Mind, Learning, and Knowledge in Educational Contexts
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Research Perspectives in Bioeducational Sciences

Edited by

Elisa Frauenfelder and
Flavia Santoianni

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In the past twenty years, educational sciences have approached the study directions outlined by neuroscience and cognitive science. Do you think it is possible to define a research ground astride the borderline? Do you think that the neuroscience community may be interested today in human educational issues?

There is no denying that different texts of educational sciences and psychology highlight conceptual positions regarding the strategies to be adopted in everyday educational practice which have been borrowed from neuroscience and cognitive sciences in general.

I think that this can be viewed as a praiseworthy sign of an interdisciplinary approach to other human sciences and a positive attempt to compare on the one hand the educational process and, on the other, the biological structures and potentials of the protagonists of the process, i.e. learners. Unfortunately, this has also meant an a-critical adoption and a hasty application of concepts that not only are unobjective, but may even prove detrimental to the educational process given the infinite cognitive potentials of the brain, which only the latest research has started investigating fully. Responsibility for this lies not only with educators but also with brain researchers.

The most commonly accepted of these notions is, no doubt, the notion that it is necessary to provide the two cerebral hemispheres into which our brain is sub-divided, i.e. the so-called right and left hemispheres, with different types of information, and use different strategies to maximise learning effectiveness. This concept has generated the “myth”
of the existence of individuals whose mental activities predominantly depend on either the right or the left hemisphere. This approach developed as the theory of hemispheric differences started gaining ground. The theory derives from the studies initiated by the Nobel Prize winner Roger Sperry (1982) and then continued by Michael Gazzaniga (Gazzaniga, 1985), which were conducted on individuals affected by severe epilepsy who had undergone resection of the corpus callosum (the bundle of nerve fibres connecting the two hemispheres). Since this is the most important trans-hemispheric transmission system, the resection results in hemispheres which are split and cannot communicate, or, at best, can communicate only in an extremely approximate manner. The ability these individuals, the so-called “split-brain” individuals, to process information and their capacity to control their surrounding personal space differs from one hemisphere to the other (Gazzaniga, 1985; Proverbio et al., 1994; Berlucchi et al., 1997). To put it simply, the left hemisphere is more analytical and more specialised in the areas of language and control of the contra-lateral space, while the right hemisphere has a greater ability for holistic analysis, spatial information processing and bilateral spatial control. This well known interpretation applied to the field of education totally ignores the fact that in neurologically intact learners, the two hemispheres communicate efficiently and balance out their potentials. Even though the theory of hemispheric differences is well-founded, there is not much sense in classifying learners as individuals whose mental activities depend prevalently on the right or left hemisphere. I wonder to what category the advocators of this idea would attribute Albert Einstein’s genius, whose “theory of relativity,” while being an outstanding achievement of scientific-analytical thought, was apparently the product of “visual thought” processes, and only later expressed in words (if we are to believe the interviews between Einstein and the Gestaltist scholar, Wertheimer, regarding its “birth” (1945)).

Another concept borrowed from neuroscience, whose value has proved to be questionable in everyday school practice, is the idea that the brain is characterised by growth spurts which occur in all of its districts in exactly the same manner and regarding which specific educational objectives must be put in place. Passing a given “critical age” without proper stimulation would entail considerable learning difficulties (e.g. language). Indeed, it is becoming increasingly clear today that there are growth spurts which can involve some districts only, and that the same type of stimulation has selective effects on some specific districts of the
brain only in critical periods, whereas it can potentially impact many other districts for a longer period of time.

The other great myth is that only some 20% of our brain is utilised and that we should learn to use a higher percentage of it. This belief stems from early observations made by neuroscientists who suggested that a large part of the cerebral cortex consisted of so-called “silent areas”. However, it is now widely recognised that these “silent areas” mediate complex cognitive functions and not just basic sensory and motor activities. This discovery was made thanks to current advances in neuroscience and the widespread use of haemodynamic techniques (e.g. Positron emission tomography (PET) and Functional Magnetic Resonance Imaging (fMRI)) capable of visualising brain activity “on line” during basic and complex mental tasks (Posner & Raichle, 1994; Cabeza & Nyberg, 2002).

