How In-Service Teachers Perceive Neuroscience as Connected to Education: an Exploratory Study

Amauri Betini Bartoszeck [1*], Flavio Kulevicz Bartoszeck[2]

[1]*Department of Physiology, Laboratory of Neuroscience & Education, University of Paraná; Curitiba, Brazil*
[2]*Institute of Neuroscience & Education of Paraná, Brazil*
[*]E-mail: abbartoszeck@gmail.com, bartozek@ufpr.br

This exploratory study is concerned about the extent to which a sample of 163 pre-school, primary and secondary Brazilian school teachers, expressed their opinion on how neuroscience might help their teaching and pupils´ learning. Evaluation instruments for Brazilian pupils were analysed. Two questionnaires were completed by the teachers. Results of a quantitative analysis indicated that in general teachers believe that neuroscience may contribute to the teaching and learning of their subject matter. An outline for an elective neuroscience and education course is presented. Educational implications are discussed.

Key Words: teaching, learning, educational neuroscience, teachers.

Introduction

Neuroscience is a relatively new area of biological knowledge joining, amongst others, neurophysiology, neuropharmacology, neurology, psychology, and neuro-imaging (Purpura, 1992; Kandel et al., 2000; Lent, 2001; Purves et al., 2005). In the last few years many aspects of physiology, biochemistry, pharmacology and detailed structure and behavior of invertebrate and primate nervous system have been elucidated (Abramson, 1990, 1994; Calafate, 2002; Moyes & Schulte, 2006). Studies of basic perception, emotion and learning & memory functions are making substantial progress by adopting approaches from neurobiology (Shepherd, 1990, 1994; Le Doux, 1996; Johnston, 1999; Thompson & Madigan, 2005). Teaching, learning and education can be studied as a new field of natural sciences, ranging from early years up to old age (Eliot, 1999, 2009; Gopnik et al., 1999, Gopnik, 2009; Strauch, 2010).

Imaging and Basic Neurophysiology

The development of modern techniques for recording the physiological activity of the brain (fMRI) when children, adolescents and adults are performing a cognitive activity have allowed scientists to localize of a more precisely neuronal circuits or areas which fire in synchrony within the brain (Gazzaniga & Ivry, 2002; Blakemore & Frith, 2005; Willingham & Lloyd, 2007). A multitude of neuronal circuits support basic functions of the human nervous system as well as those of the other animals. Human´s emotions expressed as fear, hatred and joy originated from specific areas of our brains with relevance to education (Del Nero, 1997; Damásio, 1999; Johnston, 1999; Le Doux, 2002; Immordino-Yang & Dámasio, 2007).

The human ability to think and retain memories depends on complex physic-chemical activities in the neuronal circuits of the pre-frontal cortex and hippocampus (Dudai, 1989; Rose, 1992; Fields, 2005). On the other hand, neural circuits in the brain and spinal cord program and fine tune our move-

ISSN 2165-8714

http://www.akademikplus.com/eujer/index.html

ments, such as our ability to thread through a needle´s eye or kick a football in a soccer play (Lundy-Ekman, 2004). Additionally, other body functions as for example temperature and blood pressure are controlled automatically by inner sensors located in the nervous system without our conscious knowledge. These are vegetative functions controlled unconsciously by means of highly sophisticated servo-mechanism developed through evolution (Kelso, 1995; Shepherd, 1994; Goodenough et al., 2007).Studies in biology have shown that all animals (and also plants) are the product of a complex interaction between their genetic load and environmental factors (Dawkins, 1995; Mayr, 1997: Elgin, 1999; Foley, 2003).

Evolution and Nervous System

In the beginning of the history of primitive living beings the mechanism of evolution provided animals whose nervous system could predict future actions based on past activities a competitive advantage in relation to other animals and almost certainty an advantage of leaving offspring with these characteristics (Nickel, 2010). Therefore, the "learning brain" provided adaptive advantages to its owner when seeking food, sex partners, shelter and risk taking, thus assuring increased longevity (Greenfield, 1996; Allman, 2000; Churchland, 2002; Barrett et al., 2002; Churchland, 2004).

Children Development and Learning

Children are intuitive observers and learners. They learn to collect information even while in by the womb from the inner and outside worlds by means of receptors and sense organs. These structures bring children the primary sensations that quite soon will turn into gustative, olfactory, aural, visual and tactile perceptions. In the early years children improve their abilities to understand better their environments and make decisions based in the integration of an array of sensory data. Then, children move to the next stage were talking and listening are the first stages in learning (Eliot, 1999; Rocha, 1999 Bransford et al., 2000).

Pupils´ learning and recalling are performed by brain structures. However, just knowing how the brain works is not enough teachers want to help their pupils learn the subject matters or knowledge of how the world works. Learning and techniques for teaching are related to the development of the brain according to a series of stages and responses to stimuli from the environment which shape the nervous tissue of brain structures (Fischer & Rose, 1998). Stimuli from the environment make neurons create new synapses with other neurons. Thus, learning in cellular terms is a process by which the brain reacts to stimuli strengthening synapses, developing new ones, enlarging the post-synaptic area and producing a larger number of receptors for neurotransmitters. Therefore, new neural circuits are able to process information and store knowledge codified in molecular traces (Black, 1991; Mussak, 1999; Hebb, 2002/1949; Koizumi, 2004).

Teaching and The Brain

Contemporary studies of learning contribute to bridge the gap between neuroscience and education. The recording of cortical activity allows a better knowledge of patterns of neuronal activity correlated to mental representations (Szücs & Goswami, 2007). Successful teaching will change synaptic connections and the whole function of the brain. However, it will depend on various approaches such as curriculum, teacher´s skills, teaching methodology, and out-of-school factors such as the pupil´s family and opportunities for learning outside the classroom. In fact, all the above factors will interact with the children´s brains, as for instance food quality. If the diet and home environment are poor pupils will not progress in spite of all the teachers´ efforts (Given, 1998; Lowery, 1998; Westwater & Wolfe, 2000; Ramos, 2002; Gómez-Pinilla, 2008).

Methods of cognitive neuroscience such as reaction time studies, EEG and MEG, fMRI, lesions studies reveal a relationship between brain areas and cognition that might be relevant for education (Norton et al., 2007). The approaches listed above will allow better understanding of learning, early diagnosis of learning disabilities and the development of methods for special education (Markram & Markram, 2010). It will also allow to investigation of learning "abilities & cognitive styles" and the best way to introduce innovative teaching methods in school settings, as for example, the KVP model by analysing school texts (Byrnes & Fox, 1998; Carvalho & Clément, 2007) . Further investigations are bringing new light to aspects of attention, memory, language, reading and writing, mathematics teaching, sleep and, emotion useful for education (Berninger & Corina, 1998; Byrnes & Fox, 1998; Stanovich, 1998; Brown & Bjorklund, 1998; Geake & Cooper, 2003; Geake, 2004;).

