratory is committed to the child development and learning science, carrying out multidisciplinary translational research in the area of neuroeducation. Its target is to provide evidence–based studies to support for child development, basic education reformation, and cultivating innovation ability of students in China. After more than ten years of work, a great deal of achievements on the project of "learning by doing (LBD)" inquiry based science education (IBSE) [5][6], the assessment of child social emotion competence [7], and the evaluation of student's key concept scientific learning [8] were obtained in RCLS and the key laboratory of child development and learning science. In what follows, we will briefly review some of these achievements.

The LBD project was co–initiated by ministry of education (MOE) of P.R. China and Chinese association for science and technology (CAST) in August 2001 as a successful result of international collaboration pilot project, which aimed at promoting the children's science education as well as their holistic development and wellbeing. LDB is an IBSE project for 5–12 years old students in kindergartens and primary schools. Over 10 years' practice, LBD reaches out to 22 provinces and benefits over 200,000 students and thousands of teachers. It has become a sound foundation for revising the national standard of science education in primary schools and facilitated the national policy changing on early child development. In 2010, the work of LBD has achieved Purkwa Price in 2006 and the first class award of education research from MOE, P.R. China [6].

The development of IBSE has faced a lot of new challenges in the pedagogy, including preconception, concept construction, the role of interaction between teachers and students, choosing of key concepts and building learning progressions in science, and more importance of the creativity cultivating of students, etc. Conducting scientific research on mind, brain and education can get more reliable and clearer arguments that come from the process of the implementation of LBD. Research findings start to shed lights on how students learn and provide supports to understand the controversial questions in science education. The knowledge of the limited human working memory capacity, as well as the research on behaviors and neural mechanisms showing that the experts use core concepts, models and inquiry skills to solve their problems supports the importance of the key science concept [7–9]. The biology of long–term memory emphasizes the pedagogy based on students' prior knowledge and the assessment of their learning progression. All these pedagogies are emphasized in LBD.

Additionally, we make breakthrough in cultivating children's social emotion competency in LBD [10]. Although it is realized that the social emotional competence is the best predictor for the future success and happiness of our children, the present education curricula focus more on children's academic development than on cultivating children's social emotional competence. Based on our knowledge of emotional influences on learning and development, we have included the social emotional learning standard for the first time in the content standard of LBD science education. Children are expected to improve their social abilities and social skills during science inquiry practice. Considering the special status quo of one–child policy in China, priority is given to children's empathy of emotional competencies and self–esteem of personal characteristics. The requirements and learning stages are also proposed in the standard. Research has shown that IBSE has effectively promoted the social emotion competency of students, particularly the empathy and cooperation behaviors.

Recently, research applying brain imaging techniques to discover the neural activities underlying science learning starts to elucidate the mental processes that happened when a student acquires a new science concept [11–13]. Based on this knowledge, we design and carry out the research of science education in the perspective of neuroeducation [14]. We present the scientific phenomena consistent or inconsistent with the key concept on the computer screen. Students observe the phenomena and perform the relevant tasks according to the experimental instruction, at the same time, their brain signals are recorded. We examine the differences in EEG and ERP parameters related to the students' comprehension of science concept. The pilot experiment results reflect the potential ERP indicators relevant to science concept understanding.

The trans–disciplinary research on neuroeducation can not only support the pedagogy of IBSE and practice of cultivating children's social emotion competency, but also create scientific tools applying to measuring learning outcome in classroom practices. Four series of instruments and software are being developed in RCLS:

(1) Multiuser on–line assessment and record system for inquiry–based education. It can provide the response opportunity for over 40 learners. The teacher can record and analyze the answers from all learners at same time. These results provide for teachers with the learners' cognitive outcomes and learning progression promptly for suitable next step Inquiry–Based Education methods.

(2) Social emotional competence assessment system. The system focuses on empathy and communication assessment. In addition to the traditional questionnaire, this system will also utilize the physiological signal analysis, behavior analysis and the facial expression recognition, such that the assessment of empathy as well as the related social emotional competence becomes more reliable.

(3) Evaluating executive function system. Virtual reality created by computers and presented to the students, their behavior and brain signal data were acquired by the wearable EEG sensors measuring connected to database which forms the major parts of the system.

(4) Estimating key concept proficiency system. Virtual reality were created and presented by computers, the EEG/ERP technology are combined together to assess the students' science concept understanding.

In the future, we will continue the researches of applying neuroeducation to the child development and learning science. The work will focus more on the following three major topics:

(1) Research laboratory establishment in schools.

We are going to establish research laboratory in school to support collaboration between researches and teachers. It provides an authentic learning environment and strong foundation to formulate the research questions, analyze the puzzles of cognitive process during learning, as well as generate practical evidences that have great practice value to directly affect the students' learning process. It also contributes to train the interdisciplinary researches and future teachers who connect research with educational practice. Recently, we have implementing inquiry based science education practice in Suzhou No. 1 Middle School. We assess the students' inquiry skills and science concept understanding either by observing their activities or administering the exams. Some students' EEG signal during solving science problems will be recorded using our EEG system with the permission of their parents and the student themselves. These data are analyzed in our research lab, and the characteristics parameters and modes of EEG signal have valuable potential to reflect the underlying mental process associated with science understanding and scientific reasoning.

(2) Scientific tools development for science education.

In [5], the Nobel laureate Carl Wieman pointed out the importance of using tools of science to teach science in the 21st century science education, in which scientific tools can be used for measuring the learning outcome in classroom practices. The measuring may record the individual development pathway of learners and reflect the progress of learners during IBSE activities, and may be accessed via internet [15]. Consequently, to further facilitate students' science learning and to assess teacher's teaching effectiveness in classroom, a major task of our future work is the development of better instruments and software based on the achievements what we had obtained at RCLS during the last several years.

(3) Research platform construction for assessment of social emotion competence, executive function, and key concept understanding.

As what we have pointed out above, social emotion competence plays a crucial role for children's future success and wellbeing. Poor capacities of social emotional competence, for instance, will be strongly predictive of risky outcomes [16]. On the other hand, the well development of executive function is also crucial for children's development and learning. In addition, our preliminary work on physics key concept learning and assessment in inquiry based science education had demonstrated the possibility of using EEG to evaluate the key concept understanding for students. Hence, it is very desirable to construct a platform for children's social emotion competence assessment, executive function evaluation, and key concept understanding evaluation in the future. The desired platform is able to deal with both data collection and the assessment or evaluation tasks from gene to behavior. Most of major approaches for copying with these tasks, e.g., facial expression recognition approach, physiological parameters based approach, and EEG based approach, would be included in this platform.

In summary, our research work neuroeducation during the last decade had significantly promoted the development of early education as well as the research strategy of science education in China. Our future work will continue to this research work to promote the further development of neuroeducation in China.

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TECHNOLOGY
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SECTION 4

Informatics and Neurosciences

Neurotechnology–mediated communication: a new tool for personal rights of patients with disorders of consciousness?[1]

Michele Farisco

In the inspiring and friendly environment of the ninth *International Summer School on Mind, Brain and Education*, titled *Body, Brain and Personal Identity: Historical and Contemporary Perspectives*, and directed by Antonio M. Battro, Kurt W. Fischer and Fernando Vidal, I presented the provisional results of my investigation of the impact of neurotechnology on the speechless subjects' ability to communicate. In particular, I focused on the possible use of neurotechnology to communicate with comatose patients.

The instrumental investigation of consciousness has witnessed an astonishing progress over the last years. Different neurotechnological tools and methods have been developed in order to assess residual consciousness in patients with disorders of consciousness (DOCs). Functional neuroimaging technologies such as electroencephalography (EEG), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), positron emission tomography (PET), single photon emission tomography (SPECT), event-related potentials (ERPs), magnetoencephalography (MEG), magnetic resonance spectroscopy (MRS), and transcranial magnetic stimulation (TMS) [1], give researchers the possibility to visualize and monitor the brain activity during the execution of particular tasks. These methods of studying consciousness and the related emerging technological applications are very promising in regard to the study and the treatment of DOCs. Notably, identification of activated brain areas and real-time

1. This is a summary of the research published in

Farisco, M., Laureys, S. and Evers, K. (2015). Externalization of Consciousness. Scientific Possibilities and Clinical Implications. Current Topics in Behavioral Neurosciences. 19: 205–222 observation of cerebral activity potentially allow a new form of technology-based communication in the absence of overt external behavior or speech, thus going beyond the behavioral manifestation of awareness [2].

My research is aimed at assessing some issues emerging from this kind of communication. First of all, the relationship between brain activity, which is the specific object of the neuroimaging investigation, and awareness: how to judge when the first implies the second. Another important issue concerns the level and the kind of consciousness that patients with DOCs retain (e.g., can they perceive the same emotional meaning of the provided information?). As a further development of these analyses, the question of how to assess the capacity of patients with DOCs to make an appropriate informed decision also arises.

The application of neurotechnology to assess residual consciousness in patients with DOCs and to develop an alternative form of communication with them raise important conceptual and ethical issues, such as: what is consciousness and what is its relationship with the brain activity; what is communication; what is an ethically and legally relevant communication for decisions affecting the patients' healthcare; how to assess residual capacity of self-determination; whether and how much a prospective 'cerebral communication' may be considered as valid for an informed consent; whether a prospective direct communication with patients with DOCs through neurotechnology implies the necessity to rethink their clinical management, particularly the role of legal guardians.

It is a matter of fact that today a deep diagnostic change concerning patients with DOCs is in progress: a more graded nosology based on a quantitative assessment of consciousness and on functional neuroimaging technologies is emerging. Through brain imaging researchers have been able to detect important neurological differences between patients that are behaviorally classified as equal. The increasing refinement of modeling and simulating techniques, both at the neural and the whole brain level, are increasingly allowing more detailed description and diagnosis of DOCs and new nosographic criteria and categories have been elaborated [3]. Furthermore, advancements in neuroimaging research have allowed the development of novel investigational paradigms that provide an imaging indication of volition and awareness: this indication may appear but is not unanimously assumed as unambiguous [3].

One of the earliest studies, conducted by Owen, Laureys and colleagues in 2006 [4], is particularly relevant in showing the possible dissociation between the clinical examination based on the behavioral appearance and the results of a neuroimaging assessment (in this case, an fMRI examination). A young woman who survived after a car accident was behaviorally diagnosed as being in a vegetative state (VS) according to the international guidelines. The researchers' team pronounced some sentences (e.g., "There was milk and sugar in his coffee"), and measured through fMRI her neural responses comparing them with responses to acoustically matched noise sequences. Interestingly, the woman's neural reaction to the sentences was equivalent to the control subjects' reactions, yet this result alone is not sufficient to conclude that the woman is aware because there is the possibility of implicit processing: some aspects of human cognition, as language perception and understanding, can go on without awareness [5]. For this reason, the research team developed a complementary fMRI study asking the woman to mentally perform two tasks: imagining playing tennis and imagining visiting her house. The relevant result was that the brain activation of the woman was not distinguishable from that of the control subjects, a group of conscious volunteers.

Similar results were obtained in the follow-up study jointly conducted in Liege and Cambridge. 54 patients with severe acquired brain injuries were scanned through fMRI: in response to the request to perform imagery tasks, 5 of them were able to modulate their brain activity by generating blood-oxygenation-level-dependent (BOLD) responses which were judged by the researchers as voluntary, reliable and repeatable [6]. Additional tests in one of the 5 responsive subjects revealed his ability to correctly answer yes-no questions through imagery tasks, showing the feasibility of communication. These results are ethically very significant: if new diagnostic tools are available, then it is ethically warranted to use them and to give all the patients the possibility to be rightly diagnosed through them.