I believe that the latest breakthroughs in neuroscientific research on learning mechanisms can favour a more fruitful research spanning the disciplines of neuroscience and the science of education. For example, the discovery that learning modifies the physical structure of the brain, turning into a unique entity not equal to any other, or the discovery that these structural modifications turn into modifications of the functionality of the brain and, consequently, that learning of any sort has the power to re-organise brain functionality, or, lastly, the most exciting of present day discoveries, i.e. that different portions of the brain may develop at different times, and consequently have different levels of learning capacity at different moments. At this juncture, it is obvious that it does not make sense to hold that differences in the learning ability of a prepuberal child as compared to an adolescent only depend on the global immaturity of the former’s brain. Certain functions which are crucial to learning, such as sensory and perceptive functions, expressed by the maturity of the primary, secondary and tertiary cortical areas of certain districts of the brain, above all of the posterior cortical areas, do not differ at all in the two age groups in terms of ontogenetic development.

The latest findings of the research conducted on brain plasticity using electro-physiological and neuro-imaging techniques are even more exciting. These findings show that the brain areas that in neurologically healthy individuals are responsible for the sensory analysis of auditory and visual information, in adults who are deaf and blind from birth are found to respond better to stimuli of other nature. This suggests that these cerebral areas are called upon to analyse types of sensory information other than the specific ones they already know, and to re-organise
these individuals’ brains in terms of functional adaptation (Kujala et al., 1995; Neville et al., 1997; Röder et al., 1999). These findings re-confirm that even though the functional organisation of the brain is determined by biological constraints, nonetheless this organisation is basically influenced by experience-induced effects. It is therefore crucial to re-think educational and rehabilitative strategies addressed to these particular learners, bearing in mind that specific areas of their brain effectively respond (in more or less the same manner as occurs in individuals without neuro-sensory impairments) to types of information which are completely different from those traditionally used.

This is even clearer if we analyse other interesting findings of the research conducted on subjects deaf from birth who have precociously learned sign language, a linguistic communication mode characterised by lexical and grammatical rules similar to verbal language, but founded on the need for spatial patterns linked to the use of hands (Poizner, Klima & Bellugi, 1987). The results of a fMRI study conducted by Neville et al. (1998) confirm the findings of earlier studies in late 1970s/1990s based on the recording of Event-related Potentials of the Brain or ERPs (for a review of these studies cf. Bavelier, Corina & Neville, 1998). Neville and colleagues in their 1998 study compared three groups of subjects: (I) English mother tongue hearing subjects, (II) subjects deaf from birth who used the American Sign Language (ASL) since infancy and had learned English through the visual mode only at a later stage, and (III) English speaking hearing subjects who used both ASL and English fluently since infancy. Regardless of the type of language, all groups showed a high activation of the traditional language cerebral areas of the left hemisphere of the brain during the processing of the specific language (English or ASL) they had learned in the early part of their life. However, the group of deaf subjects did not show any activation of these regions when reading English. Moreover, the “ASL groups,” both hearing and deaf subjects, also showed high activation of homologous areas of the right hemisphere during ASL processing, an activation which was not observed in the hearing group which did not know ASL.

In general, these findings highlight that, on the one hand an early acquisition of a language is necessary so that the brain areas potentially responsible for its mediation develop an active functionality, and on the other, the specific requests of a particular language partly determine the specific functional organisation of the brain’s linguistic system.
Do you think that the neuroscience community may be interested today in human educational issues?

I think that it is particularly important to integrate research on the brain with findings from other research fields as this is the only way to verify the theories and practices of this research in the light of human experience. This would allow us to acquire a clearer picture of the potentials of the human brain. In fact, cognitive neuroscientists have long been aware that the brain can store a great amount of information transmitted by a complex network of neurones, i.e. nerve cells, through the synaptic contacts made by their dendritic and axonic extensions. They also knew that there is a theoretically unlimited number of potential connections between dendrites and axons of different neurones. However, one of the most recent and most exciting findings of present-day research is that the number and strength of these connections are affected by experience (e.g., Black et al., 1990), a phenomenon which is now known as “plasticity” (Kolb, 1995). This process implies that the physical structure of the brain does not grow just because it is nurtured and protected. It is the experiences of an individual’s life that lead to new connections between neurones and the secretion of chemical neurotransmitters which facilitate transmission of information. The brain, with its complex architecture and infinite potentials, is a highly plastic and constantly changing entity, shaped by our experiences, above all during infancy and to a lesser extent, throughout our entire life. From this perspective, cerebral development and learning can be considered as two sides of the same coin. However, considering the entire life span, it is during the first three years that the pace of growth, as far as number of connections created is concerned, is thoroughly astounding. This shows that there are specific sensitive periods when the impact of experience is stronger, and above all that different parts of the brain react to experiences in different ways (Diamond & Hopson, 1998).