Education researchers are very optimistic that findings in neuroscience might contribute effectively to the improvement of educational practices. Therefore, a massive quantity of narratives and stories in daily newspapers, popular science magazines and even scientific journals has been exaggerating the benefits of "neuropedagogy" a recent fancy neologism. These articles vary from totally speculative and esoteric to those in the line with the late "new wave" movement in California (Bruer, 1997, 1998,). Examples are the development of new primary & secondary school curricula partially based in neuroscience and, exercises for the "right and left" hemispheres of the brain. Thus, building on "neuromyths" without empirical data to support the allegations offered to improve education, are taking us nowhere (Williams, 1986; Springer & Deutsch, 1998; Crossland, 2008; MacNeilage et al., 2009).
Against claims that neuroscience will not contribute to education due to lack of integration, other voices argument that with the introduction of a "level of analysis" performed by computational neuroscience it might find commonalities similar to studies of biology and physiology (Bruer, 2002; Connell, 2004; Nomura, 2010). Thus, neuroscience, psychology and cognitive neuroscience plus pedagogy may produce a new way to frame and integrate these areas of knowledge with mutual benefits (Anderson, 1992; McKnight & Walberg, 1998). The advances in neuroscience research by itself will not introduce new educational strategies. However, neuroscience provides concrete and not speculative clues why certain educational approaches might be more efficient than others (Reynolds, 2000; Ramos, 2002; Smilkstein, 2003).

Teaching Strategies

Teachers from preschool to graduate school apply pedagogical strategies on an everyday basis in the process of teaching and learning their subject matter (Jonassen et al., 1993; Novak, 1998; Michael & Rovick, 1999). Although neurobiological changes occur in the brain and "fixation" of knowledge occurs in the cognitive structure of the individual´s mind, few know how the brain and peripheral nervous system as a whole works as a relevant factor in the educational world (Claxton, 1995; Calvin, 1998; Rocha & Rocha, 2000; Relvas, 2009). Therefore, if neuroscience is to have any meaning for the teacher, it must move far beyond what is available in teaching techniques which emphasize cognition (McGilly, 1994; McNeal & D´Avanzo, 1997). It is not enough to describe how the human brain is functioning during a task or why it is difficult to learn something. One must be take into consideration the level of analysis undertaken to survey the task and the thought process involved (Dehaene, 2007). For instance, attention and learning do not occur in isolated brain structures but are due to various layers of neuronal nets interconnected in complex and instable links (Edelman, 1987; Pozo, 2005; Edelman, 2006). A further understanding how information is "translated" by sense organs and turned into perception and later stored in long term memory, might be a rich strategy to improve pupil´s school success (Rosenfield, 1988; Lieury, 1997; Izquierdo, 2002; 2004 a, b; White, 2012).

The early elementary school teacher is particularly concerned with the concept of "critic period" or better said "sensitive periods" when dealing with her pupils. It is a period of brain development shaped by a genetic program and by environmental experiences (neuronal plasticity) induced by a variety of stimuli such as colors, movement, sounds, and affectivity (Bartoszeck, 2006; Penn et al.,, 2008). However, the lay press and media created a catchy phrase "windows of opportunity" which could shut if urgent educational methods are not utilized with children in early infancy. Experimental data from publications were interpreted optimistically and transferred straight to education. Bruer, (2001) reviews this event critically.

On the other hand, some researchers argue that certain kinds of students do not get full advantage from curricula developed from studies on learning and educational strategies. For example, there are some clues that male students get better grades than female students in mathematics and science as a function of their skills in visual-spatial orientation as they grapple with problem solutions. It seems that gender counts (Brizendine, 2006; Selçuk et al., 2007; James; 2007). Neuro-imaging is pinpointing brain areas involved in the visual-spatial processing and thus suggest an integration of our understanding of these skills in mathemathics education as a means to develop more efficient methods of teaching (Dehaene, 1997; Simons. 2003; O´Boyle et al., 2005; Geake, 2006). Additionally, further studies in neuro-genetics and neuro-imaging may help understand if the visual and phonological processing in brain areas are the roots of dyslexia and other learning problems (Fisher & Francks, 2006; Plomin et al., 2007; Scheneps et al., 2007; Grigorenko, 2007).

Unfortunately, undergraduate courses in Education (Pedagogy) do not carry in their curricula "Educational Biology" or "Neurobiology of Learning" as subject matters in Brazil, with exceptions (Scaldaferri & Guerra, 2002). However, there is interest in universities to offer outreach courses to in-service teachers covering further aspects of literacy, numeracy and conceptual change (Guerra et al., 2004; Blake & Gardner, 2007; Cosenza & Guerra, 2011).

Although teachers are interested in the cognitive development of the students they teach, there is a lack of knowledge about the biological basis of learning. Thus, the main purpose of this exploratory study is due to the scarcity of other Brazilian studies on the topic, is to survey what teachers really know about brain and mind, what misconceptions they might have and propose to remediate this situation with outreach courses and suggest practices based on sound neuroscience findings.

Research Questions

The main purpose of this exploratory study is:

- To evaluate teachers´ knowledge of how the brain works;
- To highlight potential contributions that educational neuroscience might offer;
- To survey how much pre-school, primary school, and secondary school teachers know about brain, mind and their educational implications.

Methodology

Participants

The authors developed a questionnaire with 10 items to measure the perception of a sample of in-service teachers from pre-school, primary school and secondary school have of how the brain works, and how this knowledge might contribute to the teaching and learning of their pupils. The items were rated on a 7 point-Likert-type scale with anchors of 1=strongly disagree to 7=strongly agree. The questionnaire was anonymously answered by 83 teachers (74 women and 9 men) whose ages range from 25 to 54 and who have at least 5 years of teaching experience.

First Questionnaire

The contents of the sentences vary from a basic knowledge of the brain and central & peripheral nervous system to "critical" and " sensitive" periods during infancy, and experiences in the environment, neuroplasticity and learning, "enriched" environments, development and learning, biology of memory and teaching, emotion & teaching, sleep & memory & learning, zoo and museum visits and learning, PBL and mental models and learning (TABLE 1).

Twenty-four questionnaires were collected from pre-school teachers, twenty-six from primary school and 33 from secondary school teachers. The sample was collected at the schools in the town of Curitiba, Paraná State, southern Brazil. Previously the project was reviewed and approved by the Research Committee of the Institute of Biological Sciences and the Ethical Committee in Research of the University of Paraná, Brazil. Teachers signed the Consent Term before the data were collected at one private and two public schools located in downtown and in the outskirts of the town as to reflect the social-cultural strata of the teachers.

Table 1. First questionnaire to evaluate how the brain might contribute to teaching and learning (Partially Adapted from Herculano-Houzel, 2002; Howard-Jones, 2010).

1. A better knowledge of human brain and nervous system might contribute to teaching and learning.
2. There is a "critical period" which is crucial in the early years learning.
3. There is a "sensitive period" in developing which is influenced by environmental experiences.
4. The brain is subjected to changes in neural circuits (neuroplasticity) during one´s life span.
5. Do "enriched" school settings improve learning and brain development in children?
6. Visits to natural history museums, zoological and botanical gardens might promote informal learning and greater pupils´ sociality.
7. A better knowledge concerning the molecular mechanisms underlying learning and memory might improve teaching?
8. Does knowing the molecular mechanism of human emotion might contribute to better teaching?
9. There is a close relationship between sleep, memory and school learning.
10. Using problem-based learning, case method and concept map might facilitate management of new information?

The findings of the first survey provided the topics for a short course (20 h) entitled "Neuroscience meets Education" delivered at the Department of Physiology, University of Paraná to 20 participants in February 2007. Teachers from public schools and graduate students for the Master of Biology degree attended this course voluntarily. The same outreach course was delivered at the "Support Group for People with Special Needs", University of Paraná to 60 participants as compulsory course attending for public secondary school in–service teachers during September to November 2007.The topics covered were: basic neuronal and neuroglial mechanisms, neuronal plasticity and environment experiences, critical and sensitive periods in brain development with relevance to education, "enriched environments" and school settings, synaptic development, pupils´ age and education, sleep, circadian rhythm and learning in infancy and adolescents pupils.