A prospective ethical and scientific challenge is to translate the outstanding technical advancement in assessing residual consciousness, modeling brain activity and implementing new forms of "cerebral communication" from laboratories to clinics. In particular, I am currently co-editing a book titled *Neurotechnology and direct brain communication. New insights and responsibilities concerning speechless but communicative subjects* focused on the application of these prospective developments to infants and comatose patients [7].

My present research, developed within the European Human Brain Project as part of the Subproject 12, devoted to Ethics and Society, is aimed to conceptually clarify the relationship between consciousness and brain, trying to develop a general theoretical framework for assessing specific practical issues concerning patients with DOCs, such as the cerebral communication with them.

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Studying teaching using robots

Anna-Lisa Vollmer

There is a lot of research about how we learn, but only relatively little about how we teach and in particular how we learn to teach (Strauss et al., 2002). It is difficult to study teaching, because experiments with teaching situations are foremost asymmetric with the learner lacking the knowledge the teacher wants to convey. Interactions with learners like children, impaired persons or elderly people in experimental settings are difficult to control such that individual behavioral aspects could be varied and their effects studied.

Humanoid robots that can be fully programmed to exhibit ever constant performance, such that they always produce the same behavior, could serve as a tool for understanding the cognition of teaching. A robot would not involuntarily emit social signals in interaction like even the best trained experimenter most likely would. The advantages are twofold: (a) On the one hand, we can advance our understanding of human teaching behavior. (b) On the other hand, we can pave the way towards building better robot systems capable of learning from the instructions of non–expert users, which is one of the big challenges in the field of robotics today.

Even though robots seem to be a promising experimental tool, there are still many unknown variables that are being explored at the moment. For instance the appearance of the robot is a strong factor in how we act towards it (e.g., Goetz et al., 2003).

Also towards humans our behavior differs depending on our audience. Infants for instance receive a special kind of input called ‘motherese’ (behavior modifications in speech) (Fernald & Mazzie, 1991) and ‘motionese’ (behavior modifications in movement) (Brand et al., 2002). What are the factors that cause these behavioral adaptations?

Concerning motionese, Herberg and colleagues for example already found differences in task demonstrations when presenting adults with images of an adult, a child, and a computer (Herberg et al. 2008). However, images are not responsive learners, which one might argue to be essential for teaching. So, when adults demonstrate actions to a responsive robot simulation with a child–like appearance, they exaggerate their motionese behavior even more for the robot than for the child (Vollmer et al. 2009a). In contrast to adult–child interaction (ACI), where the tutoring behavior seems to bear lots of variability, in adult–robot interaction (ARI), more stability can be observed. This suggests that ARI indeed allows controlling for the parameters of the learner and is thus a promising method for studying teaching behavior. But something is missing in the robot's behavior, as the teacher's eye gaze behavior shows even less contingency toward the robot than toward another adult. These results raise an interesting question: why is the behavior of the tutors in the ARI condition less contingent than in the ACI condition? The robot that we used in this study showed purely reactive behavior in the form of a low–level attention mechanism (Nagai & Rohlfing, 2007). As contingency is a bi–directional phenomenon (Csibra & Gergely, 2006), it is likely to be related to the robot's feedback behavior. The tutor is waiting – possibly in vain – for a sign of understanding from the robot. And as the tutor does not receive the expected feedback of understanding from the robot, s/he does not search for eye contact with the robot.

Thus, even though the robot's behavior does induce some characteristics of parent–like teaching (as indicated in a qualitative study by Nagai et al. (2008), and similar to the findings of Herberg et al. regarding still images), it does not seem to be sufficient to produce a contingent interaction.

To assess what is missing in the robot's behavior and in order to understand which factors might influence teaching, we further studied adult–child tutoring interactions. We observed that the teacher's movement modifications depend on the child's age and capabilities (Vollmer et al. 2009b, Rohlfing et al., submitted). Whereas hand movements attracting attention can be found in tutoring of younger infants, interactions with older children seem to benefit either from the increase of children's attention abilities or that parents use other means (such as language) to attract their attention. Parameters accounting for the structure of the action persist over age and verbal capabilities.

But also on the learner side children give different feedback according to their age and capabilities (Vollmer et al., 2010). This feedback operates as continuous involvement and at specific places within the structure of the interaction. Prelexical infants of 8 to 11 months of age primarily show gazing behavior displaying attention, early lexical infants of 12 to 24 months anticipate next actions and make use of gestures, vocalizations and smiles, and lexical infants (25–30 months) give feedback much more systematically according to the structure of the task.

In qualitative and quantitative analysis we observed an interactional loop of micro–adaptations between the infant's gaze and the adult teacher's hand movements (Pitsch et al. 2009, 2014). For example, we found high arcs in the hand movements to engage the infant to follow the hand and peaks in the movement to organize attention. In contrast, we found flat trajectories were shown when the child anticipated correctly a next action. When comparing motionese when the child is monitored vs. when the tutor rather concentrates on the task, we found stronger motionese when the child is monitored. And when it is not, the tutor cannot directly react to the child. Motionese thus at least in part is a reaction on the infant's actions, which in turn act upon the tutor's actions.

The above studies emphasized that teaching is a bidirectional endeavor. According to this interactionist view (cf. De Jaegher et al., 2007), the feedback of the learner is important, because the learner shows his/her understanding and knowledge of the action with feedback. The tutor monitors the feedback to build hypotheses on what the learner understands and alters his demonstration according to the built hypotheses. In the studies, we identified first factors concerning learner behavior and mutual adaptations crucial to teaching/learning interactions to be studied in human–robot interaction (HRI) in a next step.

To investigate how a *robot*'s feedback modeled after infant feedback influences people's teaching behavior, we conducted a HRI experiment with unexperienced users (Vollmer et al., 2014a, Pitsch et al., 2013). In this example of a study in which an embodied humanoid robot was used as interaction partner, and only carefully selected parameters (identified in the above ACI studies) in the robots behavior were modified, the robot gave feedback online (gaze), but also at specific points in time (beginning and end of a demonstration, and replication of the demonstrated action). To summarize the results of this HRI study: The users' action demonstrations strongly depend on the feedback that the robot gives. They adjusted their demonstrations online according to the robot's behavior and their derived conception of the robot's capabilities.

To conclude, we do not only teach other humans, but also extend and adapt our teaching to objects we anthropomorphize, like robots. Interactional adaptations seem to be able to be activated by robots as well (cf. Vollmer et al., 2014b for the case of alignment). Robots can be used as a valuable tool to study the cognition of human teaching, but the robot's role as a learner in the interaction seems to be an important one. However, so far robots are not capable of interactions with a flexibility similar to the one we observe in human interaction. One important next step is thus to enable robots to interact more flexibly. This is an important key challenge for robotics research, which may only be solvable in interdisciplinary collaboration and with parallel insights from human–human interaction research.

One prospective way to study teaching and even interactional processes like alignment and grounding, and the impact of perspective taking and role reversal, is the development of novel experimental setups (e.g., Vollmer et al., 2014c) in which two adults interact in very controlled, but unfamiliar, settings forcing them to learn anew how to interact.

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Toward physiological understanding of mind, brain and education

Yusuke Seki

Introduction

Education has been a critical issue for human societies [1]. Investment in education technology (EdTech) in the United States soared to $1.1 billion in 2012 [2]. Although there are multiple levels of educational processes, they can be quantitatively described using various indices such as test scores, study hours, number of teachers/students, etc. In addition to these conventional indices, the use of other indices based on physiology and biology such as behaviors, neurons, molecules, and genes has been investigated [3]. The idea that multiple levels of analysis are necessary to dissect teaching and learning can be expanded from individual to school and even to human society. The multiple levels of educational processes form complex networks [4]. For example, performance on a behavioral test is affected by several cognitive processes related to different areas of the brain. It is thus important to recognize that complex educational processes underlie every quantitative result obtained at each level.

Neuroscience is being used to advance the study of education. For example, learning disabilities such as dyslexia are now understood in the context of a neurological disorder. Effective educational methods have been developed on the basis of neuroscience. Therefore, observation of physiological signals such as neuronal activity and cerebral hemodynamics by using state–of–the–art technologies is important to understand education. This review discusses possible applications of neuroimaging technologies to educational research. The future of neuroscience and education is also described.

YUSUKE SEKI

Physiological understanding of education

Application of neuroscience to learning disabilities

Several imaging technologies underpin neuroscience. Since non–invasiveness is basically required for human neuroimaging, electroencephalography (EEG), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), and near–infrared spectroscopy (NIRS) are typically used to observe neuronal activity in the human brain. EEG and MEG detect electromagnetic signals induced by neuronal activity with a time resolution below one millisecond. fMRI, which is widely used, captures hemodynamic activation patterns correlated with neuronal activity in the brain by detecting blood oxygen level dependent (BOLD) signals. NIRS uses near–infrared light to reveal hemodynamic activity and enable visualization of activation areas in the cortex.

These neuroimaging technologies have been used to delineate learning disabilities. For example, the late mismatch negativity, which is a component of the event–related potential (EEG signal) in response to an odd stimulus in a sequence of stimuli, might be a potential endophenotype for dyslexia [5]. The overall interhemispheric amplitude balance and timing in the auditory–evoked field (MEG signal) in response to a speech sound and artificial speech sound were altered in dyslexic subjects [6]. Brain areas involved in typical reading development and dyslexia have been measured using fMRI [7]. Activations of two language areas (Broca's and Wernicke's areas) induced by a writing task were mapped using optical topography (i.e., multi–channel NIRS system) [8].

Neuroimaging technologies (MEG/NIRS)

The intensity of a MEG signal is less than a few hundred femtotesla, which is less than one hundred millionth of the earth's magnetic field. MEG signals are thus measured using ultrasensitive magnetic sensors based on a superconducting quantum interference device (SQUID). Moreover, the effect of environmental magnetic field noise must be reduced by using a magnetically shielded room (MSR) and SQUID gradiometers. However, an MSR is an obstacle to reducing both the cost and size of MEG systems. In response to this, my group developed an unshielded MEG system [9] using a high–performance SQUID gradiometer [10,11].

Furthermore, understanding the correlation between neuronal activity and hemodynamics, namely, neurovascular coupling (NVC), is a key to understanding brain functions and neuronal diseases. For example, Alzheimer's diseases have been widely studied by focusing on NVC, which can be investigated by simultaneous observation of both neuronal activity and hemodynamics [12]. When a stimulus is applied to the body, neurons are activated, triggering a hemodynamic response [13]. Therefore, NVC can be studied by simultaneously measuring neuronal activity and cerebral hemodynamics. For example, Logothetis *et al*. simultaneously performed fMRI and measured various kinds of extracellular potentials in a monkey. They found that the origin of BOLD signals is not a spike but a local field potential (i.e., synaptic activity) [14]. Investigation of NVC in the human brain requires the use of non–invasive methods. Using our unshielded MEG system in combination with an optical topography system, we simultaneously measured both the auditory–evoked magnetic field and the blood flow change in the auditory cortex [15].

Future of neuroscience and education

Cutting–edge technologies for neuroscience

Neuroscience research is currently attracting much attention. Both Europe and the United States are planning billion–dollar ten–year investments to clarify how the brain works [16]. To understand brain function, we need to identify not only the function of each part of the brain but also how the parts are connected [17]. A remarkable innovation in neuroscience is "see–through brain technology," which makes tissue transparent [18,19]. This technology enables three–dimensional views of fluorescently labeled neurons to be obtained for areas ranging from the cortex to deep structures such as the thalamus. It will thus help clarify our understanding of connectivity in the brain. The *Blue Brain Project* is aimed at making a complete brain model by using a supercomputer to integrate all biological knowledge about the brain [20]. Such an ambitious project will be made possible by state–of–the–art computing technologies.