Obviously, these advances in brain research clearly indicate that the brain can store information and is plastic, and that a wealth of experiences is important in order to create a higher number of neural connections. But these findings give no indication to neuroscientists as to what type of information is necessary, because this does not fall, and has never fallen, within the area of interest of these researchers. However, this issue has been addressed by education and cognition scientists, educators and other professional figures who study the effects of experience on human
behaviour and potentialities. It is our belief that the time has come for neuroscientists to start addressing issues which are related to human education and which have derived from the experience of educators in order to acquire a fuller understanding not only of the brain, of which we know a lot, in a broad sense, but also of the mind, i.e. its greatest and most complex product, of which we know very little.

This is crucial if we think that, during its ontogenetic development (i.e. its life-long maturational development), the brain is at first engaged in playing and imagination, and then has to tackle an educational programme destined to last several decades, started at the kindergarten and later school, where it is shaped through the learning of computation, writing, reading and social norms, before finally facing the world of work and social relationships.

From this perspective, the brain and the mind which it expresses must be viewed as entities constantly confronted by the history and culture they interact with on a daily basis, and not as entities essentially equal in all individuals, with properties which automatically develop thanks to the expression of a genetic inheritance. This should stimulate the opening up of a new and fruitful dialogue among experts from the various disciplines which focus on human beings and their behaviour, such as biology, psychology, psychiatry, sociology, just to mention a few and without any intention of slighting the many other disciplines which are equally as important.

This would bring about significant consequences in terms of knowledge of the brain and mind, both for neuroscientists and for other scientists interested in human beings and their education. In my opinion, the most important of these consequences would be, on the one hand, to bring human sciences back to their roots, to their “biological humus”, in order to attempt to give neurophysiological explanations to phenomena which have previously been explained only from the phenomenal and psychological standpoint, while, on the other, to suggest ways through which individual and social history and experience (the latter largely represented by the educational experience in each person’s life) become a biological reality shaping the functionality of the brain so as to make it become a single entity different from the others.
What do you think of Sperry’s statement according to which brain processes and consciousness are inseparable but distinct, since the mind is to the brain as an emerging property is to its structure?

It is increasingly clear that most cerebral and mental processes take place outside our consciousness. This fact prompts some scientists to contend that unconsciousness is real, as argued by LeDoux (1996), or that “many experiments point out that the brain acts even before we know it” as stated by Gazzaniga (1998). This occurs at different hierarchic levels of the complex mind/brain entity, a unitary entity if we consider that “the mind is what the brain does,” as suggested by Marvin Minsky. To be more explicit, the various hierarchic levels of the neural processes of which we can never be aware—even though they are crucial to understanding the mind which stems from them—range from intra and inter-cell ionic exchanges at the micro-cellular level, to flows of information at the macro-systemic level, along the various functional circuits responsible for the functionality of the brain and mind. Moreover, at the macro-systemic level, this unconscious neural and/or mental process manifests itself in nearly all the areas of the mind, from the basic operations of analysis of the physical attributes of stimuli made by our sensory systems, to the memory of past events or decision-making.

If Sperry’s assumption is evaluated allowing for today’s neuro-cognitive theories of the mind, we can state that it is almost automatically in line with them. In fact, there is no denying that, since the conscious contents of the mind are the result of cerebral processes which for the most part are unconscious, these contents must be considered inseparable from these processes, even though the latter must be considered completely different from the contents, according to Sperry’s assumption. Perhaps this concept can be better understood if we use a metaphor. Let us compare cerebral processes to an aggregation of operations or general procedures which lead to a given result, and conscious properties to the products of this aggregation of operations. It follows that being acquainted with the product of these operations, for example the final balance illustrated in a multinational’s annual report, does not mean being acquainted with the many operational steps, countless processes, mutual exchanges of information among the various administrative areas of that multinational. However, what is clear is that the final balance, a result of all these processes, is inseparable, albeit different from them.
Unquestionably, understanding how these unconscious processes translate into conscious products is one of the most exciting targets of present-day and future neurocognitive research.

