Chapter 7
Neuromyths for Educational Research and the Educational Field?

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7.1 Neuroscience

There is a new hype in educational research: it is called educational neuroscience or even neuroeducation (and neuroethics)—there are numerous publications, special journals, and an abundance of research projects together with the advertisement of many positions at renown research centres worldwide. An interesting starting point to see the gist of what is argued for is offered by a number of position papers published in a special issue[1] of one of the philosophy of education journals

To identify relevant publications I started from a bibliographical search in the *Philosopher's Index* and the *Social Sciences Citation Index* (July 2014) and used as keywords neuroscience and education.

[1] The special issue (Patten and Campbell 2011) contains the following contributions: Introduction: Educational Neuroscience (pages 1–6), by Kathryn E. Patten and Stephen R. Campbell; Educational Neuroscience: Motivations, methodology, and implications (pages 7–16) by Stephen R. Campbell; Can Cognitive Neuroscience Ground a Science of Learning? (pages 17–23) by Anthony E. Kelly; A Multiperspective Approach to Neuroeducational Research (pages 24–30) by Paul A. Howard-Jones; What Can Neuroscience Bring to Education? (pages 31–36) by Michel Ferrari; Connecting Education and Cognitive Neuroscience: Where will the journey take us? (pages 37–42) by Daniel Ansari, Donna Coch and Bert De Smedt; Position Statement on Motivations, Methodologies, and Practical Implications of Educational Neuroscience Research: fMRI studies of the neural correlates of creative intelligence (pages 43–47) by John Geake; Brain-Science Based Cohort Studies (pages 48–55) by Hideaki Koizumi; Directions for Mind, Brain, and Education: Methods, Models, and Morality (pages 56–66) by Zachary Stein and Kurt W. Fischer; The Birth of a Field and the Rebirth of the Laboratory School by Marc Schwartz and Jeanne Gerlach; Mathematics Education and Neurosciences: Towards interdisciplinary insights into the

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(*Educational Philosophy and Theory*). Incidentally, the contributors are not philosophers of education, but researchers working in the area of neuroscience. The guest editors identify as a common aim of educational neuroscience "to produce results that ultimately improve teaching and learning, in theory and in practice" (Patten and Campbell 2011, p. 6). I hasten to add that the articles are full of warnings, for example not to misapply science to education, that filling the gulf between current science and direct classroom application is premature, and insist not to exaggerate what this area could mean for education, thus to work in close collaboration with …. Yet almost all are also expressing the hope (and the confidence) that a lot may be expected from this, called by some, an emerging subdiscipline. Here are some typical quotes from these papers.

> The 'holy grail', for a transdisciplinary educational neuroscience as I see it, would be to empower learners through the volitional application of minds to consciously perceive and alter their own brain processes into states more conducive to various aspects of learning. (Campbell in Patten and Campbell 2011, pp. 8–9).
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> The question is not whether there are connections between minds and brains. There clearly are. The evidence is insurmountable and growing. The question then is to what extent, subject to intrinsic theoretical and practical limits of measurement and analysis, can we identify changes in mental states as changes in brain and brain behaviour, and vice versa. (Campbell in Patten and Campbell 2011, p. 11)

Working in the area of mathematics education Stephen Campbell, who has a particular interest in the nature of mathematics anxiety and mathematical concept formation (for example in ways in which the former impedes the latter), outlines that he has in his educational neuroscience laboratory (the ENGRAMMETRON,[2] Faculty of Education at Simon Fraser University) equipment to record

> electroencephalograms (EEG), electrocardiograms (EKG), electro-oculograms (EOG), and electromylograms (EMG), which pertain to brain activity, heart rate, eye movement and muscle movement. . . . All these psychophysiological metrics are augmented with eye-tracking technology, screen capture, keyboard and mouse capture, and multiple video recordings of participants from various perspectives. These data sets can then be integrated and synchronized for coding, analysis, and interpretation, thereby affording comprehensive observations and insights into the learning process. (Campbell in Patten and Campbell 2011, p. 13)

development of young children's mathematical abilities (pages 75–80) by Fenna Van Nes; Neuroscience and the Teaching by Kerry Lee and Swee Fong Ng; The Somatic Appraisal Model of Affect by Kathryn E. Patten; Implications of Affective and Social Neuroscience by Mary Helen Immordino-Yang.