Human iPS cell technology (nuclear reprogramming) is another key to understanding brain functions and neuronal diseases. Animal models such as the knockout mouse and transparent zebrafish are indispensable for translational medical research and drug discovery. Unfortunately, establishing an animal model for educational research has proved difficult. Although some animal models of cognitive dysfunctions such as Alzheimer's disease have been reported, an animal model for researching human education is difficult to establish because education is an essential human activity.

In contrast, it is likely that an *in vitro* model of education will be established. This is because human iPS cell technology enables creation of an *in vitro* model of a neurological disorder such as Alzheimer's disease, Huntington's disease, Rett syndrome, Lesch–Nyhan syndrome, Parkinson's disease, and spinal muscular atrophy [21]. Human iPS cell technology should lead to early diagnosis and preemptive therapy [22]. Therefore, early diagnosis and preemptive therapy of learning disabilities should be possible in the future.

Educational issues in the digital era

The advent of EdTech has brought a paradigm shift in the educational environment. EdTech has been propelled by high–speed mobile networks, cheap tablet devices, the ability to process huge amounts of data cheaply, sophisticated online gaming, and adaptive–learning software [2]. How EdTech–based education can make a difference in the context of neuroscience will be an important topic in educational neuroscience. The ability to now access any kind of information by using the Internet means that integrating information and taking action will become more important in the future. Development of creativity and leadership abilities will become a key educational issue in the digital era.

Summary

Noninvasive neuroimaging technologies are useful for evaluating educational processes. However, more complex analysis such as analysis of neurovascular coupling and connectivity is needed for further physiological understanding. As for educational modeling in neuroscience, human iPS cell technology should enable creation of an *in vitro* model of education, which should lead to early diagnosis and preemptive therapy of learning disabilities. The educational environment is rapidly changing, and neuroscience based on educational technology will attract much attention. Development of creativity and leadership abilities will thus be increasingly important in the digital era.

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Teaching and Learning as interpersonal and innerpersonal phenomena: Where bodies and minds meet

Katsumi Watanabe

My first visit to Sicily, and in fact Italy itself, was during the summer of 2012. Prior to that, my only knowledge of Sicily entailed what I had seen by watching The Godfather. Initially, I was overwhelmed by the scenery and foods, but later mesmerized by the intense, yet friendly discussions that transpired at the International Summer School on Mind, Brain, and Education. Indeed, I learned a great deal from this experience. Although it is impossible for me to describe this experience in its entirety, I would like to summarize and reflect on some of these discussions, the idea of education as dynamic interpersonal phenomena and the interplay between body and mind in education, which eventually spawned a research project.

Education as implicit interpersonal and interbrain phenomena

There are many forms of implicit agreement or tacit knowledge in education. Regardless of educational consequences, we are aware that environments exist leading to either good or bad instruction. Nevertheless, describing these environments is problematic, and it is markedly difficult to implement processes to mediate such contexts. In my talk at the 8th International Summer School on Mind, Brain, and Education (and also in a subsequent paper; Watanabe et al., 2013), I argued that the implicit processes of behavioral contagion and inter–brain synchrony support a concept of dynamic, interactive, and context dependent teaching and education in general.

Behavioral contagion is one potential foundation of personal interaction. The implicit tendency of people to imitate each other is well known. In both low–level sensorimotor and high–level conceptual processes, mimicking of other people occurs through explicit and implicit processes. One of the theoretical foundations of explicit and implicit mimicking assumes and emphasizes the indispensable relationship between perception and action. If the execution and observation of behaviors inevitably interact, it is assumed that the execution and/or preparation of behaviors will be influenced by the observation of others' behaviors. The teaching and education process in its essence is an interaction that is much more complex than a mere connection. A teacher perpetually absorbs sensory information from his or her learners, which is then used as a basis for the modification of their instruction. This further supports the notion that teaching is an interaction, and certainly one that is highly reciprocal when performed correctly (Rodriguez, 2013). Behavioral contagion can therefore be considered a foundation for ambient educational contexts.

Another indispensable foundation is brain and bodily synchrony, which is considered to be a social self–organizing process. While many studies show synchronizing phenomena in simple periodic behaviors, behavioral synchrony also occurs in more complex, real life situations, such as in teaching and during human development. The synchrony of bodily movements and behaviors between a teacher and his or her students in teaching and learning interactions is actually a self–organizing synchronization process (Kent, 2013; Clunis D'Andrea, 2013). A line of our studies demonstrated that inter–brain couplings change in the absence of explicit instructions for interactions between persons (Watanabe et al., 2011; Yun et al., 2012). Here, it is the connected network formed by both brains that changes. Moreover, information, knowledge, and concepts are not simply transferred, but can emerge spontaneously through interpersonal interactions between students and teachers. This again supports the notion that teaching is a process that combines several theories concerning a learner's mind with an instructor's meta–processes and their effect on an interaction (Rodriguez, 2012), which evolve to form a highly complex, self–organizing system.

Embodied implicit knowledge in education and metacognition in learning: where bodies and minds meet.

Education, specifically teaching, is a miracle that manifests itself when more than two minds interact. I stated in one of my papers that, "Teaching by definition involves at least two agents," and is therefore "different from learning" (Watanabe, 2013). However, after being afforded some years to reflect on and observe how people learn, I have come to realize that my assertion was partially incorrect: both teaching *and* learning are miracles. Like teaching, learning does not take place within the confines of a single mind. Furthermore, learning not only requires more than two minds, but also a structured environment and meta–knowledge of one's self and the world. This especially true given our contemporary information environment, wherein the opportunity and importance of the selection and recurrent usage of information, in addition to self–regulation, are increasing. In the digital era, learning is similar to teaching, and has become a form of self–education and self–organization.

To understand complex pedagogical phenomena in the digital era, scientific knowledge and technologies to assist in measuring and controlling human behavior and mind are vital. This is because learning, practicing, and teaching all include implicit processes. Additionally, in this respect, my discoveries concerning interpersonal information are relevant, as the underlying research was based on a desire to facilitate effective communication and, by extension, education. However, doing so is heavily dependent on implicit, non–symbolic information, which emerges through dynamic interactions among agents during collaborations and self–education. However, how such interactions are manifested and regulated in everyday life is largely unknown. Likewise, technological developments based on implicit inter– and inner–personal communications have not yet materialized.

For example, consider the kinds of educational interactions that transpire between an athlete (student) and a coach (teacher), wherein there are several different channels though which information can be conveyed. Such channels might include explicit and implicit (a) bodily feedback based on an athlete's actions, (b) feedback from a coach through the observation of an athlete's movements, and (c) feedback derived from observations of an athlete's own performance, in addition to

(d) direct conversations, (e) social encouragement and discouragement, and (f) an athlete's life patterns. Similarly, patterns that appear on the surface of an athlete's body, such as complexion, perspiration, breathing patterns, and movements can be indicative of his or her state. Furthermore, it is known that environments exist conducive to either good or bad performance, although these results are often consequential, and frequently independent of the consequences of interactions between agents. Such outcomes may appear to transpire spontaneously, but are nonetheless felt by participants in a given interaction. To describe what these environments actually comprise is a rather difficult undertaking, yet less so than implementing processes to produce them. This is largely because agents are unaware of said processes when they are thoroughly engaged in activities.

In line with the aforementioned notions, in addition to recent advances in performance materials capable of measuring biometric information, I commenced a new project focusing on information processing systems based on implicit ambient surface information ("Intelligent Information Processing Systems based on Implicit Ambient Surface Information"). This project combines and extends the knowledge and technologies discussed in prior research endeavors in order to understand information that is present on both the surfaces of human bodies and machines, but nevertheless ignored. By utilizing this information, it is possible to establish intelligent information processing systems for creative human–machine and human–human collaborations. The specific aim is to develop technologies capable of recoding and decoding implicit bodily movements and physiological responses, while also being heedful not to disrupt natural behaviors. In doing so, scientific knowledge can be attained for theoretical advances. The use of implicit ambient surface information through explicit and implicit feedback will be affording learners and teachers to opportunities to think (or even not think) about how a given implicit interaction might be impacted by them. This will lead to metacognition and emotional regulations in order to understand their performing context. The knowledge and technologies that are eventually born from the aforementioned project should contribute to facilitating explicit and implicit collaborations between humans, humans and machines, humans though machines, and possibly machines themselves. This, in turn, will produce a new approach to understanding the miracles of learning, teaching, and education as they relate to the human mind and how they will evolve in the digital era.

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SECTION 5

The Teaching and Learning Brains

A time to learn, a time to teach

Daniel P. Cardinali and Diego A. Golombek

Eight years ago we had the pleasure to serve as the Directors of the Second International School on Mind, Brain and Education Basic and applied topics in biological rhythms and learning, Ettore Majorana Center for Scientific Culture Erice, Italia. The meeting was devoted to the role of sleep and circadian rhythms on teaching and learning activities. It was a very active scientific endeavor that eventually resulted in the publication of two issues of *Mind, Brain and Education*, i.e. volume 2, number 1, 2008 and volume 8 number 4, 2014.

Our knowledge of the basic mechanisms, physiology and molecular biology of sleep and circadian rhythms, including the deleterious effects of circadian disruption has significantly expanded in recent years [1]. Specific polymorphisms that affect the timing of sleep have been identified and, in addition, the idea of "social jet–lag" (i.e., the situation in which external —environmental, work and school–related— timing is separated from, and sometimes opposed to, endogenous circadian timing) has gained a significant momentum, with data suggesting this situation is a clear symptom of contemporary society [2].

Indeed, sleep is an essential process in life. It is a behavioral state defined by: (i) characteristic relaxation of posture; (ii) raised sensory thresholds; (iii) distinctive electroencephalographic (EEG) pattern; and (iv) ready reversibility [3]. Based on polysomnographic measures, sleep has been divided into categories of rapid eye movement (REM) sleep and non–REM (NREM) sleep (also called slow wave sleep). Sleep alternates between NREM and REM stages approximately every 90–120 min and these recurrent cycles of NREM and REM sleep are accompanied by major changes in physiology [3]. It can be said that we live sequentially in three different physiological states ("or bodies"): that of wakefulness, that of NREM sleep and that of REM sleep.

Since epidemiological data indicate that in our modern society we indulge about 6 h of sleep per day, the relatively longer wakefulness stage, and the relatively shorter NREM stage, have strong negative consequences for health. There is an increasing evidence that a number of endemic pathologies like obesity, the metabolic syndrome and neurodegenerative diseases can be related to the prevalence of wakefulness in face of NREM sleep loss in contemporary, 24/7 Society [4].

Healthy adults need 7–9 hours of sleep per day and school–age children might require 10–11 hours of sleep [5]. In 2010, approximately 30 % of USA adults and 44% of shift workers reported less than 6 hours of sleep / day [6], which has been associated with fair/poor general health, frequent mental and physical distress, depressive symptoms, anxiety, and pain. Sleep insufficiency and poor sleep quality can also result from sleep disorders such as chronic insomnia, restless legs syndrome, sleep apnea, or narcolepsy.

An extreme case of sleep deprivation resulting in poor performance is found in adolescents, whose circadian clock appears to be phase–delayed and, therefore, inappropriate for the usually very early timing of high school start time of classes. Sleep in adolescents has been shown to be an important factor when looking at physical, mental and social well–being. Adolescents with short sleep duration are at an increased risk of accidental injuries [7] and a number of studies have demonstrated that sleep of insufficient duration or quality is associated with different negative mental health outcomes that include anxiety, depression, and bipolar disorders [8]. Youths who experienced sleep problems had greater odds of interpersonal dysfunction [9]. Also, late bed and rise times, erratic sleep–wake schedules, shortened total sleep time, and poor sleep quality are negatively associated with academic performance [10] [11].