**How would you define the mind?**

I think that it is far from easy to give an exhaustive and short definition of the mind, a definition on which everybody can agree. However, the results which have been achieved by cognitive scientists permit us to give an advanced definition of it in terms of neurofunctionality, a definition focused on a fundamental concept: “The mind is what the brain does.” But given the gap that frequently exists between neuroscientific knowledge and the average culture of the population, this concept is no doubt far from being accepted by scientists who study the mind, including many psychologists. Traditionally, the mind has been analysed by scholars of different disciplines, such as philosophers, men of letters, churchmen, psychologists, psychiatrists, neuroscientists, etc. constantly in conflict among themselves in a lively and century-old dispute focused on the mind’s seat and essence. This dispute, universally known as the issue of the mind-body dualism, was originally introduced by Aristotle and then formally codified by Descartes. It postulated that the soul or psyche existed independently of the body. More recently, as a result of the developments in neurocognitive knowledge, the dispute has shifted towards the issue of mind and brain: i.e. is there an identity or a clear-cut separation between these two entities? Traditionally, this question has often been solved by means of a pervasive dualism between these two entities (Mecacci & Zani, 1982; Finger, 1994).

The so called cognitive revolution (Baars, 1986) which permeated the study of mind in psychology and neurosciences in the 1980s, led to the acknowledgement that cognition, and the resulting knowledge, rather than being an accumulation of sensory experiences, is a constructive process requiring the verification of assumptions which are influenced by prior knowledge, past experience, current aims and emotional and motivational states. This has implied not only the rejection of the mind-brain dualism by the most open-minded cognitive scientists, but also the establishment of the notion that the nature of the mind is strongly affected by the structure and functions of the brain. This is important as it implies that in order to know the mind, the study and a knowledge of the brain is
indispensable (Gazzaniga, 1995; Posner & DiGirolamo, 2000; Proverbio & Zani, 2000). In my opinion Candace Pert (1997) has summarised this principle in a most original manner:

I like to speculate that what the mind is is the flow of information as it moves among the cells, organs and systems of the body . . . the mind, then, is that which holds the network together, often acting below our consciousness, linking and coordinating the major systems and their organs in an intelligently orchestrated symphony of life.

I think that the notion implicit in this definition of the mind is extremely important: knowing the mind does not at all means knowing its conscious processes. On the contrary, it means investigating its non-conscious neural processes. This is no surprise if we consider the findings of modern research on the brain, which prove the existence of subliminal or unconscious perception and knowledge processes affecting manifest behaviour, or the ability of the brain to “filter” or suppress the processing of stimuli (Knight et al., 1999; Proverbio & Zani, 2002). This ability, which has already been investigated by Freud who had denoted it with the term “repression,” enables us to become aware of certain specific percepts and thoughts (and not others) thanks to an apparent faculty of choice and free will.

If we consider the importance of this conspicuous unconscious component of the mind in the light of the close relationship between thought processes and emotions highlighted by various brain scientists (cf. Le Doux, 1996; Damasio, 1997), as well as of the strong unconscious component of emotions themselves which are linked to the functionality of the amygdala and of the so-called limbic system, it is clear that a more appropriate cognitive theory of the mind is one that allows for the indissolubility between its rational and cognitive aspects—maintained by neocortical activity—and emotional and irrational aspects—expressed by the amygdala and the areas of the limbic paleo-cortex and anterior cingulate cortex (ACC) (see for instance: Bush et al., 2000; Luu & Tucker, 2002). This implies a theoretical logic which views the brain as a “living system,” i.e. a system which, although the sum of different parts, each with its own specific functionality, acts as an organic whole in which each function inextricably affects the other.
Another point to be considered is that, in the course of our life, the mind and the brain from which it derives constantly interact with other individuals, and consequently they must be viewed as integral parts of a hierarchic system which comprises larger and larger systems up to the largest of all, i.e. the social system. From a heuristic perspective, the mind should be considered not only in the light of an individual dimension, but also in the light of a social dimension, because the brain, which is extremely receptive and plastic, is shaped by reiterated, continuous individual relationships with the external world and interpersonal relationships. The smile of a mother, her voice, or the funny faces of Aunt Mary generate repeated modifications in the way in which neurones communicate (Diamond & Hopson, 1998). In the light of the stimulus-means (from the Russian “stimul-sredvsto”) theory of Vygotsky and Lurija, we might say that during development, highly specialised areas of our brain establish increasingly complex functional relationships as a result of the influence of environmental stimulation and biological maturation. Language, a typical example of stimulus-means, deeply influenced by social interaction, plays a crucial role in this growing functional complexity. According to Vygotskij (1978), for instance, the ability associated with internal linguistic activity, i.e. the linguistic thought, is also learned after experimenting dialogue with the external world. Similarly, though from a different viewpoint, Federmeier et al. (2002) argue that:

Language affords human beings an incredible degree of representational flexibility . . . Every day, humans produce and comprehend completely new strings of words, at a rate of about 150 words per minute . . . the degree of flexibility and efficiency we exhibit in this cognitive domain is a consequence of the structure of language, together with the structure of the entity that represents it and mediates its processing, the human brain.

Moreover, irrespective of the idea of the mind that is being taken into consideration, it is not heuristically correct to view it as an entity which is necessarily immutable. In fact, the mind has to be viewed as a dynamic entity that changes constantly as a result of developmental and experiential processes. Therefore, we must bear in mind that the functional processes linked to it vary as a function of the individual’s ontogenetic development—and, consequently, of the diversified maturation of its brain structures—as well as of the specific learning processes and experiences.
of the individual as a function of the developmental stage reached (see for instance: Nelson & Luciana, 2001; Posner et al., 2001; Mitchell & Neville, 2002). The cognitive strategies of partially immature and developing brains are different from those of more mature individuals.

This idea can be better explained by the data obtained in a study carried out in our laboratory (Figure 1), based on the recording of event-related potentials (or ERPs) of the brain (Zani & Proverbio, 2002). These responses were acquired from different areas of the scalp corresponding to the areas of the parietal, central and frontal cortex of a group of subjects in prepuberal age and a group of adolescents. The subjects were administered sequences of auditory stimuli which varied in number (1000Hz = 80%, 2000Hz = 20%) and pitch (1000 o 2000Hz). As the study focused on a task that involved attention, the subjects were asked to ignore frequent signals and to answer by pressing a button as fast as possible in response to rare stimuli (2000 Hz). To test the mental strategy adopted by these volunteers, we recorded brain electrical response to the RARE stimulus and also to the frequent stimulus that preceded (PRE) and followed (POST) it. It clearly emerges if we look at the recordings of the electrical responses to the RARE stimulus that the brain response of the two groups was quite similar at the parietal level (Pz), while the greatest differences in the brains of the two groups were observed at the central level (Cz) and, above all, at the frontal level (Fz). This confirms the concepts developed by us earlier in the present chapter, i.e. that the brain itself develops in a differentiated manner in its different districts, and that biological individuals of different ages are not necessarily characterised by brains with a different maturity level in all the districts taken into account. However, what we would like to underscore is that the comparison of the electrical response to the PRE and POST stimuli, identical from the physical point of view but different from the cognitive point of view in relation to the task, suggests something even more important for our purposes. In fact, the differences observed as a function of time, both at an early level (within 200 msec post-stimulus: N1) and at a later level (between 250 and 500msec post-stimulus: P300), between the responses of the groups of subjects to the PRE and POST stimuli suggest in all likelihood that younger subjects used a “bottom-up” or “data driven” information processing strategy. In practice, the rare stimulus generated a negative activation of their frontal lobes (named Selection Negativity, SN), or an orienting of attention response which, lasting in time, ended up influencing the response to the irrelevant POST
Figure 1. Event-related potentials (ERPs) of the brain recorded from parietal (Pz), central (Cz) and frontal scalp sites in young volunteers of different ages during an active discrimination task of auditory stimuli. The three columns represent ERPs elicited by rare stimuli to which volunteers had to give a motor response (target = RARE T.), and by frequent stimuli—to be ignored—immediately preceding (Frequent = F. PRE) and following (Frequent = F. POST) rare stimuli during the task. Bottom: Schematic description of the stimuli, the task and recording modality.
stimulus. Instead of ignoring this, the brain processed it in a more refined and discerning manner in its central and frontal districts. Conversely, the group of adolescents who gave a certain type of response to the PRE stimulus very probably influenced by their expectations of the stimulus sequence or by their probabilistic calculations on the appearance of the RARE stimulus, they seemed to be able to suppress, as required, the processing of the irrelevant POST stimuli once the rare stimulus appeared. This processing mode would suggest that these subjects have developed a “top-down” or “conceptually driven” processing strategy, i.e. a strategy founded on active predictions as to the appearance of the relevant rare stimuli and up-dating of the predictions themselves.