[2] See http://www.engrammetron.net/about.html (retrieved October 22 2013) "ENGRAMMETRON facilities enable simultaneous observation and acquisition of audio data from talking-aloud reflective protocols; video data of facial and bodily expression; and real-time screen capture. Instrumentation most notably supports: multi-channel electroencephalography (EEG); electrocardiography (EKG); electromyography (EMG); and eye-tracking (ET) capability. Orbiting this constellation of observational methods around computer enhanced learning platforms allows for unprecedented flexibility of educational research experimental design and delivery, and for subsequent data integration and analyses."

According to Campbell:

> The main challenge has been to muster evidence and rationale to justify this initiative to funding agencies traditionally supporting educational research. (Campbell in Patten and Campbell 2011, p. 14)

In the same issue Howard-Jones refers to an OECD Brain and Learning project and to the UK's NeuroEducational research network at the University of Bristol (NEnet, www.neuroeducational.net). He argues in favour of a multiperspective approach (from neuroscience and education) and refers for instance to work within NEnet, i.e., an fMRI study of creativity fostering strategies:

> This imaging study, which included a focus on the biological correlates of creativity, was useful in revealing how those parts of the brain associated with creative effort in a story telling task were further activated when unrelated stimulus words had to be included. Results provided some helpful indication, at the biological level of action, of the likely effectiveness of such strategies in the longer term. (Howard-Jones in Patten and Campbell 2011, p. 26)

Similarly Ferrari (in Patten and Campbell 2011) argues:

> . . . unlike cognitive neuroscience—which aims to explain how the mind is embodied—educational neuroscience necessarily incorporates values that reflect the kind of citizen and the kind of society we aspire to create (p. 31) . . . What are the biological foundations of authentic and deep understanding? Of an appreciation of art and beauty? Or of compassion for those in need at home and around the world? All these concerns reflect different values that matter to particular communities and neuroscience could inform us about all of them. (Ferrari in Patten and Campbell 2011, p. 35)

As I said, the papers are full of warnings, for example Ansari, Coch & De Smedt (in Patten and Campbell 2011, p. 41) write:

> . . . close inspection of these claims for a direct connection between particular 'brain-based' tools and teaching approaches reveals very loose and often factually incorrect links . . . the direct application of neuroscience findings to the classroom has not been particularly fruitful (Ansari, Coch, & De Smedt in Patten and Campbell 2011, p. 41)

Nevertheless, they too remain 'believers' when they identify for example as a topic for research:

> How might non-invasive neuroimaging methods be used to measure the relative success of educational approaches? (Ansari, Coch & De Smedt in Patten and Campbell 2011, p. 42)

Let me offer a few characterizations of what is envisaged:
Offering support (a neuronal 'explanation') for what is 'known':

> In a second study we compared activations associated with fluid and non-fluid analogizing with letters, numbers and geometric shapes. We found overlapping patterns of neuronal activation between fluid and non-fluid analogizing in all formats. These results suggest that analogizing is a basic cognitive process and therefore critical for successful school performance. We also found in frontal cortical working memory areas modest correlations between non-fluid analogizing, but not fluid analogizing, and general IQ test scores, suggesting that conventional IQ tests, not to mention school assessments, might not capture abilities of fluid analogizing which underpin creative thinking. Teachers have long suspected that IQ tests, although predictive of academic success, do not reveal all there is

> about a child's cognitive potential. Our findings, in supporting conjectures that the brain might develop separate working memory systems for general intelligence and fluid cognition offer an explanation of such skepticism. (Geake in Patten and Campbell 2011, p. 46)

7.2 Use a Way to Identify Brain Activity

Lee & NG (in Patten and Campbell 2011) report on investigations in their laboratory concerning heuristics commonly used for example to teach algebraic word problems (respectively the model method and symbolic algebra).