Several factors affect sleep in this age group. Developmental changes due to intrinsic regulatory mechanisms in the homeostatic and circadian sleep processes delay the timing of sleep. Psychosocial issues as self–selected bedtimes, academic pressure, the use of technological resources and social networking in the evening also delay bedtime. On the other side, social pressures determine an early rise time for starting school day timely. Therefore, adolescents are asked to be awake at an inadequate circadian phase and sleep too little. Indeed, since school start time is a deterministic factor in adolescent sleep loss and disruption [12;13], a simple solution would be to slightly delay such timing. There is substantial evidence that demonstrates that delaying high school start times results in significant improvements in academic performance, reduced mood disorder–related complains and, in particular, an increased sleep time and quality [14;15].

In addition, a "sleep disparity" exists in the general population since poor sleep is strongly associated with poverty and race. A differential vulnerability to factors such as health, education and employment was suggested as mediator for this effect [16;17]. Adolescents from lower socio–economic households have poorer and less consistent sleep than those from more favored backgrounds, being the neighborhood and home conditions the aspects associated with these observations. This is aggravated by the fact that in poorer households child work is much more common, which tends to increase the risk for sleep problems since adolescents are involved in dual duties that further limit their time for sleep. According to the International Labor Organization (ILO) around 168 million children aged 5–17 years worldwide are engaged in child labor, accounting for almost 11% of the child population as a whole [18]. In Argentina, approximately 20% of teens between 13 and 17 years were involved in economical activities and 14% was involved in intensive domestic work in 2012.

In this context, less attention has been paid evidence to the sleep problems in adolescents from households facing extreme poverty conditions, where conditions like crowding, poor housing, sanitation or educational level, and a precarious employment set an adverse environment for sleep. For instance, slum dwellers report bad indexes of sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, daytime dysfunction that improve after minimal changes in the quality of basic housing. Understanding sleep patterns in this population could help to define interventions to reduce sleep disparity [17].

Sleep in adolescents has been shown to be an important factor when looking at physical, mental and social well–being. Little evidence is found regarding sleep patterns in adolescents from households facing extreme poverty, where conditions like crowding, poor housing, sanitation or education, and precarious employment set an adverse environment for sleep.

In a recent study our research group sought to assess in a nation–wide sample comprising 1682 adolescents, how the presence of extreme poverty affects the relationship between sleep duration and school, work and other daily activities in Argentina [19]. The Unsatisfied Basic Needs (UBN) index was used as an indicator of extreme poverty. The presence of UBN was defined when children or adolescents lived in a household that presented at least one of the following: a. more than three people per room (crowding); b. house built with irregular materials or living in a rented room (housing); c. not having an indoor flush toilet (sanitation); d. having a child between 6–12 years old who is not attending to school (school attendance); and e. households with four or more people per employed person the maximum educational level of the household head being elementary.

A global high prevalence of short sleeping time, a slight increase of sleep time in adolescents with UBN, and different patterns of wake activities that predict sleep deficit, depending on the presence of UBN, were found. The poor academic achievement, increased risk of accidents and adverse health outcomes associated with sleep deprivation support the view that sleep is an additional unsatisfied basic need that worsens living conditions at this age. The results may help to design public health policies that contribute to ameliorate this adverse situation.

In our study the presence of UBN increased rise time and sleep duration. This contradicts previous literature, where a lower socioeconomic background is usually associated with less sleep duration and more sleep disruption in adolescents. Socioeconomic demographics like income, educational level, and employment status are usually associated with more delayed, shorter duration, and less consistent sleep patterns [20]. However, none of these studies focused in situations of extreme poverty. Among the factors associated with the presence of UBN that may justify these findings, the assistance to nearby schools probably explain the increased rise time and indirectly the increased sleep time. The association between UBN and attendance to neighborhood schools is as expected, since better schools tends to be available for families with higher socio–economic status through residential mobility and enrolment in private schools. Another factor that could explain the increased rise time is the observed lower percentage of children that assist to extra–curricular intellectual or physical activities.

School starting time and full–day schooling were strong predictors of sleep deficit in adolescents with and without UBN. Starting school at the morning school is a well–recognized risk factor for sleep deprivation, determining less time spent in bed, worse sleep quality and increased daytime sleepiness which in turn leads to bad mood and poor performance. Unlike other school systems, in Argentina some schools have half–day schedules while others full–day schedules. It is expected that the extended day pose a higher risk of sleep deficit, because it combines an early school starting with being at school most of the day, thus preventing the possibility of taking naps or delaying bed time.

Child labor was a predictor of sleep deficit. In adolescents without UBN, the risk is associated with paid work, while in adolescents with UBN is associated with intensive work at home. Our results were consistent with those of previously published studies that show that adolescents who work wake up earlier and have decreased night and total sleep duration during the week than nonworking students [21].

To conclude, in the first issue on Mind, Brain and Education devoted to the subject (volume 2, number 1) we finished our introduction by stating that "The concepts of time and timing —deeply controlled by the brain— need to be incorporated into any general view of educational processes" [22].

Six year later the prediction is still unfulfilled. This occurs in spite of the fact that chronobiology has certainly advanced our understanding of the strong influence of timing on education and academic performance, as well as for the quality of life of not only students but also teachers and parents. Indeed, the scientific study of biological rhythms and clocks can be considered part of the necessary bridge between neuroscience and education, which was originally defined as "too far" but only recently has been considered to be possible. Indeed the construction of direct links between brain data and pedagogical interventions promises to be a particularly important field of research for future neuroscience.

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Meno, the whole experiment

Andrea Paula Goldin

Almost 25 centuries ago, Plato wrote Meno. Meno is the name of a person that engaged in a dialog with Socrates, a dialog which seems to be the first written educational method of humanity, the "Socratic dialog". At that time it was thought that soul was immortal and, after somebody died, their soul would go to another body. And, in each of their lives, souls would learn a bit more. Talking to Meno, Socrates states that the role of a teacher is not to teach, but to help the student to "extract" from her soul the needed knowledge already learned in previous lives.

To prove his point, Socrates told Meno that he could show that somebody who apparently does not know anything, does actually know something. Meno proposed to use a slave who was with him since his birth and who never went to school. Socrates replied that, if the slave spoke Greek[1], he would be perfect. Meno's slave (who did not even have a name) interlocked with Socrates in a passionate dialog consisting of 50 questions posed by Socrates and answered by the slave, while drawing in the ground with a stick.

Socrates presented the slave with a 2–by–2 feet square and, after exploring whether the slave knew some basic geometrical notions about squares[2], they agreed that if a square were to duplicate the area of that 2–by–2 square, the resulting square's area should be eight. At that point, Socrates posed the question that would guide the whole dialog for the first time, question number 10 (Q10): «And now try and tell me the length of the line which forms the side of that double square: this is two feet —what will that be?» He was asking about the length of a side of the second square. And during the fifty questions, the slave went forth and back to finally say that the side of the resulting square would be the diagonal of the original square.

1. This was mandatory as they needed to comunicate.

2. For the complete dialog, please refer to Ref. (Plato, n.d.) or Ref. (Goldin, Pezzatti, Battro, & Sigman, 2011).

During the fifty questions, the dialog also explores basic geometrical and mathematical principles that underlay Pythagoras' theorem. For instance, that length and area grow in different proportions (i.e. duplicating the side of a square should quadruply its area) or that irrational numbers exist (i.e. the side of the new square ought to be between 2 and 4 but it is not calculable). A few years ago, Antonio Battro showed this amazing dialog to Mariano Sigman, and we decided to conduct an experiment at the lab to find out if two and a half centuries of education had made an impact on the way our society solves the double–square problem. We would engage twenty–first century free–thinkers in the same dialog that a slave had had with Socrates so long ago.

The original transcription was a smooth dialog that flowed between two persons: Socrates posed a question and the slave answered freely. In an experiment, we could pose one specific question but the subjects could virtually answer anything. Hence, we decided to pilot every question to find all the possible answers that our subjects could give. We then classified those answers as 1) being the same, or 2) being different than the slave's answer. Also, many of the different answers could be mathematically correct or not. For instance, the first time the slave answered Q10, he said that in order to duplicate the area, the side should be duplicated. The slave, guided by Socrates' questions, would then elaborate on this idea until he understood that a side of four would not give an area or eight but of sixteen. If an experimental subject understands more things than the slave, he might say that the side should be smaller than four, which is a correct answer though different than that of the slave.

We then transformed the dialog in an experimental setup as follows: each question included what the experimenter should say while performing an action (where to point, what to draw, etc). Then, the experimenter should compare the subjects' answer to a list of possible responses (obtained as previously explained) and, depending on that, the experimenter would decide which question s/he should pose. If an answer was the same as the one given by the slave[3], the experimenter would pose the question that immediately followed. But if a subject's answer was correct and different than the one the slave gave, it was pointless to ask the following question. The experimenter would rather jump to another (predefined) question. For instance, the second time the slave answered Q10, he understood

3. If two answers involved the exact same concept but used different words, we considered them as being equal (i.e. saying “two”, “twice” or “double”).

that the side should be between 2 and 4 and answered "three" and, after that, the slave explored with Socrates why three is bigger than needed. So, if a subject answered "it has to be less than three" and s/he proved to understand why s/he says so4, the experimenter would jump to the question that Socrates posed after the slave understood that the side ought to be less than three.

Using the script, we conducted all the experiments with each dialog following its own path. The experimenter would play the role of Socrates, "the teacher", and the experimental subject would play the role of the slave, "the student". We found a very high agreement between the answers of the illiterate slave and those of our educated subjects (Goldin et al., 2011). As explained before, many of the subjects could skip some of the questions but more than 65% of the questions were answered and, for those, over 90% of the responses were consistent with the slaves' (and most of the differences resulted from responses that were mathematically correct).

Our first conclusion was that whoever Socrates was, his understanding of the human cognition was outstanding, exceeding times. But we did not stop there. We already knew that after following the dialog, both the slave and all of our subjects succeeded in answering that the side they were looking for was the diagonal of the original square, and they could even point at it5. Furthermore, the last three questions of the dialog (48 to 50) reverberated and reinforced this answer.

If this Socratic dialog is truly educational, it should promote learning. To test this hypothesis, we added a question (Q51) in which we gave our subjects a new square (without explicit size but different from the 2–by–2 one) and posed them the same question that ruled the dialog they had been following for 20 minutes: they had to find the side of a square whose area were the double of that of the new square.

4. If, at any point, an experimenter doubted that the subject understood his/her answer, the experimenter would request the subject to explain his/herself and, if the explanation did not satisfy the experimenter, the answer was not considered correct. In this example, a proper answer for an explanation should be "it should be less than three because three gives a square of nine and we needed a square of eight". But if in the example the subject answered "less than three because I think so", the experimenter would go through all the following questions as if the subject had answered "three".

5. At Q33, the slave seems to quit while answering "I do not know, Socrates". At that point, Socrates does what he denies: he teaches. He orientates the slave's attention specifically to the diagonal, which is the answer.

We run all experiments on adults (who had all at least finished high school) and adolescents (who were in high school). Q51 was posed immediately after the answer of Q50, and nobody knew that it was “something special”. Puzzlingly, we found that half of the adolescents and almost one third of the adults could not answer Q51 properly. A lot of the subjects could not generalize that what had happened to the original square would happen to every square, even those that had strictly followed the dialog. The latter suggests that if we had posed Q51 to the slave, he would have failed. Actually, we found a negative correlation between the number of skipped questions and the probability of generalization (i.e. answer Q51 correctly). This insinuates that those subjects that could learn were those that already knew the things that were essential to extract the important information from the dialog, and hence, those that were “more prepared” to really learn what Q50 was originally testing.

We added more evidence to this result in a follow–up experiment looking at what was happening in the brains of the teachers and the students while they were engaged in the dialog.

For the first time, a two–brain educational process was being literally watched (Holper et al., 2013). We explored the hemodynamic response6 of the prefrontal cortex (PFC) of both participants during the whole dialog searching for a neural marker that could help explain the differences between those students that could generalize and those who could not.