I think that these findings provide a neurobiological foundation for certain phenomena with which educators and experts in children’s learning modes are familiar. In other words, the fact that children in prepuberal age are unable to attentively follow educational curricula based on the use of homogeneous information modes, even though they actively respond to different, copious flows of information capable of capturing their attention processes. The higher organisational levels of the brain’s frontal areas as well as the more efficient control functions regulated by these areas allow adolescents to effectively and efficiently use expectations which are generated internally and compared with the actual input. This ability to project themselves into the future, to analyse the present and compare it with the past, which is founded on a mature functionality of the frontal areas (Knight & Grabowecky, 1995; Shimamura, 1995), equips adolescents with a greater ability in efficient learning when they are provided with environments which can be explored by them effectively.

What would a researcher in educational sciences ask neuroscientists to explain? How do you view education from your scientific perspective?

Many findings of brain research have been used by educators and cognitive psychologists to formalise what should have been, or was already being done within the dynamics of the educational process. In fact, when analysing the advances of research on cerebral processes linked to learning and on individual differences, many good educators traditionally felt that these findings confirmed what they already viewed, intuitively, as
the most correct strategy in their everyday practice at school, i.e. the use of different types of teaching and learning strategies according to a learner’s characteristics.

In the light of the considerable advances in cognitive research on the mind and brain, the time has probably come for educators to pose specific questions to neuroscientists which can help them to better understand their students and learning processes in general. In fact, a cognitive approach to education requires a more thorough knowledge of the nature of the mind itself. If teaching, and conversely learning, actually does facilitate further learning, emotional and cognitive development, intelligence, general cognition and motivation, then we must gain more knowledge about these processes which undoubtedly are processes of the mind, and of the brain, of which it is a function. This, of course, is in the broadest sense possible since the mind and brain change as a function of their interaction with other people (i.e. from family microcosms to large social systems).

However, it is necessary to ensure that the present advances in cognitive neuroscience are not misinterpreted nor applied inappropriately. It would be advisable for cognitive neuroscientists to interact with teachers in order to evaluate directly in the field how the results of their studies affect educational practice and planning. This common research area should also deal with certain issues, which strongly impact educational development and learning phenomena, both of which are inextricably correlated, in a broad sense, to social issues.

There are many questions to be asked and many phenomena requiring explanations. I will list here but a few:

1. At present the prevailing issue in neuroscience is “neuroplasticity.” This refers to the modifications in the nervous system as a function of age and/or experience, as well as to the variability and modifiability of intelligence. In spite of this, the conventional method used in schools to assess the average IQ is still elective and pervasive. However, responsibility for this lies also with psychologists and neuroscientists, the majority of whom have to date provided an average representation of the brain with structures and functions common to all individuals. One theory which is beginning to take root among scholars—albeit with some difficulty—is that each brain is different from every other brain and that brains differ according to the culture to which they belong. To fully understand the brain we have to consider the characteristics that make one brain different from another, bearing in mind, on the one hand, that these differences
need not be interpreted only as the result of innate attributes of an individual or a population and, on the other, that history takes on a real biological dimension as it influences the formation of the organisation of the brain. More detailed examples of these theoretical positions and data in support of such theories can be found in the essay by Luciano Mecacci (1978) and the more recent popular essays—which are no less valid than more so-called “serious” scientific works—by Mecacci (1984) and the distinguished neuroscientist Lamberto Maffei (1998). I believe that these theories are important as they imply that “each brain can learn in its own way” and that there are different forms of intelligence which range, for instance, from a scientist’s logical-mathematical-analytical intelligence to the more holistic but no less creative intelligence of an artist. These implications provide objective neuroscientific support to the theory of the existence of various types of intelligence first advanced by the psychologist Howard Gardner in 1983, who later elaborated it in greater detail (Gardner, 1993). According to this theory, in addition to a logical-mathematical intelligence and a spatial and linguistic intelligence, there is a corporeal-coenaesthetic intelligence, a musical talent, an intrapersonal ability (ability to know oneself) and an interpersonal ability (ability to know the others). Each of these probably has its own sphere of influence, its neurological representation and a specific model of impairment of its function. It is interesting that this theory implies that different tasks require different “typologies of intelligence” but also that individuals in whom one of these typologies prevails may excel in certain tasks and not in others.