> In our laboratory, we conducted two studies using functional magnetic resonance imaging (fMRI) and focused on the cognitive underpinnings of the two methods. . . . All participants in our study were pretested for competency in the two methods: we selected only those who were highly and similarly competent. Ensuring behavioural equivalence allowed us to infer differences in neural activation in terms of processes involved in executing the two methods rather than differences in task difficulty. Despite the lack of behavioural differences, we found difference in the degree to which the two methods activated areas associated with attentional and working memory processes. In particular, transforming word problems into algebraic representation required greater access to attentional processes than did transformation into models. Furthermore, symbolic algebra activated the caudate, which has been associated with activation of proceduralised information. . . . Findings . . . suggest that . . . Both methods activate similar brain areas, but symbolic algebra imposes more demands on attentional resources. . . . If symbolic algebra is indeed more demanding on attentional resources, one curricular implication is that it is best to teach the model method at the primary level and leave symbolic algebra until students are more cognitively matured. (Lee & Ng in Patten and Campbell 2011, pp. 83–84)

Another example is the research by Koizumi:

> Although acquisition of a second language from early childhood is not undesirable, our main concern is whether it has negative effects on the normal course of language development in one's native tongue. At present, there is no scientific data available on the relationship between language acquisition (both the first and second) and brain maturation. (Koizumi in Patten and Campbell 2011, p. 51)

7.3 Labelling 'Standard' Educational Research as 'Neuroscience' or 'Bolster Your Case' by Invoking 'Science'

There are for example the cohort studies on language acquisition, brain development and language education (Hagiwara, Tokyo Metropolitan University). Although their objectives to propose a guideline for second language learning and education, especially for English, including the optimal ages and conditions surrounding it, is very interesting, they phrase this as 'a cognitive neuroscience-based guideline'.

7.4 Bring Frameworks Together

In most of these papers it is argued that bringing together frameworks respectively from educational research and from neuroscience will offer opportunities to deepen our understanding:

> The driving force behind bridging mathematics education and neuro-sciences in this project is the prospect of combining knowledge from both research trajectories to contribute to early diagnostic practice and prevention. If we succeed in developing and comparing two valid measures for the development of kindergartner's mathematical ability, we may help to foster young children's early mathematical insights and to stimulate those children who could be prone to experiencing difficulties in their mathematical development. The earlier we may grasp children's mathematical learning trajectories, the more we can anticipate and furnish a supportive instructional setting, and the more we may be able to support the children in the development of their mathematical thinking and learning. (Van Nes in Patten and Campbell, p. 79).

In a similar voice Tommerdahl (2010), writes:

> The paper supports the idea that the neurosciences have a role to play in education, but emphasises the distance and the complex relationships that exist between the brain sciences and proven teaching methods ready for the classroom. It is highly doubtful that any single given study in neurology will have a direct application to the classroom but, on a more hopeful note, it is almost certain that aggregations of findings from several studies, mediated through higher levels culminating in the behavioural and educational levels will indeed provide new teaching methodologies. (Tommerdahl 2010, p. 98).

She presents a model:

> Five basic levels are offered in the model, the levels of *neuroscience*, *cognitive neuroscience*, *psychological mechanisms*, *educational theory*, and finally the *classroom*. For effective teaching methods which are based on neuroscientific findings and which are supported by a scientific evidence base, most or all of these levels of work, and possibly more in some cases, are necessary to their development. (Tommerdahl 2010, p. 99).

further she argues that:

> . . . the separation between the terms *brain* and *mind* could perhaps more appropriately be seen as different perspectives of the same thing, much like the famous figure/ground images where a viewer can see either an old lady with a large nose or a young women's profile. (Tommerdahl 2010, p. 101)

Examples of this are:

> In the field of bilingualism, brain scanning has shown there is a difference between bilinguals who learn a second language before age five and those who learn a second language at a later age. The first group processes their two languages in overlapping left hemisphere language centres while the second group calls more upon right hemisphere zones, working memory and inhibition areas when using their second language . . . In mathematics fMRI [is used] to distinguish whether precise mathematical calculations and numerical estimations used identical or distinct brain areas. A dissociation was shown to exist which also allowed the researchers to postulate that linguistic systems were likely to be mediating the precise calculations while visual centres were implicated in the approximations. (Tommerdahl 2010, p. 106)

Similarly, Hardiman e.a. claim that

> Although applying research from the neuro- and cognitive sciences to classroom practice certainly remains a challenge, interdisciplinary collaboration has yielded considerable educationally-relevant information about learning mechanisms that could not have been acquired solely through behavioural methods. (Hardiman e.a., 2012, p. 137)

7.5 Finally, "The Sky Is the Limit"

> Since the emergence of dispositions and basic emotions are to a large degree autonomic and unconscious, they cannot be recognized nor stopped until they become conscious feelings. However, they can be attenuated and avoided in the future through emotion regulation by recognizing their emergence triggers and enacting preventive measured related to specific object and situations. … This model [Somatic Appraisal Model of Affect] identifies quintessential functions, components, and facets of affect necessary to provide a new research domain, namely educational neuroscience, with a basis on which to build a dynamic model of affect serving to challenge current pedagogy and inform and build a new praxis, called neuropedagogy. (Patten in Patten and Campbell 2011, p. 94)

Thus far some aspects of the 'emerging field'. It is time to make a few observations and comments.

1. Tools that are used:

> PET scan (Positron Emission Tomography): a radioactive isotope is injected which allows the amount of glucose being metabolised in the brain to become visible (indicative of the amount of blood in each part of the brain which in turn represents brain activity); provides an image of the working brain; disadvantages: the need for radioactive material, the high cost of use;
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> fMRI (functional Magnetic Resonance Imaging): measures blood flow in the brain; provides an image of the working brain;
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> EEG (electroencephalogram) shows cortical activity of the cortex in the form of electrical signals directly harvested from groups of thousands of neurons through electrodes placed on the scalp; no images of the brain, but instead detailed information about the time course of neural activity and indications of where brain activity is being carried out;
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> MEG (magnetoencephalogram) measures the magnetic field outside the brain caused by electrical activity; no images of the brain, but instead detailed information about the time course of neural activity and indications of where brain activity is being carried out.

2. The studies are correlational. It is often assumed that for instance fMRI techniques offer 'visual proof' of brain activity. However, as Narvaez and Vaydich argue, few studies test theories and most are primarily correlational.

> Far too often readers assume that fMRI techniques enable researchers to capture 'visual proof' of brain activity, without taking into account the complexities of acquiring the data and processing the images. To ease the task of interpreting and reporting results, neuroimaging studies often highlight responses in specific brain regions; however, these regions are rarely the only ones that produced activity. Moreover, every human brain is distinctive, so the fMRI studies look at areas of agreement across brains, which often vary greatly. In fact, laboratories often use their own techniques to test and analyse the messy and inconsistent data across participants and trials. Due to limited knowledge, few studies test theories and most are primarily correlational. Moreover, correlative approaches, such as human brain

> imaging and psychophysiology, are not sufficiently robust to adjudicate what is 'basic about basic emotions' because 'autonomic physiology is regulated by generalized sympathetic and parasympathetic controls' which are not measurable through fMRI. Activation can vary for a range of reasons. (Narvaez and Vaydich 2008, p. 291)

Though aware of this, often nevertheless a particular conclusion is drawn in terms of the kind of research we need (granted, it comes with a warning as well):

> Given the current state-of-the-art in brain imaging, most neuroimaging data are correlational and do not provide information about causation. As in all scientific enquiry, therefore, experimental design is crucial to how useful the data will be for contributing to research questions. For example, it is important to control for other factors that might be important for any correlations that are found, and to use control groups. . . . When evaluating neuroscience research, it is important to be vigilant: correlations are still correlations, even when they involve physiological measures. Yet many correlational findings that reach the popular media are given causal interpretations. (Goswami 2008, p. 386)

3. Several philosophers have pointed to problems with the nature of the concepts that are used: for example they speak of a reductionism, or of a confusion of 'activity' and 'content'. Reference is made to Wittgenstein's position concerning the 'inner', and to Ryle's notion of 'category mistake', moreover to the issue of 'underdetermination'.