After the diagonal argument was exposed for the first time and until the end of the dialog, the PFC activation (measured as increase in oxyhemoglobin concentration, [O_2Hb]) of each student correlated with the [O_2Hb] of the corresponding teacher. Interestingly, the correlation was positive for those dyads whose student would transfer the learned knowledge, and it was negative for the dyads whose students would not generalize it, suggesting that there is a need of some kind of brain synchrony between the student and the teacher for the student to properly learn.

To our surprise, we found that the [O_2Hb] of those students who were not going to answer correctly Q51 was significantly higher (during the dialog) than that of

6. A wireless device of functional near infrared spectroscopy (fNIRS) located on the skin of the forehead served as an optical method that allowed to calculate the ratio of oxi- and deoxi-hemoglobin and to use it as a meassure of cognitive work.

those who were going to generalize. Furthermore, this increase was independent of their teachers, all of whom showed similar PFC activation levels, no matter if their student was going to be able to generalize or not.

If we think about the building of knowledge as the construction, maintenance and growing of brain networks 7, this result can be understood under the light of economy of resources. If a person has the proper background to incorporate a new knowledge to it, then that incorporation will involve less brain activity, it is "cheaper". But if a person has to learn too many new things, getting to the appropriate level to incorporate knowledge will be more expensive and could not be done to the whole extent. Some things will be learned while others will not.

Educationally speaking, those students who could not apply the new knowledge to any square puzzled us the most. What had they learnt? They did not get to the proper level to apprehend what they were meant to. But for sure, after being immersed in almost the whole dialog, they had learnt something. The "extra" PFC activity shown by those students who could not generalize went in the same direction: their brains were learning so many things that could not handle all. The question now is what those who were not yet prepared to transfer did learn. We are exploring this right now.

7. "Schemas", may be? Ref.(Tse et al., 2007).

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Teaching's exponential power

Sidney Strauss

This short piece honors a full decade of meetings of the Mind, Brain and Education schools held at the Ettore Majorana Foundation and Centre for Scientific Culture in Erice, Sicily. I had the good fortune to attend two schools in 2012 and 2015, the latter of which I co–directed with Elena Pasquinelli. Both had to do with teaching, the area that has occupied my passions for the past two decades. Each meeting matched the exhilarating surroundings of Erice, a town spanning the millennia from ancient Greeks times to this very day. In our deliberations on teaching, there were especially wonderful moments when echoes of our Greek forefathers of philosophy could be heard.

In addition, the spirit of the origins of the Ettore Majorana Foundation and Centre for Scientific Culture imbued our deliberations. The Director of Ettore Majorana, Antonino Zichichi, in describing the Foundation on its website, wrote about the "values instilled by Science: love for Creation and respect for life and human dignity". The Ettore Majorana Foundation and Centre for Scientific Culture was established on the heels of World War II when respect for life and human dignity were trampled underfoot by dark forces anathema to the proclamations of the Ettore Majorana Foundation. Science, our enlightened and noble enterprise, had been undermined by appeals to the most base of human urges. There was a burning need to reassert science as an important jewel in the crown of human culture. It was with the end of WWII as a background that the Ettore Majorana Foundation and Centre for Scientific Culture was founded.

At the heart of science is friendship, as Antonio Battro (this volume) teaches us. And so it is with teaching. At its best, when a teacher passes on knowledge to another person, trust stands at the forefront of what transpires between the two. A bond of friendship is born out of that connection where a teacher and learner are now inextricably intertwined in openness and mutual hope.

A Global Emergency: Disenfranchised Children

Some of what follows sketches my recent thinking about teaching and draws sustenance from the Erice meetings. It relates to a global emergency that is upon us. It is not a problem we will be facing in the future. The future has already arrived. Around the world, but mostly concentrated in sub–Saharan Africa and Asia, approximately 215 million children between the ages of 5–17 do not attend schools. They often work, sometimes in dangerous conditions (International Labour Office, 2013).

In the cases where there are schools, many are far from adequate in terms of teacher and classroom conditions. For the former, teachers are often ill–trained. Their knowledge of the subject matter they teach can often be quite impoverished, making what they teach to their pupils problematic.

Another impediment to adequate teaching and learning is tremendous over–crowding of classes. As a yardstick, the average number of children per classroom in OECD countries is 21. In comparison, in sub–Saharan countries where there was data, more than half had an average of over 50 children per classroom. The range of average number of children per classroom runs from 24 in Seychelles, to 44 in Togo, 75 in Tanzania and 90 in Malawi (UNESCO, 2015). Children at the back of the class, and probably those who are closer but are not within the teacher's voice range, will have difficulties following the class presentation. This situation is compounded by many schools not having enough textbooks for the pupils and having neither toilets nor running water.

Most likely as a consequence of both poor teacher preparedness and overcrowded schools, research conducted in 2008–2009 showed a deeply disturbing finding in Africa and other continents: after 2 years of schooling, large percentages of the children tested could not read one word in their language (Gove & Cvelich, 2011). For example, in the Honduras, the figure was 29%; in Gambia, 54% could not read in the language of instruction (English), and in Mali, 84% and 94% of the children could not read in Songhoi and French, respectively.

Children in these situations, both without schools and with less than adequate schools, will not acquire even minimal 21st century skills, such as reading, writing and numeracy. They are relegated to poverty and are neglected by their own societies. Lest the reader think that Western societies are immune from similar problems, they are mistaken. The dimensions of the acuity of similar problems may be less pronounced, but they exist in their own back yards. And with the recent large immigrant flow from Africa and the Middle East to Western Europe and Turkey, immigrant children are almost surely not being educated properly there.

Eradicating Illiteracy and Innumeracy

In the case of non–Western countries mentioned above, various individuals and organizations who are working long and hard have suggested solutions to alleviate the severity of the problems with the ultimate goal of eliminating illiteracy and innumeracy.

The areas related to this deep problem are manifold and, to make matters worse, they are interrelated. Sachs (2015) suggests that forces at play in poverty and the resultant illiteracy in language and arithmetic are macro–economic forces about the division of wealth, policies of social inclusion, respecting the sustainability of the environment and the politics of good governance. All four contribute to poverty and all four must be addressed, in concert, to reduce poverty, especially extreme poverty. The level of complexity in engaging all four is enormous.

That having been said, in situations such as those being discussed here, a way to think about how to address them is to find levers.

Levers

Levers are mechanisms where even a small change in one place can lead to large changes in other places in the complex system. By way of illustration, statistics show that as women become more educated, they are more likely to give birth to fewer children and that makes their joining the labor force more likely. At the level of the individual, this increases the likelihood that she can pull herself and her family out of poverty. Her children are also more likely to attend school, as well. And at the societal level, by having many women joining the labor force, the economy will grow. This is a lever of significance.

If we want to pull off large changes, we should locate the levers that can do that. I mention two.

Digital Technology as a Delivery System

One central question regarding illiteracy and innumeracy in remote areas concerns how education for these basic cultural tools can be made available to them. The question, as posed here, is about delivery. How can we get education to so many children who are not in schools or whose schools are inadequate and are scattered over vast distances in sometimes remote areas with little access?

A lever regarding rampant illiteracy and innumeracy among large swaths of our world's children is the use of digital technology. The idea is that through laptops, tablets, smart phones and more, we can democratize education by giving those devices to disenfranchised children across the globe and teaching them, through appropriate applications, to be literate about the written word and numeracy.

This has already been underway in several locations around the world. One example is One Laptop Per Child (OLPC) which originated in the Media Lab at MIT. This non–profit organization has supplied inexpensive laptops to children around the world. The most striking example of this is Uruguay which is saturated with laptops. All school–age children and their teachers have laptops. And that is currently being extended to Uruguay's elder citizens. For the first time in human history, a government decided to provide digital communication to all its youth. Some of these children live in remote parts of Uruguay where there is no electricity. Yet children from there now have the possibility of being connected to other children and their teachers. This social experiment, on a large scale, can be envisioned for neglected school–age children around the world.

It is with this in mind that another attempt is being made to bring literacy to disenfranchised children via digital technology comes from Maryanne Wolfe's work in Ethiopia as part of the Global Literacy Project (Wolf, this volume; Wolf, Gottwald, Galyean, Morris & Breazeal, 2013; Wolf, Gottwald, Galyean & Morris, 2013). She chose to work in two villages there in order to help foster literacy. In one of the villages, in a remote part of Ethiopia, none of its citizens is literate. This means, of course, that there is no school there.

Digital technology was brought to the village in the form of a tablet to see if the village's children could become literate when interacting with the technology Wolf and her colleagues introduced. The situation was set up so that every key stroke on the tablet was recorded and video cameras were set up to tape all events where the tablet was located. The tablet, placed in a strategic location in the village, had apps that were specially built to take into account, as much as possible, children's exposure to written language for the first time. For many important reasons, the written language was English. The thinking behind this ambitious project was that if illiterate children in a village of non–readers could become literate through the use of digital technology, a case could be made for bringing such technology to other remote villages and towns around the globe with similar or less severe literacy problems.

For the moment, the results have been encouraging although success has not been complete. The encouraging, even incredible, findings are that some of the children, who prior to the introduction of the tablet had never seen a pencil, could sight–read some words.

What is sight–reading? You may have noticed this with your toddler children or grandchildren. They can recognize their name. My name is Sidney and when I was age 3, I could recognize it, and I also knew that others' written names weren't mine. I sight–read. I recognized my name as a whole. What I hadn't yet known was that each of the letters represented a sound and that combinations of symbols created combinations of sounds that were a word. This leap, what Wolf calls the Helen Keller leap, is the one that has not yet happened for the Ethiopian children, and it is the one that is necessary for these village children to enter the world of print as literate people.

Being literate goes beyond this, of course. We have to learn to decipher meanings, authors' intents, and much more. Even graduate students at the Ph.D. level are still learning to decipher written texts. But the more advanced aspects of reading will be denied if the basic aspect of connecting symbols to sounds is unavailable. As mentioned, at present, the Helen Keller leap has not yet happened with these children.

That is where things stand now regarding the heroic project to foster literacy without teachers among children who live in places where there are no schools or where there are schools but they are woefully overcrowded and understaffed. In an attempt to find a digital solution to this leap, the X–Prize is holding an international competition to encourage teams to build apps that will enable these village children and eventually hundreds of millions of children to enter the world of literacy.

Underlying these efforts is the understanding, based on research and plain observation, that someone who has deciphered the symbol–sound code by her/himself is a rarity. A teacher is needed for that to happen. In lieu of situations where there are no schools or overcrowded classes, digital technology is being developed to do the teaching. The jury is out about whether or not it can be done. If it can, all of us gain.

A New Lever: Children Teachers

I suggest that there is another lever that can bring teaching to disenfranchised and neglected children: children. No, this is not a typographical error. Children can teach children. Indeed, they do that naturally and spontaneously all the time from an early age. They are natural–born teachers. They do not need teacher training courses nor do they need to be licensed to be teachers. They teach, and do so at a remarkably early age. They have learned how to teach as part of their cognitive, emotional and social makeup with which they enter the world.

Work I have done with my colleague, Margalit Ziv (Strauss, 2005; Strauss, Ziv & Stein, 2002; Strauss & Ziv, 2012; Ziv, Solomon, Strauss & Frye, 2015) indicates that teaching is a *natural cognitive ability for humans*. Children age 3½ already teach, and they do it mostly through demonstrations with explanations accompanying the demonstration; children age 4 teach contingently, meaning that they adjust their teaching to the learner's changing knowledge state that changed because of the teacher's teaching; and children age 5 teach mostly through explanations with demonstrations accompanying the explanations. For a review, see Strauss & Ziv (2012).