Second Questionaire

Therefore, a second questionnaire with 10 questions was developed by the authors and data was collected from 42 teachers (aged 28 to 45 year-olds) and all teachers returned it. All teachers were from public secondary schools and answered the questionnaire anonymously. The items were rated on a 6 point Likert-type scale with anchors of 1= strongly disagree to 6=strongly agree. Again, because females represented more than 95% of the sample, the role of gender could not be meaningfully analyzed. The topics covered in these lectures (20 h) were: brain development and environment experiences, neuronal communication, information, chemical and electrical synapses, molecular mechanism of learning, age range and learning, neuromyths (e. g. one only uses 10% of one´s brain capacity), and potential educational implications of neuroscience (TABLE 2).

Table 2. Second questionnaire to evaluate how the brain might contribute to teaching and learning (Partially Adapted From Herculano-Houzel, 2002; Howard-Jones, 2010).

1. Brain development from fetal to adult stage is totally under control by genes independent of environmental experiences.
2. Brain and peripheral neurons communicate by neural circuits similar to home wire electrical design.
3. Cranial and spinal nerves communicate by action potentials and release of neurotransmitters at synapses.
4. Learning occurs through changes of the brain´s nervous connections.
5. Brain areas are progressively involved for learning during developing stages.
6. Brain nervous connections are fully active during 24 hours a day even when one sleeps.
7. Holistic teaching techniques should be use to compensate for the 10% brain capacity.
8. The mind is a product of brain electrical activity and not from soul stimulation.
9. Neuroscience research has direct implications for educational practices and science teaching and learning.
10. Only teaching methods, intuition, and teacher skills can improve education in spite of neuroscience research.

Results

The responses were put together in a table to simplify analysis (Table 3). Because females represented more than 89.0% of the sample, it precluded any meaningful analysis of the role of gender in the perception of the relevance of neuroscience to education. The raw scores for each participant across the 10 questions are reported. In this way, the data have archival value and can be readily compared to other studies in which the questionnaire might be used in other regions in Brazil and elsewhere.

Answers for the 1st. questionnaire

Question 1 asked teachers if a better knowledge of the brain function could contribute to teaching and learning of their subject matter. Analysis indicated that 68.7% of this sample strongly agree (category 7) that knowing more about the brain function could contribute to their teaching. This percentage increased to 87.4% when the data for the adjacent Likert category was included (Category 6). Question 2 asks if the teachers think there is a "critical period" in infancy for learning. Only 30% of the sample strongly agrees (category 7). This percentage increased to 34.8% when the adjacent category "agree" was included. However, there was a larger disagreement (36.14%) with the statement when middle category 4 is included. The answers for question 3 which asks about the importance of "sensitive periods" indicates that 44.5% of the sample strongly agree, which increases to 59.0% when the adjacent category 6 is included. The relationship between neuroplasticity and learning over the life span is acknowledge by 66.2% of the sample which strongly agree with the statement of question 4 which increased to 80.7% when the adjacent category 6 is included. Question 5 deals with "enriched environment" and learning. Ratings indicated that 74.5% of the sample strongly agrees (category 7) with the statement which increased to 80.0% when the adjacent category 6 is included. When teachers were asked about the importance of visiting museums, zoological and botanical gardens (question 6) as factors which improve learning and sociability of the pupils, 72.2% of the sample strongly (category 7) agree with the statement which increased to 79.4% when adjacent category 6 is added. Question 7 evaluates teachers´ opinions about whether having a better grasp of the physiological mechanisms responsible for learning and memory would improve teaching. Analyzing the data showed that 66.2% of the sample strongly agrees (category 7) with the statement which increased to 79.5% when the adjacent category 6 category is added. Question 8 assesses teachers´ opinions about the influence of emotion on learning. 61.4% strongly agree with the item which increased to 84.2% when category 6 is added. Question 9 asks about the relationship between hours their pupils sleep and, learning. Sixty-four percent strongly agree (category 7) and when category 6 is included it increased to 87.0%. Finally, when teachers were asked whether using the techniques of PBL (problem-based leaning, case study) and concept mapping and mental mapping could be factors to modify the "cognitive structure of the mind" of their pupils (question 10), the ratings indicated that 44.5% strongly agree (category 7) which rose to 57.8% when the category 6 is included. However, 20.5% of the middle category 4) in this sample disagrees. Table 3 depicts the number of participants and their ratings of each of the 10 questions.

Table 3. First questionnaire. Ratings for neuroscience and education scale by pre-school, primary and secondary school teachers, N=83 (M=mean, SD=standard deviation).

	Rating								
Question	1	2	3	4	5	6	7	M	SD
1	0	1	7	3	3	14	57	6.42	1.10
2	4	6	2	27	10	4	30	4.70	1.91
3	2	4	3	16	10	11	37	5.54	1.69
4	6	1	0	8	3	12	53	6.0	1.77
5	7	1	0	3	0	5	67	6.28	1.81
6	6	0	1	6	3	6	61	6.19	1.72
7	1	0	3	8	4	12	55	6.28	1.31
8	2	3	0	6	3	19	50	6.13	1.47
9	2	3	0	6	4	14	54	6.22	1.46
10	4	5	1	16	8	12	37	5.46	1.83

Answers to the 2nd questionnaire

Item 1 of the second questionnaire asked participants if the development of the children´s brain from fetal phase to adult age is entirely controlled only by genes and is independent of environmental experiences. The data indicated that 59.5% of the sample strongly disagreed that brain development is only controlled by genes. The percentage increased to 78.5% when the adjacent Likert category is included (category 2). Question 2 asked for the teachers´ opinions about whether information travels in neural nets via of electrical impulses and release of neurotransmitters at the synapses. 59.5% of the participants strongly agreed and the percentage increased to 85.6% when the adjacent category 5 is included. Question 3 asked the teachers if they were aware that communication between different areas of the brain and cranial and spinal nerves are carried out by electrical impulses produced by the movement of ions across the neuronal membrane and the release of neurotransmitters at the synapses. 42. 8% of the participants strongly agreed and the percentage increased to 85.6% when the adjacent category is included (Category 6). Question 4 asked the teachers if they agree (or disagree) that the learning process results from molecular mechanisms and structural changes in neural connections at different sites in the brain. The responses showed that only 21.4% of the sample strongly agreed but this percentage increased to 90.3% when the adjacent categories 5 and 4 are included respectively. Question 5 asked the teachers if they were aware that different areas of the brain are ready for learning at different ages of the pupils. Only 28.5% of the sample strongly agreed but this percentage increased to 85.6% when the categories 5 and 4 are included, indicating a degree of disagreement with the statement (M=4.50, SD=1.40). Question 6 asked teachers if the brain is in active 24 hours a day even when we sleep. 88.0% of the sample strongly agreed and this percentage increased to 95.1% when the adjacent category is included (Category 5).Question 7 asked teachers if they believed that we only use 10% of our brain capacity. Fifty percent of the sample strongly disagreed but 28.4% strongly agree with the statement (Categories 5 and 6).It is noteworthy that 21.4% were in doubt on the brain capacity issue, M=2.81, SD=1.60, (Categories 3 and 4). Question 8 asked teachers whether mind is the result of the supreme action of soul over the brain structure. 45.2 % strongly disagreed but surprisingly 42.7% of the sample strongly agreed with the statement. Question 9 asked teachers if research in neuroscience could contribute to the understanding how the brain codifies and records information, providing valuable implications to teaching and learning in schools settings. All respondents (100%) of the sample strongly agreed with the statement (Categories 5 and 6). Finally, question 10 of the questionnaire asked teachers if only pedagogical methods, teacher´s intuition and will power could improve education doing without neuroscientific knowledge. 64.2% strongly disagree but 33.2% of the sample (M=2.45, SD=1.45) strongly agreed that pedagogical methods and teacher personality would suffice. Table 4 depicts the number of participants and their ratings of each of the 10 questions.