   Purdy & Morrison refer to a remark from Ter Hark "measuring pain with a thermometer is to change the very concept of pain, since the uncertainty of the psychological attribute of pain cannot be reduced (Purdy and Morrison 2009, p. 104).

   They also refer to Bennett and Hacker (2003) who, following the work of the later Wittgenstein, have asked whether we know 'what it is for a brain to see or hear, for a brain to have experiences, to know or to believe something'. That the brain thinks, believes, etc. is for them the result of a conceptual confusion. Thus they point to the separation of the inner and the outer

> a 'mutant form of Cartesianism' where psychological attributes once ascribed to the mind, Descartes' immaterial *res cogitans*, are now ascribed unreflectively to the material brain instead (Purdy and Morrison 2009, pp. 105–106).

For them, the brain is not a logically appropriate subject for psychological attributes (the expression 'the brain sees' lacks sense, Bennett and Hacker refer to this as a case of explanatory reductivism).

> Bennett and Hacker (2003) conclude by maintaining that it makes no sense to attribute psychological attributes to either the mind (Cartesianism) or to the brain (cognitive neuroscience). Instead psychological attributes must be ascribed to the whole person 'who is a psychophysical unity, not a duality of two conjoined substances, a mind and a body' (p. 106). Far from discrediting neuroscientific research, Bennett and Hacker simply argue that neuroscientists are often guilty of conceptual confusion in ascribing psychological attributes to the physical organ of the brain. (Purdy and Morrison 2009, pp. 105–106).

Purdy and Morrison (2009, p. 108) conclude therefore:

> While neuroscience can reveal what is happening in the brain . . . the imagery is never more than a neural concomitant of that thinking. . .

Obviously, though nothing prevents scientists from using psychological expressions metaphorically, neuroscientists and cognitive scientists typically presuppose that they are using psychological expressions literally.

A corollary to this is the dependence of technical concepts on ordinary psychological concepts (which are not concepts of theoretical entities). Here the argument runs as follows: without our ordinary concepts the technical concepts from neuroscience would lack meaning. Moreover, though our ordinary concepts are interrelated by way of implication, compatibility and incompatibility this does not imply that these are theoretical (see Chap. 13, Bennett and Hacker 2003). For Bennett and Hacker therefore, neuroscience though it can contribute to the explanation of irrational action and forms of incapacitation, it cannot explain normal human behaviour (Bennett and Hacker 2003, p. 365).

A further step is the use of neuroscience concepts in the area of learning and education. Davis (2004)) discusses brain-based learning and points to articles presenting attempts to run together ideas about connectionism in the brain with 'connectionism' at the level of knowledge and learning. There, two types of connections are systematically conflated he argues: connections of a neurophysiological character that obtain in the brain during learning one the one hand, and connections made by learners between 'new' knowledge and resident knowledge on the other hand (Davis 2004, p. 25).

4. Unless the neurological mechanism that lies behind (and which is made explicit) could be directly influenced, it is not clear what the educational implications are which surpass those already available on the basis of relevant research in for example educational psychology. That neuroscience offers a description (or even explanation) in terms of neurological concepts and theories does not in itself warrant an *educational* surplus value. This remains to be argued and established. It is possible that the techniques, methods, concepts and theories of psychology will be replaced by those of neuroscience, in which case there could be some gain in our understanding of learning. This presupposes, however, accepting that the object of study of psychology coincides with that studied by neuroscience. And as dealt with in the previous point, this is doubtful.