In and of itself, it is remarkable that children age 3½ teach. But teaching is unlikely to appear magically at age 3½. It almost surely has preparation before that age. Very few researchers have studied teaching among children below age 3½, and that may be due to a possibly hidden assumption that teaching requires language. However, children at age 1 year who are preverbal (they do not speak but they understand language) do communicate socially, and they do that by pointing.

Research conducted by Ulf Liszkowski and his colleagues (Liszkowski, Carpenter, Striano & Tomasello, 2006; Liszkowski, Carpenter & Tomasello, 2008) indicates that preverbal 1½–year–old infants have some of the basics of teaching in their command. They recognize a knowledge gap; they act to close it; and they correct mistakes and even anticipate others' mistakes and act to ward them off before been made.

Briefly, regarding recognizing a knowledge gap and acting to reduce it, Liszkowski did the following. He showed an array of objects on a table to a preverbal 18–month–old infant and talked about each of them. He then inadvertently (but really on purpose) knocked one off the table, say a key. The infant saw it falling to the floor. After a short time, he looked around and asked the infant where the key was, and the infant pointed to its location.

You might think that nothing extraordinary happened here. After all, the experimenter didn't know where the key was, and when he asked the knowledgeable infant where it was, the infant pointed to it. At first glance, nothing much of importance seems to be happening here. But notice that there is a knowledge gap. The infant knew something that the experimenter (presumably) didn't, and the infant acted to reduce the knowledge gap by pointing to it. So as to test this idea further, the experimenter dropped an object and saw where it fell. When the experimenter asked infants where it was, many fewer infants pointed to its location. That may be the case because there is no knowledge gap here because both the infant and the experimenter knew where the object was.

Much more research is needed to understand what teaching's precursors are in infancy, from birth to age 3½, when actual teaching begins. For the moment, it appears that there are cognitive precursors for teaching among preverbal infants age 1½, and there is reason to believe that prior to age 1, infants have other precursors, such as eye contact, joint attention and more that are not unique to, but are a part of, teaching. All of this lends credence to the idea that teaching may be a natural cognitive ability.

On top of that, even a cursory attempt to describe all that is involved in teaching indicates that it is extraordinarily complex. And much of teaching is invisible to the eye. The decisions a teacher makes when teaching cannot be seen by the learner. They can be inferred when teaching acts are performed, but the decisions that led to this teaching strategy or that are unavailable to the learner. Yet despite this complexity and opacity, children age 3½ teach. All of this suggests that teaching is a natural cognitive ability on the part of children. They teach spontaneously and effortlessly.

Given this, I argue that children can supplement teaching that gets to disenfranchised children via digital technologies of various sorts. Children who already know how to read can be brought to villages, towns and areas of cities where illiterate children live. My guess is that as soon as literate children are put in touch with illiterate children to teach them reading, with the latter having been prepared for reading by digital technology, it wouldn't take long before the illiterate children will have made the Helen Keller leap. This is a guess, but it is a deeply–informed guess.

Notice how this idea helps us think in another way about the 1:90 ratio of teachers per children in a classroom. Think about this: Instead of despairing that the lonely teacher cannot genuinely teach under these circumstances, we can view it differently. We can see that we now have 90 teachers.

Organization and Logistics

I will not enter the details of how to organize matters so that literate children will teach illiterate children to read. The logistics should not be overwhelming, but they have to be taken into account.

What is important, though, is to make sure that important groups and individuals, sometimes called stakeholders, are on board the project. Among the stakeholders are the children themselves, their parents, the school headmaster and teachers, if they exist, the village or township community, the relevant local district government and the federal government, if appropriate.

And there are local customs and religious aspects that should be respectfully taken into account. For example, in some communities it would be inappropriate for girls to teach boys or vice versa. In other communities, where age is a significant factor in the culture, it might be better that younger children don't teach older children.

The factors of stakeholders and cultural and religious sensitivities are a theme common to all societies. What make the various societies different are variations on a theme. Each society must make its own decisions.

Who Gains: Teachers and Learners

As is usually the case, we would want to know if the introduction of children as teachers will lead to effective and long–lasting learning on the part of child learners. This is an empirical issue and research would have to be conducted to provide us with an answer. But I can say this. Children teach, and do so willingly and often spontaneously engage in teaching without prompting. I believe that children brought to teach other children will be effective in that task.

As is my wont, and without neglecting the importance of the learner, I would like to dwell for a few moments on the benefits of teaching that accrue to the teacher. There are several, I believe.

First, teaching empowers teachers, including child teachers. It gives them a sense of efficacy, and they gain prestige in their community by teaching others. It also allows them a small peek into the adults' world.

And no less important, we learn when we teach others. This reverses what we generally think about the direction of information flow. We often conceive of it as going from the teacher to the learner. In what I am suggesting here, teaching affects the teacher's own learning and understanding. This is a nothing–new–under–the–sun phenomenon. Approximately 2,000 years ago Seneca the Younger wrote Lucilius Junior: *docendo discimus*. Roughly translated, it means: when we teach we learn. And fast–forwarding to 1842, French essayist, Joseph Joubert, wrote in *Pensées*: "To teach is to learn twice".

Research findings corroborate this insight. In an active line of research, a recent study by Nestojko, Bui, Kornell & Bjork (2014) divided university students into two groups. One was told that they will learn about the Crimean war in a mini–course with a test at the end. The second group was told the same except that they were told that at the end of the course, they would be required to teach what they learned to other students. Both groups were given a test after the mini–course and the findings were that, when compared to the first group, those in the teaching group learned more, had deeper knowledge and remembered more details. This affirms the 2,000 year old insight as well as our own modern intuitions.

Everyone who has taught (and that is all of us by virtue of teaching being a natural cognitive ability) knows that the knowledge we have for ourselves is usually insufficient for teaching others and that, when teaching, we have to know and understand in ways that will make it easier for others to learn. When a teacher moves from her own personal learned knowledge and understanding to the knowledge and understanding that is made public for the purposes of teaching, it requires her to transform it to and to understand it better so that it will be understandable for others. This holds for child teachers, as well. Hence, when teaching, we learn twice.

And if that is not enough, recent research indicates that among toddlers, teaching leads to teachers' increased use of their prefrontal cortex (Moriguchi, Sakata, Ishibashi & Ishikawa, 2015). Children ages 3–5 taught rules of cognitive shifting for certain tasks. The results indicated that when teaching, children significantly improved their performance and strengthened activations in the lateral prefrontal regions as measured by near–infrared spectroscopy, suggesting that teaching may have a significant impact on the development of the executive function.

In short, teachers benefit from teaching. They become empowered, learn the material to be taught better and their teaching seems to impact their executive function that is responsible for cognitive and emotional self–regulations.

Summary

In this brief odyssey into teaching disenfranchised and neglected children, I offered a brief review of statistics regarding the appalling situation of over 200 million children who are disenfranchised and without education or proper education. From there I went to what this situation leads to: illiteracy and innumeracy. This was followed by levers that can be used to make large–scale changes, one of which is introducing digital technology to remote areas where children are unschooled. An important instance of this is Maryanne Wolf's use of this technology for reducing or even eradicating illiteracy. The temporary conclusion is that, at this point in time, there is a need for digital technology to help children make the Helen Keller leap. This development is in the works at present. I then suggested that a supplement to teaching via digital technology is to have children teach other children how to read, as well as numeracy and other areas in need of teaching. I made the case for children's teaching being a natural cognitive ability and pointed to research that shows that children spontaneously engage in teaching and are quite competent at it at an early age. From there, I noted the benefits of teaching to the teachers, and not only to the more obvious benefits to learners.

Despite the whirlwind pace of what I presented, I hope the reader both recognizes the burning need to help neglected children become literate and numerate and sees the role that children as teachers can play, along with digital technology, to alleviate this injustice.

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SECTION 6
Literacy

Dyslexia and the Brain Difficulties in "Temporal Sampling"

Usha Goswami[1]

One of the most interesting discoveries in the brain imaging of language is that patterns of fluctuation in speech energy (signal intensity) are important for understanding speech. This doesn't mean speaking loudly, although we do automatically raise our voices and speak more distinctly when we are talking to foreigners. Rather, research in auditory neuroscience shows that speech intelligibility is affected by the constant and ongoing energy fluctuations that are produced as we speak. These fluctuations in the energy of the speech soundwave, called amplitude modulations, are produced by the opening and closing of our jaws and by the other articulatory movements that we make (sound is a pressure wave). Amplitude modulation turns out to be critical for speech intelligibility.

My research suggests that children with dyslexia are less sensitive to slow changes in amplitude than other children. Their difficulties are particularly marked in gauging how fast an increase in intensity reaches its peak, called "rise time". For children with dyslexia, sensitivity to rise time is significantly worse not only in comparison to age–matched children without dyslexia, but also in comparison to younger children matched for reading level (Goswami et al., 2012). These "reading level matched" children have a lower mental age and are developmentally less mature than the dyslexics, yet by around 9 years they can discriminate changes in rise time in the range of around 50 ms. Children with dyslexia aged around 11 years need around 100 ms to perceive a change (Goswami et al., 2012). This suggests that the difficulties in perceiving amplitude rise time in dyslexia are profound, and may be one cause of this developmental learning difficulty.

1. I would like to thank Victoria Leong for her helpful comments, and the Medical Research Council for funding this work. (Published in "The Psychologist", 2103; with permission).

AM and FM — Just Like the Radio?

A simple way of thinking about rise times is to think about music. In music, we can have notes of the same pitch which are made by different instruments. For example, the note G can be played on a trumpet, or on a violin. The trumpet player will produce a note that starts very abruptly —it reaches its maximum intensity very quickly. A violin player draws the bow across the string, and produces a note of the same pitch, but this note takes much longer to reach its maximum intensity. The violin note has a more extended rise time. In order to play in time with each other, the two players need to begin making their notes at different times, so that peak intensity is reached at the same time. In this scenario, we perceive the players to be "in time". If the two sounds reach peak intensity at different times, we perceive one player to be "coming in late". The rise time difficulties found in dyslexia suggest that an orchestra of people with dyslexia would be poor at keeping in time, even though each individual player may have reached a high standard of skill with their own instrument.

Just as both pitch and timing (rhythm) are critical for music, both frequency modulation and amplitude modulation play critical roles in speech perception. Indeed, they play complementary roles. Both AM and FM can be used to transmit sound, as illustrated by AM radio versus FM radio. While in radio transmission AM and FM are artificial transformations, in speech these two types of modulation arise naturally and convey complementary information. Traditionally, changes in frequency were thought to be of primary importance for perceiving speech sounds, as a key aspect of speech is formant frequency structure. While frequency cues are indeed important, it turns out that speech is quite intelligible even when formant structure is largely removed, and just the AM patterns from a few frequency bands are retained. Hence amplitude modulation also plays an important role in speech perception. The AM patterns in speech are also known as the "amplitude envelope" of speech.

Very slow rates of amplitude modulation (typically < 4 Hz) are experienced by listeners as speech rhythm and syllable stress patterning (prosody). Rise times in the amplitude envelope of speech correspond to syllable onsets, and stressed syllables have larger rise times. Accurate perception of prosodic patterning turns out to be crucial for word recognition. As an analogy, consider listening to a non–native speaker of English. This non–native speaker is likely to have learned all the individual speech sounds (the "phonemes") correctly and is likely to say them in the right order (the order in which they are written). However, he/she may still use the stress patterning of their native language. In such cases, it can be very difficult to understand what is being said. We need listening experience to "train our ears" to persistent mis–stressing of English words. This analogy shows that prosody (strong and weak syllable "beats") is part of the hidden structural glue that makes individual speech sounds into recognisable words. Prosody, however, is not represented in the writing system for English.