Discussion and Conclusions

Recent evaluations by the Brazilian Ministry of Education (MEC) of current teaching and learning in Brazilian schools indicated disappointing results nationwide. These evaluations are based on instruments such as the SAEB (National System of Evaluation of Basic Education , ENEM (National Examination of Secondary School) and Pisa. Brazilian evaluation results are very poor as compared to foreign pupils of the same grade and age (Bonamino & Franco, 1999; Waltenberg, 2005).For instance, pupils 15-years-old with more than 12 years of schooling present modest academic performance, but lack scientific literacy, are unable to understand a text (functionally illiterate) or are unable solve a simple arithmetic problem (Castro, 2002; Ireland, 2007).The SAEB mission is to evaluate a sample of pupils enrolled at 4th grade and 8th grade of Primary School (Ensino Fundamental) and 3rd grade of secondary school (Ensino Médio) from public and private schools in urban and rural areas nationwide. The exam is compulsory and composed of questions selected by a committee in Mathematics and Portuguese. The score runs from 0 to 10 points. On the other hand the ENEN test (Exame Nacional do Ensino Médio) which is non-mandatory evaluates students at the last grade of secondary school (3rd grade). The objective of this test is to assess the students´ academic accomplishments before entering a College or University undergraduate course. Some Brazilian Universities take the score as a partial or total mark for enrolling students in their undergraduate courses (Peixoto Costa et al., 2010). Only a few secondary school graduates and the first year of undergraduate in College or University courses, showed outstanding performance in deep understanding of mathematical and scientific concepts crucial to the whole economic and social development of an emerging country like Brazil.

Table 4. Second questionnaire. Ratings for neuroscience and education scale by secondary school teachers, N=42 (M= mean, SD=standard deviation)

	Rating							
Question	**1**	**2**	**3**	**4**	**5**	**6**	**M**	**SD**
1	25	8	8	1	0	0	1.64	0.88
2	0	0	0	6	11	25	5.43	0.74
3	0	0	1	5	18	18	5.31	0.75
4	0	0	4	13	16	9	4.71	0.92
5	3	1	2	14	10	12	4.50	1.40
6	0	0	0	2	3	37	5.83	0.49
7	12	9	4	5	11	1	2.81	1.60
8	10	9	5	11	3	4	3.02	1.65
9	0	0	0	0	5	37	5.88	0.33
10	14	13	1	12	0	2	2.45	1.45

Since the introduction of scientific techniques for recording and imaging brain activity during the performance of cognitive tasks, it has been possible to look at the brain in action surpassing the traditional approaches of using behavioral measures as patterned tests and interviews (Geake, 2009). Although there are technical limitations in these methods they provide a useful link between neuroscience and education. Another "limitation" is that most of the neuroimaging data comes from adults, not from children whose brains are developing (Howard-Jones, 2010). However, mathematical reasoning can establish a key partnership between cognition and brain function at school settings (Changeux & Connes, 1991; Changeux & Ricoeur, 2000; Varma & Schwartz, 2008b).

These non-invasive technical procedures provide plenty of data about the electrical activity in brain layers of the brain responsible for the information communication, oxygen and glucose metabolism at the moment a mental activity is being carried out (Blakemore & Frith, 2005). In addition to, the relevant data applied in neurological and psychiatric settings, cognitive neuroscience is increasingly able to identify brain areas responsible for failures in reading and language and mathematics learning by means of educational practice (Butterworth, 1999; Byrnes, 2001). Further command of neuroscience principles would enable educators to assess their pupils´ academic performance. Could it not be related to poor cognitive stimuli during the early critical period of brain development? This seems to be worldwide concern (Bayley et al., 2001; Goswani, 2004; Doidge, 2007). Therefore, more than 80.0% (M=6.42, SD=1.10) of the sample of the educators who completed the first questionnaire believed that a better knowledge of the workings of the brain could contribute to improve teaching and learning of their pupils, but might be misinformed or even mistaken(Howard-Jones, 2010 p.p. 3-19). On the other hand, findings of a similar survey with teachers in US indicated that only 57.0% are believers that neuroscience has value for education and 24.0% of the sample has reservations (Zambo & Zambo, 2011). Chedid, (2006) emphasized this point concerning child literacy as a "mirror image" of neuroscience literacy among the Brazilian public, yet undergraduate pedagogy courses list few educational psychology courses and an almost no brain science in initial teacher training in Brazil (Herculano-Houzel, 2002). Zaro et al., (2010) list principles that could be followed by the teaching community. In addition, undergraduate students of psychology are uncertain about whether psychology can be viewed as a science (Bartoszeck et al., 2005; Morales et al., 2005). There is a concern about the full endorsement of the concepts of "critical" and "sensitive periods," (M=4.70, SD=1.91; M=5.54, SD+1.69 respectively) although researchers favored cognitive plasticity and to a lesser degree "enriched environments" (M=6.28, SD=1.81) as the former related to "windows of opportunity" and the latter to rats rearing not educating human beings (Bailey, 2001; Medina, 2008).

Results showed that almost 80% of the teachers in this sample favored outside the classroom education such as visits to zoos and museums as a means for improving academic performance and sociability amongst the pupils (Braund & Reiss, 2004; Uitto et al., 2006). When looking at the items of emotion, sleep, and memory, more than 85% of the teachers in the sample agreed that these are factors that if properly investigated could improve learning in the school settings (Börsch-Haubold, 2006; Golombek & Cardinali, 2008; Menna-Barreto & Wey, 2008; Griffith & Rosbash, 2008; Schwartz, 2009). Finally, more than 50% (M=5.46, SD=1.83) of the teachers in the sample believe that the methodology of PBL, case method (Novak, 1998; Bartoszeck, 2005) and concept mapping and mental mapping (Margulies, 1991; Trifone, 2006) might be able to change the synaptic net and as a consequence the cognitive structure of the minds of their pupils (Goldberg, 2001; Buzan & Buzan, 1993; Buzan, 2004;).

After the second outreach course on Neuroscience and Education, a new questionnaire was completed by a new group of teachers. Results indicated that 88.0% of this sample considered that neuroscience research might help understand how the human brain codifies, and store information and this could be applied to improve pedagogical methods. Many neuroscience and education workshops around have generated lists of research questions in need of answers, for instance: what are the neural bases of individual differences in learning and development?, or "is there any neural reality to so-called learning styles? (Geake, 2009). However, 28.4% (M=2.81, SD=1.60) of the teachers in this sample still believe that we only use 10 percent of our brain and that thus educators should apply holistic techniques for teaching their subject matters to the pupils in the classroom. This neuromyth and the "left- and right-brained thinking" are hard to erase from the teaching community (Springer & Deutsch, 1998; Geake, 2008; MacNeilage et al., 2009).