Incidentally, responding to Schrag (2013), who asserts confidently that talk of brain lesions being mere concomitants of an inability to recognize faces, Davis (2013)) claims that this is too modest, i.e., the relevant neural states of affairs play a causal role in causing the inability (Davis 2013, p. 35). However, and interestingly, he draws attention to the *direction of causality*: "the very fact that certain patients stopped recognizing faces set in motion events that had specific effects on their brains . . . Such effects might have included the consequence that parts of the brain became 'atrophied' because they were not being used" (Davis 2013, p. 35) This matter is certainly along the lines of something Aldrich draws attention to:

> brain structures are changed and adapted with each human activity. For example, in 2000 Eleanor Maguire examined the brains of 16 London taxi drivers via an fMRI scanner and

> found that the part of the brain responsible for spatial navigation, the right posterior hippocampus, was 7 % larger than normal, a significant difference. (Aldrich 2013, p. 397)

5. Concerning what is frequently argued for, i.e. ‘bringing frameworks together’, if this is supposed to be more than the expression of what is always true, it needs to be shown in what way this is helpful. What is argued for is only true if one of these provides information for example at an earlier time than the other one. There are examples of this, but they are scarce. Goswani argues along these lines and provides such an example: neural variables can be used to identify those who might be at educational risk. (“. . . a child may be at risk because aspects of sensory processing are impaired, and biomarkers could show the presence of the processing impairment before any behavioural symptoms have appeared.”, Goswami 2008, pp. 394–395).

   That complementary information is gathered and the outcomes interpreted against two different backgrounds (one predominantly using a quantitative approach and an experimental setting,[3] the other qualitative data from a classroom-based ‘design research’) is not enough. Except for very specific cases, the gains of such an approach, i.e., ‘bringing frameworks together’ therefore remains doubtful.[4]
6. And then there is the further step to ‘education’, as implicit in for instance the idea that improved knowledge about how the brain learns should assist educators in creating optimal learning conditions—not to mention issues concerning desirable outcomes, in general educational content and processes. Some scholars realise that the possible contribution is limited:

> In relation to education the indeterminacy of psychological attributes (such as understanding) is not removed by a computer-generated print-out of neural processing, because this form of measurement creates a quite different concept. . . . Cognitive neuroscience may offer detailed pictures of neural networks, but, just as a thermometer fails to measure pain, so a brain scan fails logically to measure understanding: the concepts involved are simply different and the indeterminacy remains. Cognitive neuroscience therefore at best offers insights into the neural *concomitants* of thinking, but it offers no privileged access into the hidden world of the inner, that inner world being already manifest in external behaviour. Rather than representing a panacea to education, the cognitive neuroscientific

[3] “Before the trials begin, the researcher fits a cap on the child’s head with electrodes that register brain activity. This non-invasive EEG technique informs the researcher about the onset and duration of brain signals for particular stimuli and motor and perceptual responses. ANOVAs help determine differences in the brain activation and in the reaction times and additional analyses give more insight into the nature of interference and facilitation effects in the different experimental conditions.” (Van Nes in Patten and Campbell 2011, p. 78)

[4] Some authors remain nevertheless confident of such an approach: “With one research discipline set in a classroom environment and another that is based on a laboratory setting, the collaboration between the ME [Mathematics education component] and NS [Neurosciences component] research rests on studying the same children. The children who participate in the ME research are part of the larger pool of children who will also participate in the NAS research. In this way we hope to be able to compare children’s phase of spatial structuring with the degree to which they automatically process quantities.” (Van Nes in Patten and Campbell 2011, p. 78)

> enterprise in relation to education is therefore necessarily limited. (Purdy and Morrison 2009, p. 105)

Others seem to be inclined to forget, and proclaim the need for such an approach:

> Cognitive neuroscience is important for education because it enables a principled understanding of the mechanisms of learning and of the basic components of human performance. It also enables componential understanding of the complex cognitive skills taught by education. Many of the principles of leaning uncovered by cognitive neuroscience might appear to support what teachers knew already. For example, aspects of pedagogy such as the value of multi-sensory teaching approaches or of crating safe and secure environments for learning are highly familiar. Nevertheless, cognitive neuroscience offers an empirical foundation for supporting certain insights already present in pedagogy and disputing others. The evidence from neuroscience is not just interesting scientifically. It enables an evidence base for education in which mechanisms of learning can be precisely understood. (Goswami 2008, p. 396)

7.6 Some Conclusions

For various reasons educational research has been eager to adopt psychology's methodology (paradigm and methods) and has embraced causality/probability with the predictability and the possible elements of manipulation that go with it (see Smeyers and Depaepe 2013). What has been argued for in general for psychology is no less true for the attraction of neuroscience. But before saying more about that, I will first deal with the crucial issue of what it is exactly that concepts of neuroscience can refer to.

What goes missing in any third-personal, physical description of brain states is, Bakhurst (2008) argues, the subjective dimension: ". . .all that is observable are the neural correlates of mental activity, not mental activity itself" (p. 422). To this he adds that from a personalist position, beginning from the premise that the human mind is a psychological unity, a person's mental states are not just a rag-bag collection of representations. "One way to put this argument about psychological unity is to say that brainism [the view (a) that an individual's mental life is constituted by states, events and processes in her brain, and (b) that psychological attributes may legitimately be ascribed to the brain, p. 415] struggles to make sense of the first-person perspective. A person does not typically stand to her own mental states as to objects of observation" (p. 422). Our observing is always charged with agency: "But although a person does not relate to the contents of her mind as to objects of observation, her relation to her own brain states, as revealed, say, by MRI imaging, *is* one of observation. Thus what she observes when she observes events in her own brain can only be brain events correlated with, and enabling of, her mental life, not her mental life itself" (p. 423) To this personalism and following McDowell, he adds a distinctive view of human development: "As the child matures, however, she undergoes a qualitative transformation. She enters a distinctively human, essentially social form of life and acquires distinctively human psychological capacities that enable her to transcend existence in the narrow confines of a biological environment and to hold the world in view. With this, natural-scientific modes of explanation are no longer adequate to explain the character of the child's mindedness" (Bakhurst 2008, p. 423). And he continues: "The human mind constantly transcends its own limits; it does not simply apply old techniques to new problems. On the contrary, we set ourselves problems precisely to develop the methods to address them, a process that in turn uncovers new questions, creating new problem-spaces demanding further innovation and so on. To understand this dialectical process, we cannot represent the mind as determined by antecedent conditions" (Bakhurst 2008, pp. 423–424). Instead, as McDowell argues, human beings think and act, Bakhurst argues, in the light of reasons: "The relations in which rational explanation deals are normative in character. When I decide that Jack must believe that *q* because he believes (a) that *p* and (b) that p entails q, I am not making a causal claim. I am assuming that Jack believes what he ought to believe if he is rational" (Bakhurst 2008, p. 424). These sort of relations are not the sort of relations that are characterised by natural-scientific theories, they are different from what goes on in the brain which is exhaustively open to scientific explanation; mental states and processes occupy a different logical space—the space of reasons. Human beings inhabit a social world because their world is full of objects created by human beings for human purposes. For him psychological talk represents a fundamentally different discourse from talk of the brain. Obviously, brain science can illuminate learning in the explanation of dysfunction, deficit and disorder, he argues (a matter often referred to in the literature, see for example, Davis 2004, p. 22): "Once we adopt the causal perspective on the child's problems, we cease to see her as a rational agent, at least in this respect, and absolve her from responsibility, and hence blame, for her failings" (Bakhurst 2008, p. 426). According to Bakhurst brain science can moreover illuminate why someone is especially good at some practice (he refers to speed of thought as an example of causal preconditions of rational powers). Thus he concludes that as there is as much reason to avoid crass biological determinism as there is to eschew *a priori* nurturism, there "are no *a priori* grounds to declare brain science irrelevant to educational issues, or relevant only in 'deficit' cases" (Bakhurst 2008, p. 428); "What is critical, however, is that interest in the brain should not distract attention from the fact that education is a communicative endeavour, not an engineering problem. Education is not about getting information into students' heads or of implanting skills in them" . . . Once again, information and skills are not all that is at issue. Machines may possess those, or close surrogates, but machines have no practices and crafts (Bakhurst 2008, p. 428).