Dyslexia and the "Phonological Deficit"

Learning about the sound structure of words and learning which sound elements follow each other is a natural part of language acquisition. However, children with dyslexia, across languages, have difficulties in being able to reflect on the sound structure of words —to develop "phonological awareness". Phonological awareness has classically been assessed by tasks that measure a child's ability to detect and manipulate component sounds within single words, at the different "grain" sizes of syllable, rhyme and phoneme. For example, children with dyslexia are worse at counting the number of syllables in words (2 syllables in "toffee", 3 syllables in "viola"), at deciding whether two words rhyme, or at deciding that two words begin with the same sound element (phoneme). Prior to literacy acquisition, phonological development across languages is very similar. All children develop awareness of syllables and rhymes (or "onset–rime" units; to divide a syllable into onset and rime, we segment the syllable at the vowel, as in *m–ate*, *gr–eat*, *str–aight*; as this example shows, rime is a *phonological* category).

Learning to read is largely responsible for the development of "phoneme awareness". The development of phoneme awareness depends partly on the consistency with which letters symbolise phonemes in a language, and partly on the complexity of phonological syllable structure (Ziegler & Goswami, 2005). Because of this, there are large cross–language differences in the rate of development of phonemic awareness as children learn to read, with English learners being particularly slow. This slowness in English occurs because phonemes are not actual units in the speech stream, and so children have to learn about phonemes largely via learning letters. Letters in English are not very consistent in how they map to sound. Hence children cannot learn about (most) phonemes simply by analysing their own speech.

This was shown a long time ago by the work of Charles Read on "invented spelling" (Read, 1986). Read showed that pre–reading children think that the sounds at the beginning of "chicken" and "track" require representation by the same letter. In a way they are correct, as acoustically these sounds are indeed very similar. On the other hand, pre–readers think that the sounds symbolised by the letter P in "pit" and "spoon" are different —as indeed they are. Yet in English spelling we represent these sounds by the same letter. A beginning speller might well write SBN for "spoon". Phonologically, this child is being accurate.

Most children overcome these inconsistencies in grapheme–phoneme relations and learn about phonemes relatively quickly, but children with dyslexia do not. They struggle to learn the letter–sound correspondences of English, showing deficits in "phoneme awareness" even as university students. On the other hand, children with dyslexia in more transparent orthographies, like German or Italian, become as good at phoneme–level tasks as non–dyslexic children after a few years of learning to read. Yet these children too never attain automaticity or fluency in recoding print to sound, and so are functionally dyslexic. Dyslexic difficulties with phonology typically persist into adulthood even in transparent languages, but are more difficult to see in these languages (see Ziegler & Goswami, 2005). One possibility, which is only recently receiving attention, is that these phonological difficulties, and the associated difficulties in learning about phonemes, stem from an underlying difficulty with speech prosody.

Prosody and the "Phonological Deficit"

Tasks to measure prosodic awareness in dyslexia have been developed relatively recently. In a ground–breaking study, Kitzen (2001) converted film and story titles into "DeeDees", so that (for example) 'Casablanca' became DEEdeeDEEdee. Participants with dyslexia heard a tape–recorded DeeDee sequence while viewing three alternative (written) choices, for example 'Casablanca', 'Omega Man' and 'The Godfather'. Kitzen found that her dyslexic participants were significantly poorer in the DeeDee task than age–matched controls. However, interpretation of the group difference was complicated by the reading demands of the task.

More recently, we created a version of the DeeDee task for children with dyslexia. Our task relied on recognising pictures of "famous names". For example, "Harry

Potter" was DEEdeeDEEdee. We found that 12–year–old children with dyslexia were significantly worse in matching the DeeDee sequences to the pictures than non–dyslexic 12–year–olds (Goswami et al., 2010), and recently we found that 9–year–old children with dyslexia were significantly worse in the DeeDee task compared to 7–year–old reading level controls (Goswami et al., 2012). Individual differences in DeeDee performance are related to auditory sensitivity to rise time, pitch, duration and sound intensity.

We also developed a more direct measure of syllable stress perception. Using 4–syllable English words, we asked participants to make same–different judgements when one of the words was mis–stressed (Leong, Hämäläinen, Soltesz & Goswami, 2011). For example, they might hear a word pair like "DIFFiculty–diffICulty". Both highly–compensated dyslexic undergraduates and dyslexic children aged 12 years showed significantly less sensitivity in this task compared to age–matched controls (*d′* measure). Individual differences in stress sensitivity for adults were uniquely related to individual differences in auditory sensitivity to rise time. For children, the auditory predictors of stress sensitivity were rise time and duration.

These marked difficulties with syllable stress made us wonder whether beat perception in music might also be impaired in dyslexia. As noted, rise time is critical to the perception of rhythmic timing, and the beat structure in music depends partly on some notes having greater accentuation than others, a bit like strong and weak (stressed and unstressed) syllables. To test musical perception, we devised a musical measure of beat perception for children. Children listened to short "tunes" made by a chime bar, with strong and weak beats, and were asked to make same–different judgements. For example, they might hear "DING ding ding DING ding ding DING ding ding", repeated twice, but the second time with a longer delay between the accented and unaccented notes. This delay disrupted the overall beat structure, so that the tunes sounded rhythmically different. The children with dyslexia were significantly worse in making these judgements than both age–matched controls (Huss et al., 2011) and reading–level matched controls (Goswami et al., 2012). Musical beat perception was associated with auditory sensitivity to rise time, pitch and duration. In Huss et al.'s study, individual differences in the musical beat perception task accounted for 42% of unique variance in single word reading, after controlling for age and IQ. In Goswami et al's (2012) study, musical beat perception predicted 43% of unique *longitudinal* variance in reading comprehension. Hence individual differences in perceiving patterns of beat distribution, in both language and music, are intimately connected with reading development and dyslexia.

"Temporal Sampling" and Syllable Structure

Interestingly, the underlying beat structure in the music task was 2 Hz, (beats occurring every 500 ms. Or two beats a second). This temporal rate was chosen because we had other evidence that "rhythmic entrainment", or following rhythmic patterns, was impaired at this rate in developmental dyslexia. Children and adults with dyslexia were much more erratic than controls in tapping in time with a metronome at 2 Hz (Thomson et al., 2006; Thomson & Goswami, 2008). Across languages, speakers produce stressed syllables at the rate of approximately 2 per second, or 2 Hz. Hence one logical possibility is that the dyslexic brain finds it difficult to "entrain" to rhythmic input at this temporal rate, accounting in part for the syllable stress and prosodic difficulties that characterise dyslexia. Recently, we tested this idea in a brain imaging study using amplitude–modulated noise (Hamalainen et al., 2012).

In our study, we asked well–compensated adults with dyslexia to listen passively to 5–minute streams of amplitude–modulated noise (a kind of rhythmically beating white noise) at 4 different temporal rates, 2 Hz, 4 Hz, 10 Hz and 20 Hz. We then measured how accurately electrical fluctuations in cell assemblies (neuronal oscillations) in the auditory cortex aligned their fluctuations with the stimulation rate. We expected entrainment difficulties at both 2 Hz and 4 Hz. While stressed syllables are produced approximately twice a second across languages, speakers produce between 4–7 syllables a second in different languages, depending on what they are saying and how fast they are saying it. Studies in auditory neuroscience have identified entrainment at the theta rate (4–8 Hz) as particularly important for syllable–level processing of speech.

In our study, however, the dyslexics only showed impairment in neural entrainment at the slower rate of 2 Hz. Intriguingly, they also showed *better* entrainment than controls at the faster rate of 10 Hz. Most recently, we have begun to study neural entrainment in children. In one study, we used a rhythmic speech design, in which children listened to a speaker saying "ba .. ba .. ba .." at a rate of 2 Hz, and we measured auditory neural entrainment (Power et al., 2012). We found significant entrainment of both delta and theta neuronal oscillations in these typically–developing children by rhythmic speech input. Furthermore, individual differences in theta entrainment were related to individual differences in reading.

The brain imaging studies suggest that individual differences in oscillatory mechanisms at both the stressed syllable rate (2 Hz) and the syllable rate (4 Hz) are related to the development of word reading. Theoretically, I have developed a "temporal sampling" framework to try to explain why poor rhythmic entrainment, poor perception of acoustic rhythm, and poor perception of rise time are all associated with developmental dyslexia and with prosodic and sub–lexical phonological difficulties.

Temporal Sampling Theory

Temporal sampling theory builds on the idea that the brain "samples" sensory information at different temporal rates, effectively taking multiple "looks" at the speech signal using temporal windows of multiple lengths simultaneously (Poeppel, 2003). To help to encode the speech signal, the auditory system appears to synchronise endogenous ongoing oscillations (fluctuations in neuronal excitability that are occurring anyway) to the modulation rates in the stimulus, realigning the phase of neural activity so that peaks in excitability co–occur with peaks in amplitude modulation (Zion–Golumbic et al., 2012). As dyslexia involves rise time perception difficulties, it might be more difficult for the dyslexic brain to detect these peaks in amplitude modulation, or to align endogenous ongoing fluctuations in neuronal excitability to the modulation rate, as the different modulation rates would be less well–detected. If neuronal entrainment at the syllable and stressed syllable rates is impaired in dyslexia, then this would provide a plausible explanation for the phonological difficulties found in developmental dyslexia across languages (Goswami, 2011). Difficulties in basic auditory processing of rise time, amplitude modulation and beat structure would lead naturally to difficulties in processing the sound structure of words, and to prosodic difficulties. In turn, these prosodic difficulties would be linked to difficulties in judging phonemic similarity across different words —just like listening to a non–native speaker of English.

Conclusion

Temporal sampling theory proposes that an underlying neural problem with rhythmic entrainment accounts in part for the "phonological deficit" that characterises children with developmental dyslexia across languages. One obvious implication is that remediation with music might be very effective for improving phonology in dyslexia. Rhythm is more overt in music than in language, and so a focus on musical rhythm along with activities that explicitly link musical beat structure to the beat structure of language may help to improve rhythmic entrainment (Bhide, Power & Goswami, 2012). Co–ordinating rhythmic movement in time with speech and music may also be beneficial. Many playground games of course provide such activities, such as clapping games, skipping games, nursery rhymes and oral chants. Interestingly, research with adults who have specific musical difficulties (termed "amusia", or tone deafness) suggests that these adults are "in time but out of tune", able to organise rhythm cues but not pitch cues (Hyde & Peretz, 2004). This pattern of difficulty appears to be the mirror image of our findings with developmental dyslexia. Our data suggest that children with developmental dyslexia are "in tune but out of time". Rhythmic entrainment difficulties may be at the heart of developmental dyslexia.

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Global literacy initiative: an update

Maryanne Wolf

A Story from the Desert Fathers in Fourth–Century Egypt

One day Abba Arsenius asked an old Egyptian man about what he was thinking. Someone said:

> *"Abba, why is a person like you, who has such a great knowledge of Greek and Latin, asking a peasant like this about his thoughts? He replied: "Indeed I have learned the knowledge of Latin and Greek, yet I have not learned even the alphabet of this peasant."*
>
> **Cited in Henri Nouwen, 2013, *Discernment*, New York: Harper**

It would be fair to say that one of the most powerful, life–changing, professional experiences I have ever had involves the work on the Global Literacy Project in which my research team and I began to "trade alphabets" with children and families in some of the most remote regions of the world. My group and I have long believed that literacy is the single best foundation we can give children anywhere, whether rich or poor, traumatized by war, impoverished by harsh environments, or simply growing up in our own backyards. But I never imagined that one day I would be asked one of the most audacious of questions by a luminary in the world of technology: Would it be possible, based on our collective knowledge about the reading brain, to create a digital learning experience for non–literate children without schools to teach themselves to read?