Although, similar questionnaires were used in both surveys but with different groups of educators, the audience was up-to-a-point receptive to the applicability of neuroscience knowledge for improving in teaching and learning. Pickering & Howard-Jones (2007) using a questionnaire and in-depth interviews found after a seminar series, that teachers in the UK "show a high level of enthusiasm for attempts to interrelate neuroscience and education". But doubts still persist about how to do it and various learning strategies are being researched (Willis, 2006; Varma et al., 2008a). On the other hand, there is some persistent notions that the soul stimulates the brain (question 8, 42.7% agree with the statement, M=3.02, SD=1.65). It seems that not many teachers believe about the immaterial basis of the soul, or that the "mind results of brain process which emerged gradually in both development and evolution" (Bloon, 2004 pp. 189-198). Furthermore, the worldwide research community and particularly educators are cautious on the straight forward application of neuroscience to education (Geake, 2003; Geake, 2009 pp.15-20).

However, papers are being published to generate discussions and potential collaborations between neuroscientist and educators worldwide mainly in the journal "Mind, Brain, and Education", since 2007. In conclusion, the results of the 2 surveys and the content of the lectures delivered to the teachers allowed the development of the contents of the elective course BF-054 Neuroscience applied to Education for trainee teachers enrolled in the undergraduate course of education (pedagogy), that is being carried out by the first author since the first semester of 2009 in the Department of Physiology, University of Paraná, Curitiba, southern Brazil. The main topics are listed below complemented by a selected bibliography (not included herewith):

- Brain development and school children;
- Brain in school and neuroplasticity;
- Emotional states and learning;
- Social brain and school environment;
- Learning and recalling;
- Adolescent brain and learning;
- Brain, words and numbers, emergent science in pre-school;
- The "mathematical" brain, literacy, and reading;
- Sleep deprivation, learning, memory and attention.

Educational Implications

Therefore, educators should have easy access to the following particulars which might have potential application to their subject matter teaching creating stimulating learning environments (adapted partially from: Rushton et al., 2010).

* Practice with drawings and coloring (Kapit et al., 2000, p.p. 15-30; 83-112).

* Practice with "schemas" as knowledge is stored in human memory as a semantic network conceiving learning as a reorganization of networks in semantic memory (Jonassen et al., 1993).

* Practical classes in the laboratory or field trips and could provide associations between previous experiences and the understanding of a present topic (Braund & Reiss, 2004);

* Teaching should fine tune motivation and patterns of academic performance to the age range of students by adopting integrated thematic units, such as for example reasons for spread of Dengue Fever in Brazil (Kachar et al., 2001; DeAquino, 2008).

* The brain shows neuronal plasticity as the individual matures but greater synaptic density in certain areas of the cerebral cortex do not correlated with larger capacity for general learning. Selected learning activities where the student can choose one of them may attach him to the theme when he feels it is relevant for his life out of school (Mintzes & Leonard, 2006);

* During a novel learning experience sight and hearing are involved. Therefore, curriculum should include scenarios, that reflect real life "simulations" in a way that new information may "anchor" to previous information in the cognitive structure of the mind (de Jong, 2009; della Chiesa, 2009);

* Evolutionarily the primate and other vertebrate brains developed to identify patterns for survival and mating. The school should encourage students to accept transitory answers and project hypothesis to solve problems and "cases" based on evidences available at the moment (Geary, 2005; Buss, 2009);
* The brain perceives information mainly in the form of illustrations, images symbols due to our primitive antecessors´ ways of thinking. Thus, schools should offer opportunities for pupils to learn by means of drawings, music, drama and concept mapping (Krampen, 1991; Novak, 1998; Fisher, 2009; Hardiman et al., 2009).

Acknowledgements

A poster was presented at the I IBRO-LARC Neuroscience Congress in Latin America, Caribe and Iberic Peninsula, Búzios, Rio de Janeiro-Brazil, 1 to 4 September, 2008. The authors acknowledge comments and suggestions by Dr. John T. Bruer, President James S. McDonnell Foundation during The Second La School for Education, Cognitive and Neural Sciences, El Calafate, Ar, 5 to 16 March, 2012.

References

Abramson, C. I. (1990). Invertebrate learning: a laboratory manual and source book. Washington, D. C.: American Psychological Association.
Abramson, C. I. (1994). A primer in invertebrate learning: the behavioral perspective. Washington, D. C.: American Psychological Association.
Allman, J. M. (2000). Evolving brains. New York: Scientific American Library.
Anderson, O. R. (1992). Some interrelations between constructivist models of learning and current neurobiological theory, with implications for science education. Journal of Research in Science Teaching, 29(10):1037-1058.
Barrett, L., Dunbar, R., Lycett, J. (2002). Human evolutionary psychology. Houndmills: Palgrave MacMillan.
Bartoszeck, A. B. (2005). Promovendo a resolução de "casos" (case-method) em Terapia Educacional, Revista Uniandrade, 6(2):93-105. (Promoting case-method use in Occupational Therapy).
Bartoszeck, A. B. (2006). Neurociência na Educação. Revista Eletrônica Faculdades Integradas Espírita, 1:1-6.
Bartoszeck. A. B., Abramson, C. I., Place, A. J. (2005). Perception of students in the south of Brazil of status of Psychology as a science. Psychological Reports, 97:750-756.
Bayley, D. B., Bruer, J. T., Symons, F. J., Lichtman, J. W. (2001). Critical Thinking about critical periods. Baltimore; Paul H. Brookes Publishers.
Berninger, V. W., Corina, D. (1998). Making cognitive neuroscience educationally relevant: creating bidirectional collaborations between educational psychology and cognitive neuroscience. Educational Psychology Review, 10(3):343-354.
Black, I. B. (1991). Information in the brain: a molecular perspective. Cambridge: The MIT Press.
Blake, P. R., Gardner, H. (2007). A first course in mind, brain and education. Mind, Brain, and Education, 1(2): 61-65.
Blakemore, S-J., Frith, U. (2005). The learning brain; lessons for education. Oxford: Blackwell Publis.
Bloom, p. (2004). Descartes´baby: how the science of child development explains what makes us human. New York: Basic Books.