In the main, good teachers tend instinctively to respond differently to students with different potentials. Moreover, they are convinced that a class offering a wide range of learning opportunities increases the possibility of success of the majority of its students. In the light of this, it is plausible that teachers may expect to be given objective indications as to which are the most important factors to be considered and used to favour the potentials of all students in the most effective manner possible. If it is true that research maintains that each brain has its own specific learning potentials, then guidelines should be provided to teachers on how to create environments and use strategies and tools which make this differentiated learning possible. Taking into account the diversity and age of students and their willingness to learn, neuroscientists could suggest a series of exercises to help keep the brain active, efficient and capable of an effective adaptive interaction with the environment. These exercises need not
to be conventional logical-mathematical exercises but, in the words of Maffei (1998; p. 77), “... playful mental exercises combining usefulness and enjoyment (to which the brain is always sensitive).”

2. In my opinion, another important issue that needs to be addressed is the way in which intensive use of new information technologies, such as computers or the Internet, can contribute or has already contributed to enhancing brain functionality and, in particular, superior thought processes. Recent studies conducted by distinguished cognitive scientists (e.g. Sternberg, 2000, 2001) have found that average intelligence—measured not only in terms of IQ evaluation but also in terms of behaviour—has been on the rise starting from a few generations ago. The conclusion reached is that this phenomenon could be the result of the use of new information technologies. From the neuroscientific standpoint, this has major implications on the modular organisational differentiation of the brain as a function of experience. This is even clearer if we think that the majority of complex, specific motor competencies and abilities are managed by the motor centres of the brain, such as the brain stem and cerebellum in connection with the basal ganglia. These are sub-cortical areas deeply involved in repetition and practice. Thus, through repetition, one and the same ability or a similar one, is mastered without any effort, i.e. automatically, or, to put it differently, in a swift efficient manner, without any waste of mental resources. Conversely, understanding, i.e. the use of reasoning, abstract thought, planning and meta-cognition (in practice, the ability to recognise and to relate an input to one’s beliefs and actions) activates the frontal lobes, i.e. the anterior parts of the cerebral neo-cortex. In other words, understanding is linked to the exercise of what is defined a “control function” and thus reflects a series of controlled processes, i.e. processes which are slower and require a waste of resources as they are linked to the activation of a more extensive neural network inside the brain. The findings of Sternberg and colleagues imply that the use of new technologies may have privileged the use of abstract thought and, consequently, of the more anterior parts of the neo-cortex to the detriment of motor activities, which are more linked to central cortical areas and sub-cortical areas. This assumption is supported by a statistical-psychological and psycho-anthropologic study conducted on a sample of 1,000 children (e.g. Cicogna, 2001) reporting that in the past five years, there has been a sheer drop in motor games (e.g. the traditional games of hide-and-seek and rounders, much loved by countless generations over the past millennium) or parlour games among Italian
children aged from 6 to 12 years in favour of TV and video-games. If we think that frontal lobes must reach full maturity (generally far beyond 12–13 years of age) to ensure effective and efficient control functions, neuroscientists should be called upon to answer many questions concerning the interaction with these technologies within an educational and evolutionary context. For instance, at what age and for how long is it appropriate to use these technologies within the school-educational and extra-curricular context, considering the stage of brain development in the users? What is the correct use of these technologies within the educational process and what are the consequences on the development of the individual’s personality and behaviour? In fact, the use of these technologies requires interactive processes where the user has to produce actions and receive feedback, allowing for a constant updating of comprehension and the collating of new knowledge. Or could it be that this use helps visualising concepts which are difficult to understand and allows access to a vast amount of information which, while increasing learning, may also produce a “short-circuit” of our brain’s abilities to process information and interact with environmental hierarchies. Even though the latest developments in neuroscientific research indicate that the brain is an immensely “resilient” system which can absorb relatively large amounts of information simultaneously processed by its different functional systems, no evidence has so far been provided to prove that using an excessive amount of information for long periods of time is harmless. Another consequential problem is that all these actions take place in a context of a man-machine interaction, i.e. in a “solitary” context, without any social interaction with fellow humans. Neuroscientists do not as yet know what the possible consequences of this might be on the individual’s emotional development, especially in individuals whose emotional and intellectual development is still in progress. It is interesting to note, however, that conventional neuroscientific thinking on the non-influence of emotions on learning has today been fully reversed. An increasing number of neuroscientists view emotions as being important for thought processes and, therefore, for the underlying learning processes. For instance, Le Doux (1996) maintains that there are different functional circuits for emotions and that anxiety and fear have a strong negative impact on our thought processes. The assumption is that information does not follow the slower so-called “high road” (a specific neuronal circuit) which transmits it to the sensory cortex for its clarification and analysis, but is conveyed along a fast “low road” to the amygdala,
the big nucleus of the limbic system responsible for the regulation of emotions, thus triggering an alarm and/or fear reaction with harmful repercussions on reasoning and learning. Moreover, Damasio (1994) came to the conclusion that thought and emotions cannot be separate and that body and brain, including emotions, are an indissoluble whole. In short, theoretical differences aside, the bottom line is that emotion and cognition interact, nurture and shape each other in a recursive fashion. For the sake of analysis, they can be considered separately at times, but we should always remind teachers and psychologists that they are inseparable in the learner’s brain and in his/her experiences.