Nicholas Negroponte, creator of the MIT Media Lab and multiple technology–based initiatives, including One Laptop per Child, threw a gauntlet down with this question, and nothing has ever been quite the same. Could my research team's work on the reading brain and on intervention with struggling readers in the United States be applied in the design of digital tablets for children who would never otherwise become literate? My presentation at Erice provided a first look at

* www.curiouslearning.com

the promising results from our first deployments with forty children from four to eleven years of age, in two of the most regions of Ethiopia. This brief report will update the still unfolding story of our efforts to confront this question and in the process approach literacy and non–literacy in a whole new way.

If we step back and look at the behavioral data in the Ethiopian deployments from 40,000 feet up, there are many important insights. At a meta level, our behavioral and observational data are providing us with a totally unanticipated platform for studying the emergence of literacy in a group of children who have never seen symbolic text. The pathway to this emergence is unique because it is based on a combination of digital learning and child–directed learning.

More specifically, we have demonstrated a "first proof of concept" to show how mobile devices like the tablet can give children access to the precursors to literacy and to beginning to learn another language. Our children in the two villages had four seemingly impossible hurdles in technological, conceptual, linguistic, and literacy domains. They had never seen a pencil, much less a laptop, yet they acquired computer–literacy within days. They had never heard English, yet they acquired many basic English words. They had never seen things like an ocean or an octopus, but they acquired multiple new concepts. They had never heard or seen a letter, yet they learned how to recite, identify, and write all the letters of the English alphabet. Some of the children even learned how to identify on a sight–word basis only a group of common words like *mother*, *father*, *cat* and *horse*.

What we have not achieved to this point is the most difficult, Helen Keller epiphany– the move from sight word recognition to true decoding and comprehension. No child in either village was able to decode the words in the decoding task in our first assessments. The children remain on the cusp of learning to decode, even though they continue to learn more and more sight words. Whatever is ultimately needed, we will not stop until at least some of the children in our Ethiopian villages "crack the code".

But the ultimate question we asked —whether digital technology can help pastoral children in remote areas learn to read on their own— has only been partially answered. We may discover that the last and most cognitively demanding insights by the child into discovering how decoding works will require more direct, human intervention, even if on an itinerant basis. We may discover, just as Sugata Mitra describes for children in India, that the presence of one adult, like a non–literate "granny" or grandmother, has a helpful effect on the children's digital learning.

Regardless of what happens next, the children of Wonchi and Wolenchite have given us a never expected Petri dish for studying the beginnings of literacy with an entirely new set of questions.

For example, the questions raised are directing us to work in many new areas: e.g., improving and adding apps and tablet configurations that come closer to our original" app map" modeled after the young reading brain circuitry; examining the role of nutrition alongside learning performance; studying the possible contribution or presence of a "granny" to learning; and pilot studies in wholly different educational contexts that will begin to flesh out a far more expanded picture of literacy in remote regions. To be sure, we do not know whether we can replicate the same early learning curve we saw in Ethiopia in children in different environments which may be equally difficult, but more hostile to learning itself. For example, the parents of the children in both villages could not have been more supportive. What of children in a Mumbai undercity, like those described so eloquently by Katherine Boo, who have no such supportive families and whose basic goal must be to survive?

What of children who have schools, but schools which are so overpopulated and understaffed that 60 to 100 children may be taught in a single classroom by one insufficiently prepared teacher? And what of children in our own "backyard" in rural United States, where poverty and inadequate language environments render them at risk for school failure before they even enter the Kindergarten door? Could some versions of the same principles on our tablets in Ethiopia be employed to help diminish the insidious educational gap in the United States that begins before school and then grows wider every year after?

To address these and related questions of generalizability, we have begun new deployments in each of the above situations: in undercity populations in India; in settlement schools in South Africa; and in language–impoverished populations in rural Georgia and Alabama (See article in Smithsonian, 2014). Each of these deployments brings its own set of challenges to our work, at the same time that it provides us with unique opportunities for understanding the utility of our platform for different groups and increased numbers of children. We are already seeing many differences in these varied settings.

To address app development, we are actively working towards the development of a more comprehensive set of new apps that will better target more components of the described *app map* of the reading brain circuitry. We are in the process of helping several software groups design specifically targeted apps at blending and decoding, an area that has proven predictably difficult for the Ethiopian children. In addition, in the last year and a half graduate students at Tufts, MIT, and the Rochester Institute for Technology have been working to create apps that introduce the next phases of reading development. Such developments combined with the increased quality of the newly selected apps that are now available will increase the chances the children of Wonchi and Wolenchite will move beyond sight word recognition into true decoding.

Another major challenge throughout is to help children move more seamlessly from one skill to the next while still giving them maximum choice and a sense of engagement so that they persevere. Towards those ends, we are working to combine our app map with a new *mentoring system* that will connect the child's performance to a network of sequenced learning targets. This will allow for more dynamic learning by the child in a digital learning environment, and it will automatically connect one set of skills to multiple other related skills. Such a system will also help children who may spend less time in a particular area because it represents a weakness (e.g., vocabulary), to be encouraged to select apps that provide more exposure but through a different approach to learning vocabulary. They will be encouraged through the mentoring system along a different set of pertinent apps that enhance their weak areas, as well as help them develop their strengths. Thus, we want to be able to track children's use of every app, the amount of time engaged, and their performances, in order to build an adaptive, individualized learning system that will maximize their literacy development wherever they live.

The latter point is critical in the still larger context of *global literacy*. Ultimately, we seek to build a more universal template for learning to read across various languages and writing systems. Towards that end, we are attempting to construct principles for the choice and/or creation of all apps, regardless of language. For example, from a linguistic viewpoint, we want children to know the full repertoire of the phonemes in whatever language they are learning to read, as well as the meanings of basic concepts in early child development, regardless of culture. We want to provide a more comprehensive template for apps, therefore, that represents both the more universal perceptual, linguistic, and cognitive principles that are needed for the development of the reading circuit, and that is also specifically related to the particular language of that country and its writing system's unique emphases.

Along similar lines, we hope to construct guidelines that encourage teachers, researchers, and designers to contribute socially and culturally relevant material: for example, the development of stories and of photographs and picture collections that represent both vocabulary in the local context and also that give expression to the local myths, stories, and fables. All of these can be brought together by the children and then uploaded into interactive storybooks. As one present example in our most recent deployments, we hope to inspire children in the rural US to create materials for vocabulary (like the photographs) and stories that can be sent to Ethiopia, and vice versa in an exchange. This would not only expand and reinforce the children's understanding of vocabulary by showing variations in new physical and social contexts, but, just as importantly, it fosters curiosity and understanding about another culture. We believe that in the process of such exchanges, these children will become far better prepared to understand and empathize with other children from all over the world, and will have a new perspective on who is "other". Thus the development of apps for literacy to us is, in fact, a potential vehicle for the conceptualization of a far broader learning experience that can embody principles of ethical and character development, as well as learning to think with words in whole new ways.

By the time we have learned how to help children reach the stage in which they are reading fluently across varied domains, our very highest and most ambitious goal is to have developed a global open–source platform that is a repository of many different apps from around the world that can introduce children to multiple domains of learning. It is our hope to ensure that we are building the kind of open–source platform that will someday allow many types of learning from numeracy, science, health/hygiene to ethical development.

We conceptualize this envisioned platform as a global hub to foster a new, intellectual/technological movement in which an international community of users, developers, technologists, scientists, education practitioners, policy makers, and families work together to create a place where the digital assets, findings, and methods of best practice can be shared by all to help all children have their best chances to reach their potential.

This is our global literacy agenda.

Note

This report is based on material found in an upcoming book, What It Means to be Literate: A Literacy Agenda for the 21st Century, to be published by Oxford University Press. See also two chapters in the Proceedings of the Vatican Academy of Science meetings for Bread and Brain; Socially Disenfranchised Peoples, 2013.

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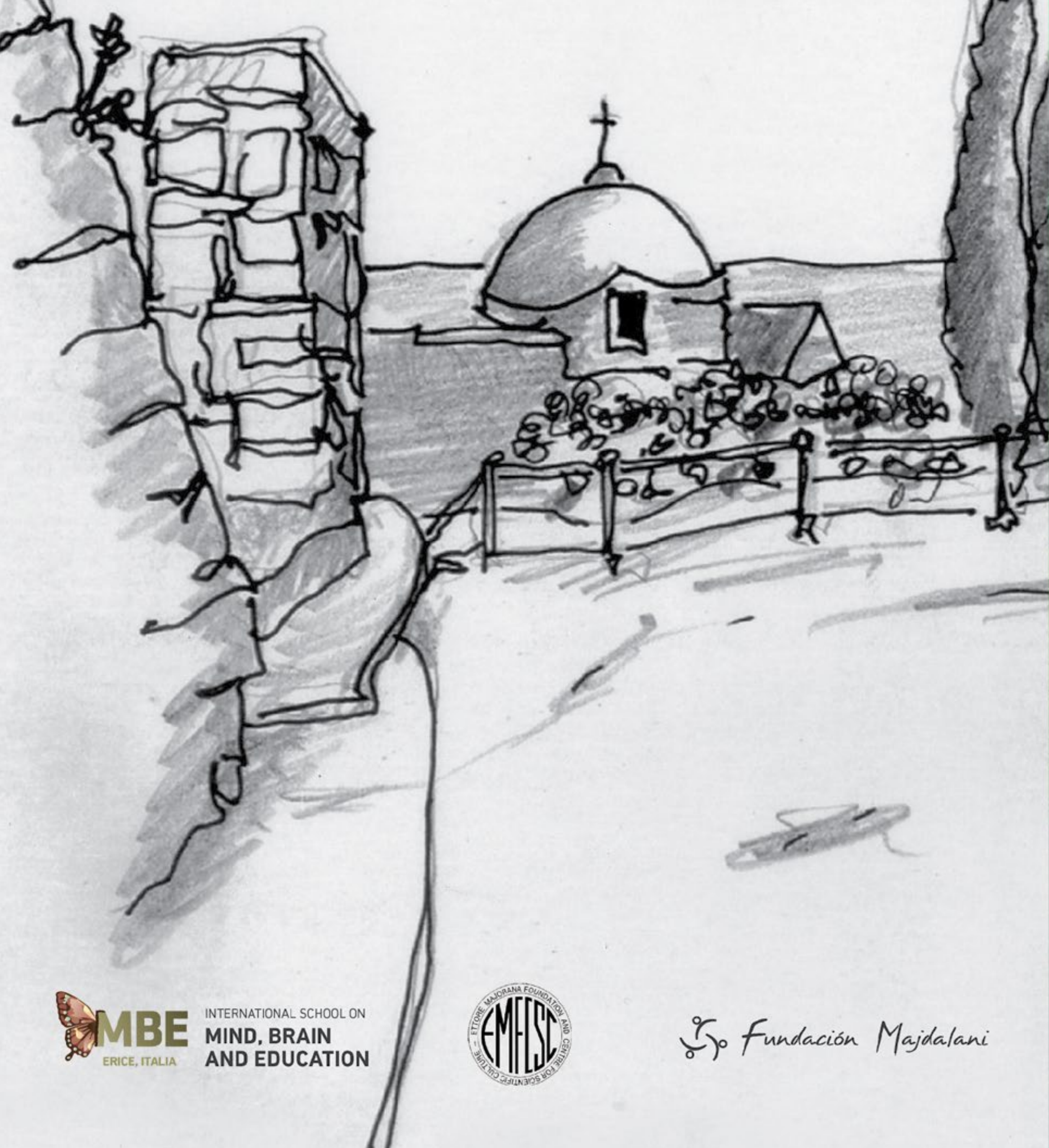
*As the entomologist chasing butterflies of bright colors,
my attention was seeking in the garden of gray matter,
those cells of delicate and elegant forms, the mysterious
butterflies of the soul, whose fluttering wings would someday
–who knows?– enlighten the secret of mental life.*

***Santiago Ramón y Cajal** (1923)*



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