Bonamino, A., Franco, C. (1999). Cadernos de Pesquisa, Exame National do Ensino Médio (ENEN Test:High School National Exammination)
Börsch-Haubold, A. (2006). Sleep and learning. Science in school. 3:1-8.
Bransford, J. D., Brown, A., Cocking, R. R. (2000). [Eds.]. How people learn: brain, mind, experience, and school. Washington, D. C.: National Academy Press.
Braud, M., Reiss, M. (2004). [Eds]. Learning science outside the classroom. London: RoutledgeFalmer.
Brinzedine, L. (2006): The female brain. New York: Broadway Books.
Brown, R. D., Bjorklund, D. F. (1998). The biologizing of cognition, development and education: approach with cautious enthusiasm.
Bruer, J. T. (1997). Education and the brain: a bridge too far. Educational Researcher, 26(8):4-16.
Bruer, J. T. (1998). Brain science, brain fiction. Educational Leadership, 26(8):14-18.
Bruer, J. T. (2001). A critical and sensitive period primer. In Bailey, D. B. et al., Critical thinking about critical periods. Pp. 3-36. Baltimore; P.H. Brookes Publishers.
Bruer, J. T. (2002). Avoiding the pediatrician´s error: how neuroscientist can help educators (and themselves). Nature Neuroscience [supplement],5:1031-1033.
Buss, D. M. (2009). The great struggles of life: Darwin and the emergence of evolutionary Psychology. American psychologist, 64(2):140-148.
Butterworth, B. (1999). The mathematical brain. London: Macmillan.
Buzan, T. (2004). Tu mente em forma: princípios eficaces para desarrollar la conexión cuerpo mente. Barcelona: Ediciones Urano. [Head Strong].
Buzan, T., Buzan, B. (1994). The mind map book: how to use radiant thinking to maximize your brain´s untapped potential. New York: Dutton.
Byrnes, J. P. (2001). Minds, brains, and learning: understanding the psychological and educational relevance of neuroscientific research. New York: The Guilford Press.
Byrnes, J. P., Fox, N. A. (1998). The educational relevance of research in cognitive neuroscience. Educational Psychology Review, 10(3):297-342.
Calafate, L. C. (2002). Cognição e aprendizagem nos invertebrados. O Professor, 76(3):37-46. [Cognition and learning in invertebrates].
Calvin, W, H. (1998). Como o cérebro pensa: a evolução da inteligência, ontem e hoje. Rio de Janeiro: Editora Rocco. [How brains think: evolving intelligence, then and now].
Carvalho, G. S., Clément, P. (2007). Projeto "Educação em Biologia, Educação para a saúde e educação ambiental para melhor cidadania: análise de manuais escolares e concepções de professores de 19 paises (europeus, africanos e do próximo oriente) Revista Brasileira de Pesquisas em Educação em Ciências, 7(2):1-21. ["Biology, Health and Environmental Education for better citezenship" Project: analyses of textbooks and teachers´ conceptions from 19 countries].
Castro, C. de M. (2002). Os dilemas do ensino superior e a resposta da Faculdade Pitágoras. Belo Horizonte: Ed. Universidade. [College teaching dilemmas].
Changeaux, J-P., Connes, A. (1991). Material pensante. Lisboa; Gradiva [Matière à Pensée].
Changeux, J-P., Ricoeur, P. (2000). What make us think. Princeton: Princeton University Press.
Chedid, K. A. K. (2006). Educação e neurociências. Neurociências, 3(3):6-11.(Education and neuroscience).
Churchland, P. S. (2004). How neurons know? Deadalus, 133(1):42-50.
Churchland, P. S., (2002). Neural worlds and real words. Nature Reviews Neuroscience., 3(11):903-907.
Claxton, G. (1995). Ruídos de uma câmara escura; um estudo sobre o cérebro humano.São Paulo:Siciliano.[Noises from the darkroom; the science and mystery of the mind].
Connell, M.W. (2004). A response to John Bruer´s bridge too far. AERA Annual conference Abstract, San Diego, CA, 32p.

Cosenza, r. M., guerra, l. B. (2011). Neurociência e educação: como o cérebro aprende. Porto alegre: artmed (neuroscience and education: how the brain learns).

Crossland, J. (2008). The myths surrounding "brain-based" learning. SSR, 90(330):119-121.

Damásio, A. R. (1999). The feeling of what happens: body and emotion in the making of consciousness. New York: Harcourt Brace Co.

Dawkins, R. (1995). River out of Eden: a Darwinian view of life. New York: Basic Books.

De Jong, T, van Gog, T., Jenks, K., Mannlove, S., van hell, J., Jolles J., van Merrienboer, J., van Leeuwen, T., Boschloo, A. (2009). Explorations in learning and the brain on the potential of cognitive neuroscience for educational science. The Netherlands: Springer.

DeAquino, C. T. E. (2008). Como aprender: andragogia e as habilidades de aprendizagem. São Paulo: Pearson-Prentice Hall. (how to learn: andragogy and the skills of learning).

Dehaene, S. (1997). The number sense: how the mind creates mathematics. London: Penguin Books.

Dehaene, S. (2007). A few steps toward a science of mental life. Mind, Brain, and Education, 1(1):28-47.

Del Nero, H. S. (1997). O sítio da mente: pensamento, emoção e vontade no cérebro humano. São Paulo: Collegium Cognitio Ltda.[The site of the mind]

Della Chiesa, B., Christoph, V., Hinton, C. (2009). How many brains does it take to build a new light: knowledge management challenges of a transdisciplinary project. Mind, Brain, and Education, 3(1):17-26.

Doidge, N. (2007). The brain that changes itself: stories of personal triumph from the frontiers of brain science. New York: Penguin Books.

Dudai, Y. (1989). The neurobiology of memory; concepts, findings, trends. Oxford: Oxford University Press.

Edelman, G. M. (1987). Neural Darwinism: the theory of neuronal group selection. New York: Basic Books.

Edelman, G. M. (2006). Second nature: brain science and human knowledge. New haven: Yale University Press.

Elgin, D. (1999) A dinâmica da evolução humana. São Paulo: Editora Cultrix [Awakening earth: exploring the evolution of the human culture & consciousness].

Eliot, L. (1999). What´s going on in there? –how the brain and mind develop in the first five years of life. New York: Bantan Books.

Eliot, L. (2009). Pink brain, blue brain: How small differences grow into troublesome gaps-and what we can do about it. New York: Houghton Mifflin Harcourt Publis.

Fields, R. D. (2005). Making memories stick. Scientific American, 292(2):74-81.

Fischer, K. W. (2009). Mind, brain, and education: building a scientific groundwork for learning and teaching. Mind, Brain, and Education, 3(1):2-15.

Fischer, K. W., Rose, S. P. (1998). Growth cycles of brain and mind. Educational Leadership, 56(3):56-60.

Fisher, S. E., Francks, C. (2006). Genes, cognition and dyslexia: learning to read the genome. Trends in Cognitive Sciences. 10:250-257.

Foley, R. (2003). Os humanos antes da humanidade: uma perspective evolucionista. São Paulo: Editora UNESP. [Humans before humanity].

Gazzaniga, M. S. , Ivry, R. B. (2002). Cognitive Neuroscience: the biology of the mind. New York: W. W. Norton.

Geake, J. (2004). Cognitive neuroscience and education: two-way traffic or one-way street? Westminster Studies in Education, 2791):87-98.

Geake, J. (2008). Neuromythologies in education. Educational Research, 50(2): 123-133.