In this context, Virtual Reality (VR) deserves a special mention. Today its role in new technologies is becoming more and more important, even though we have little or no information on how the brain responds to VR as opposed to real experience, or what role it could play in education. A recent study (Perani et al., 2001) has shown that during the observation of movements of the real hand, the frontal and parietal areas of the neo-cortex (i.e. the areas responsible for sensory-motor control) are activated, while during observation in VR, the areas activated are the occipital ones of the neo-cortex (i.e. the areas responsible for visual-perceptual functions). During the presentation in VR of the real hand, a bilateral activation of the posterior parietal cortex was also observed. These findings suggest that observation of motor actions performed by others elicit in the observer’s brain the activation of neural centres similar to those involved in the manifest motor performance. Conversely, VR seems to imply the activation of visual-perceptive processes only. The long-term effects of selective activation induced by VR on brain functionality still need to be systematically investigated. I personally believe it is important to ask for guidelines before adopting these technologies within an educational or rehabilitative context, as was done in the case of subjects who were retarded or impaired from a developmental perspective.

3. There is another important issue which is closely related to the previous one, but is here dealt with separately in order to analyse its “side effects;” I refer to the many hours children spend watching TV or playing video-games. Teachers have often spoken out against the negative effects that this habit has on the cognitive, physical and emotional development of their students, as well as on their inter-personal abilities. They have also complained that their students can only focus their attention for short periods. It is interesting that distinguished scientists such
as Torsten Wiesel and Lamberto Maffei agree with these claims as can be inferred by the ideas they exchanged during a conversation on the hills of Siena:

We agreed that…the most harmful thing was the passive stimulation of the brain: i.e. situations in which the brain is subject to a bombardment of stimuli (e.g. visual) despite not being stimulated to conscious actions, or critical thought. Visual communication, such as television, prevails in the modern world through media such as television, cinema and advertisements. Whether or not this may prove to be a good exercise for the brain in its totality in every case has led to many, serious doubts (Maffei, 1998, p. 78).

Unfortunately, despite such authoritative opinions, there are no systemic, documented studies showing absolute evidence of the effects that this has on the brain and its learning ability. For example, teachers could ask researchers if studies on the brain can reliably prove a direct relationship between an overwhelming use of multi-media and the inability to maintain or focus attention. Or, they could ask what happens to the brain when conversation, and consequently the use of language, is restricted and most of the time is spent in silence, passively watching television. Insight into the effects that new children’s TV programmes might have on the overall development of children would also be highly useful. Lastly, explanations on the implications of an appropriate use of the media in keeping with the age of users might also prove to be extremely valuable.

However, a completely different issue is the problem of violent TV programs and the effects they could cause. Is it correct to think that watching violent programs can induce violent behaviour in students who are unstable or tend towards violence? What happens from the chemical and functional viewpoints in the different areas of the brain when watching violent programs or visiting violent web sites or playing violent video-games? Why does the brain of certain individuals become physically dependent on these specific technologies? It is true that educators may think that research work that focuses on the phenomenal aspects of thought, perceptions, sensations and reasoning would be more useful to them, but they should be made aware of the fact that the latest research into the effects that attitudes and emotions have on learning ability indicate
that situations of tension and anger can prevent the normal functioning of cerebral circuits.