Geake, J. G. (2006). Mathematical brains. Gifted and Talented, 10(1):2-7.
Geake, J. G. (2009). The brain at school: educational neuroscience in the classroom. Maidenhead: Open University Press
Geake, J., Cooper, P. (2003). Cognitive neuroscience: implications for education. Westminster Studies in Education, 26(1):720.
Geary, D. C. (2005). The origin of mind: evolution of brain, cognition and general intelligence. Washington: American Psychological Association.
Given, B. K. (1998). Food for thought. Educational Leadership, 56(3):68-71.
Goldberg, E. (2001). The executive brain: frontal lobes and the civilized mind. New York: Oxford University Press.
Golombek, D. A., Cardinalli, D. P. (2008). Mind, brain, education, and biological timing. Mind, Brain, and Education, 2(1):1-6.
Gómez-Pinilla, F. (2008). Brain foods; the effects of nutrients on brain function. Nature Reviews Neuroscience, 9:569-578.
Goodenough, J. A., McGuire, B. A., Wallace, R. A. (2007). Interactive physiology for biology of humans: concepts, applications and issues. London: Benjamin-Cummings Publis.
Gopnik, A. (2009). The philosophical baby; what children´s mind tell us about truth, love, and the meaning of life. New York: Farrar, Straus and Giroux.
Gopnik, A., Meltzoff, A. N., Kuhl, P. K. (1999). The scientist in the crib; what early learning tell us about the mind. New York: Perennial.
Goswani, U. (2004). Neuroscience and education. British journal of Educational psychology. 74:1-14.
Greenfield, S. A. (1996). The human mind explained: an owner´s guide to the mysteries of the mind. New York: Henry Holt Co.
Griffith, L. C., Rosbash, M. (2008). Sleep: hitting the reset button. Nature Neuroscience, 11(2):123-124.
Grigorenko, E. L. (2007). How can genomics inform education. Brain , Mind, and Education, 1(1):20-27.
Guerra, L. B., Pereira, A. H., Lopes, M. Z. (2004). Neuroeduca: inserção da neurobiologia na educação. Anais 7º Encontro de Extensão. Belo Horizonte, Pp 1-7. (neuroeducation: introducing neurobiology to education).
Hardiman, M., Magsamen, S., McKhann, G., Eilber, J. (2009). Neuroeducation: learning, arts, and the brain. New York: Dana Press.
Hebb, D. O. (2002/1949). The organization of behavior: a neuropsychological theory.
Herculano-Houzel, S. (2002). Do you know your brain/ A survey on public neuroscience literacy at the closing of the decade of the brain. The Neuroscientist, 8(2):98-110.
Howard-Jones, P. (2010). Introducing neuroeducational research: neuroscience, education and the brain from contexts to practice. London: Routledge.
Howard-Jones, P. A. (2007). Neuroscience and education: issues and opportunities. London: Teaching and learning Research Programme.
Immordino-Yang, M. H., Damásio, A. (2007). We feel, therefore we learn: the relevance of affective and social neuroscience to education. Mind, Brain, and Education, 1(1):3-10.
Ireland, V. E. (2007). [Ed.] Repensando a escola: um estudo sobre os desafios de aprender a ler e escrever. Brasília: UNESCO/INEP. [Re-thinking school].
Izquierdo, I. (2002) Memória. Porto Alegre: ArtMed Editora. [Memory].
Izquierdo, I. (2004)a. A arte de esquecer: cérebro, memória e esquecimento. Rio de Janeiro: Vieira & Lent. [The art of forgetting; brain, memory and forgetting].
James, A. N. (2007).The teaching the male brain: how boys think, feel and learn in school. Thousand Oaks: Corwin Press

Janassen, D. H., Beissner, K., Yacci, M. (1993). Structural knowledge: techniques for representing, conveying and acquiring structural knowledge. Hillsdale: Lawrence ErlBaum Associates.
Johnston, V. S. (1999). Why we feel: the science of human emotions. Cambridge: Perseus Books.
Kachar, V.(2001). [Ed.] Longevidade: um novo desafio para a educação. (Longevity: a new challenge for education).
Kandel, E. R., Schwartz, J. H., Jessell, T. M. (2000). Principles of neural science, New York, NY: McGraw-Hill.
Kapit, W., Macey, R. I. Meisami, E. (2000). The Physiology coloring book, p.p. 15-30; 83-112. San Francisco: Addison Wesley Longman.
Kelso, J. A. S. (1995). Dynamic patterns: the self-organization of brain and behavior. Cambridge: The MIT Press.
Koizumi, H. (2004). The concept of developing the brain: a new science of learning and education. Brain & Development, 26:433-441.
Krampen, M. (1991). Children´s drawings: iconic coding of the environment. New York: Plenum Press.
Le Doux, J. (1996). The emotional brain: the mysterious underpinnings of emotional life. New York: Touchstone.
LeDoux, J. (2002). Synaptic self: how our brains become who we are. New York: Viking Penguin.
Lent, R. (2001). Cem bilhões de neurônios: conceitos fundamentais. São Paulo: Editora Atheneu.(A hundred billions of neurons: fundamental principles).
Lieury, A. (1997). A memória: do cérebro à escola. São Paulo: Editora Ática. [La mémoire, du cerveau à l´école].
Livingston, R. B. (1973). Neuroscience and education. Prospects, 3(4):415-437.
Lowery, L. (1998). How new science curricula reflect brain research. Educational Leadership, 56(3):26-30.
Lundy-Ekman, L. (2004). Neurociência: fundamentos para a reabilitação. Rio de Janeiro: Elsevier Editora. [Neuroscience: Fundamentals for Rehabilitation].
MacNeilage, P. F., Rogers, L. J., Vallortigara, G. (2009). Origins of the left & right brain. Scientific American, 301(1):48-55.Mahwah: Laurence Erlbaum Publishers.
Margulies, N. (1991). Mapping inner space. Learning and teaching mind mapping. Tucson: Zephyr Press.
Markram, K., Markram, H. (2010). The intense world theory- a unifying theory of the neurobiology of autism. Frontiers in Human Neuroscience, 4(224):1-29.
Mayr, E. (1997). This is Biology: the science of the living world. Cambridge: The Belknap Press.
McGilly, K. (1996). Classroom lessons: integrating cognitive theory and classroom practice. Cambridge: The MIT Press.
McKnight, K. S., Walberg, H. J. (1998). Neural network analysis of student essays. Journal of Research & Development in Education, 32(1):26-31.
McNeal, A. P., D´Avanzo, C. (1997). [Eds.] Student-active science: models of innovation in college science teaching. Forth Worth: Saunders College Publs.
Medina, J. (2008). Brain rule; 12 principles for surviving and thriving at work, home, and school. Seattle: Pears Press.
Menna-Barreto, L., Wey, D. (2008). Time constrains in the school environment: what does a sleepy student tell us? Mind, Brain, and Education, 2(1):24-28).
Michael, J. A., Modell, H. I. (2003). Active learning in secondary and college science classrooms. Mahwah: Lawrence Erlbaum Publishers.
Michael, J. A., Rovick, A. A. (1999). Problem solving in Physiology. Upper Saddle River: Prentice Hall.

Mintzes, J. J., Leonard, W. H. (2006). [Eds.] Handbook of college science teaching. Arlington: NSTA Press.
Morales, B. L., Abramson, C. I., Nain, S., Aleixo S. Jr., Bartoszeck, A. B. (2005). Status of Psychology as a science; undergraduate students perceptions. Psychological Reports, 96:109-114.
Moyes, C. D., Schulte, P. M. (2006). Principles of animal physiology. San Francisco: Benjamin Cummings.
Mussak, E. (1999). Cérebro de Estudante: e você sempre será um. Campinas, SP: Gráfica e Editora Paes.(Pupils´brains: you shall always have one).
Nickel, M. (2010). Evolutionary emergence of synaptic nervous system: what can we learn from non-synaptic, nerveless Porifera? Invertebrate Biology, 129(1):1-16.
Nomura, T. (2010). Toward integration of biological and physiological functions at multiple levels. Frontiers of Physiology, 1(164):1-7.
Novak, J. D. (1998). Learning, creating and using knowledge: concept maps as facilitative tools in schools and corporations. Mahwah: Lawrence Earlbaum.
Norton, E. S., Kovelman, I., Petitto, L-A. (2007). Are there separate neural systems for spelling? New insights into the role of rules and memory in spelling from functional magnetic resonance imaging. Mind, Brain, and Education, 1(1):48-59.
Novak, J. D. (1998). Learning, creating and using knowledge: concept maps as facilitative tools in schools and corporations. Mahwah: Lawrence Earlbaum Associates.
O´Boyle, M. W. (2005). Mathematically gifted male adolescents activate unique brain network during mental rotation. Cognitive Brain Research, 25:582-587.
Peixoto Costa, K. C. Q., Linhares, M. P. (2010). Novo ENEM: o que mudou? Uma investigação dos conceitos de Física abordados no Exame, XII Encontro de pesquisa em ensino de Física, Águas de Lindóia, SP: 1-12. (What changed in the new ENEM).
Penn, D. C., Holyoak, K. J., Povinelli, D. J. (2008). Darwin´s mistake: explaining the discontinuity between human and nonhuman minds. Behavioral and Brain Sciences, 31(2):109-178.
Pickering, S. J., Howard-Jones, P. (2007). Educators´views on the role of neuroscience in education; findings from a study of UK and international perspectives. Mind, Brain, and Education, 1(3):109-113.
Plomin, R., Kovas, Y., Harworth, C. M. (2007). Generalist genes: genetic links between brain, mind, and education. Mind. Brain, and Education,1(1):11-19.
Pozo, J. I. (2005). Aquisição de conhecimento: quando a carne se faz verbo. Porto Alegre: ArtMed Editora. [Adquisición de conocimento; quando la carne se hace verbo].
Purpura, P.D. (1992). A neuroscience curriculum. Em: Marston, R. Q., Jones, R. M. (eds). Medical Education in transition. Pp. 58-66. Princeton, NJ: Robert Wood Johnson Foundation.
Purves, D., Augustine, G. J., Fitzpatrick, D., Katz, L. C., La Mantia, A-S., McNamara, J. O. (1997). Neuroscience. Sunderland, MA: Sinauer Associates.
Ramos, C. (2002). O despertar do gênio: aprendendo com o cérebro inteiro. Rio de Janeiro, RJ: Qualitymark Editora. (Awaking the genius: learning with the whole brain).
Relvas, M. P. (2009). Neurociências na educação: potencialidades dos gêneros humanos na sala de aula. Rio de Janeiro: Wak Editora.(Neuroscience and education: human beings capacity in school settings).
Reynolds, S. (2000). Learning is a verb: the psychology of teaching and learning. Scottsdale: Holcomb Hathaway Publ.
Rocha, A. F. da (1999). O cérebro: um breve relato de sua função. Jundiaí, SP: EINA. (The Brain: a short report on its function).
Rocha, A. F. da, Rocha, M. T. (2000). O cérebro na escola. Jundiaí: EINA. (The brain at school).
Rose, S. (1992). The making of memory: from molecules to mind. New York: Anchor Books.

Rosenfield, I. (1988). The invention of memory: a new view of the brain. New York: Basic Books.
Rushton, S. P., Eitelgeorge, J., Zickafoose, R. (2003). Connecting Brian Cambourne´s conditions of learning to learning theory to brain/mind principles: implications for early childhood educators. Early Childhood Education Journal, 31(1):11-21.
Rushton, S., Juola-Rushton, A., Larkin, E. (2010). Neuroscience, play and early childhood education: connections, implications and assessment. Early Childhood Education Journal, 37(5): 351-361.
Rushton, S., Larkin, E. (2001). Shaping the leraning environment: connecting developmentally appropriate practices to brain research. Early Childhood Education Journal, 29(1):25-33.
Saavedra, M. A. (2002). Algumas contribuiciones de las neurociencias a la educacion. Revista Enfoques Educacionales, 4(1):65-73.
Scaldaferri, P. M., Guerra, L. B. (2002). A inserção da neurobiología na educação. Anais X Semana de Iniciação Científica. Belo Horizonte, Pp 61. (Introducing neurobiology to education).
Schwartz, M. (2009). Cognitive development and learning: analysing the buildings of skills in classrooms. Mind, Brain, and Education, 3(4):198-208.
Selçuk, G. S., Çaliskan, S., Erol, M. (2007). The effects of gender and grade levels on Turkish physics teacher candidates´problem solving strategies. Journal of Turkish Science Education, 4(1):92-100.
Shepherd, G. M. (1990). [Ed.] The synaptic organization of the brain. New York: Oxford University Press.
Shepherd, G. M. (1994). Neurobiology. New York: Oxford University Press.
Simons, U. M. (2003). Blocos lógicos. Curitiba:Hubertus.(Logic blocks).
Smilkstein, R. (2003). We´re born to learn: using the brain´s natural learning process to create today´s curriculum. Thousand Oaks: Corwin Press.
Springer, S. P., Deutsch, G. (1998). Cérebro esquerdo, cérebro direito. São Paulo: Summus Editorial. (Left brain, Right Brain).
Stanovich, K. E. (1998). Cognitive neuroscience and educational psychology: what season is it? Educational Psychology Review, 10(4): 419-426.
Strauch, B. (2010). The secret life of the grown-up brain: the surprising talents of the middle-aged mind. New York: Viking Press.
Szücs, D., Goswami, U. (2007). Educational neuroscience: defining a new discipline for the study of mental representations. Mind, Brain, and Education, 1(3): 114-127.
Thompson, R. F., Madigan, S. A. (2005). Memory: the key to consciousness. Wahtington, D. C.: Joseph Henry Press.
Trifone, J. D. (2006). To what extent can concept mapping motivate students to take a meaningful approach to learning Biology? The Science Education Review, 5(4):1-23.
Uitto, A., Juuti, K., Lavonen, J., Meisalo, V. (2006). Student´s interest in Biology and their out-of-school experiences. *Journal of Biological Education*, 40(3): 124-129.
Varma, S., Schwartz, D. L. (2008b). How should educational neuroscience conceptualize the relation between cognition and brain function? Mathematical reasoning as a network process. *Educational Research*, 50:149-161
Varma, S., McCandliss, D., Schwartz, D. L. (2008a). Scientific and pragmatic challenges for bridging education & neuroscience. Educational Researcher, 37(4):140-153.
Waltenberg, F. D. (2005). Iniqüidade educacional no Brasil. Uma avaliação com dados do PISA 2000. Economia, 6(1):67-118.(Brazil´s educational inequality Pisa data).
Westwater, A., Wolfe, P. (2000). The brain-compatible curriculum. *Educational Leadership*, 58(3):49-52.

Williams, L. V. (1986). Teaching for the two-sided mind: a guide to right brain/left brain education. New York: Simon & Schuster.

Willingham, D. T., Lloyd, J. W. (2007). How educational theories can use neuroscientific data. Mind, Brain, and Education, 1(3):140-149.

Willis, J. (2006). Research-based strategies to ignite student learning: insights from a neurologist and classroom teacher. Pp:1-31, Alexandria: Association for supervision and Curriculum Development.

Zambo, D., Zambo, R. (2011). Teachers´ beliefs about neuroscience and education. Teaching Educational Psychology, 7(2): 25-41.

Zardetto-Smith, A. M., Mu K., Phelps, C.L., Houtz, L. E., Royeen, C. B. (2002). Brains rule! Fun=learning=neuroscience literacy. The Neuroscientist, 8(5): 396-404.

Zaro, M. A., Rosat, R. M., Meireles, L. O. R. et al., (2010). Emergência da Neuroeducação: a hora e a vez da neurociência para agregar valor à pesquisa educacional. Ciência & Cognição, 15(1): 199-210. (Emergent neuroeducation: it is neuroscience turn to contribute to educational research).