If Bakhurst's position carries weight, it is doubtful that a lot may be expected from what is frequently argued for in the neuroscience subdiscipline, i.e., 'combining frameworks'. Do they make a mountain out of a molehill? The so-called frameworks that have to be brought together are fundamentally different. Moreover, there is something strange going on in the debate about neuroscience and education: the methods that are used are correlational, i.e. the tools measure indirectly brain activity, there is conceptual confusion in more than one sense,[5] and yet the proponents do not stop to argue that a lot can be expected from such an approach.

This is not to say that in some cases indeed relevant insights for education can be offered. Here are two examples given in a study by Sigman, Peña, Goldin, Riberio:

> Neuroscience research has developed signatures that may serve to diagnose cognitive impairments potentially earlier than would be conceivable by behavioural or psychological inspection. A paradigmatic example is the detection of otoacoustic emissions in neonates, a tool that helps identify congenital deafness. Traditional detection by psychological tests can only be made months after birth, missing a window of opportunity for early interventions. (Sigman e.a., 2014, p. 498)
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> The diagnosis of dyslexia is typically made in children aged 7–8 years old, when population variability in reading scores becomes evident. However, interventions to remediate dyslexia are much more likely to be successful when conducted on children who are beginning to read or even before reading if they are based exclusively on improving auditory processing. As with many other medical conditions, early diagnosis is a fundamental aspect of remediation. The development of neurophysiological markers of later dyslexic developments are therefore of great practical relevance. . . . the . . . study . . . found that, as early as birth, infants with and without familial risk for dyslexia differ in ERPs [event-related potentials] to linguistic stimuli. . . . Taken together, these studies indicate that ERPs measured during infancy might help to screen for problems in reading-related skills, serving as an indicator or risk of impaired auditory/speech processing. (Sigman, e.a., 2014, p. 500)

Francis Schrag (2011)) offers a more subtle position when dealing with the possible contribution of neuroscience. He too starts from the validity neuroscience at first sight may have as it "discovers more and more about the mechanisms of learning and memory" (pp. 222–223) but claims that "From the teachers' point of view, knowing which brain structures are involved adds nothing to the success of the strategies" (ibid., p. 226). He envisions that the ongoing research which is offered by cognitive neuroscientists is ". . . yielding continued progress in understanding neural processes at the micro level, an understanding that will be translated into interventions designed to affect micro level processes in order to reduce cognitive deficits and enhance performance at the macro level" (ibid., p. 236). Strangely enough, he is not convinced that we need philosophers ". . .to tamp down the enthusiasm of neuroscientists who may be all too ready to launch bandwagons

[5] "Psychological predicates are predicates that apply essentially to the whole living animal, not to its parts. It is not the eye (let alone the brain) that sees, but *we* see *with* our eyes (and we do not see with our brains, although without a brain functioning normally in respect of the visual system, we would not see). So, too, it is not the ear that hears, but the animal whose ear it is. The organs of an animal are part of the animal, and psychological predicates are ascribable to the whole animal, not its constituent parts. Mereology is the logic of part/whole relations." (Bennett and Hacker 2003, pp. 72–73). Bennett & Hacker term the neuroscientist's ascription of psychological attributes to the brain 'the mereological fallacy' in neuroscience. They also point to what the neuroscientist is seeing: "What one sees on the scan is not the brain thinking. . . nor the person thinking . . . but the computer-generated image of the excitement of cells in his brain that occurs *when* he is thinking." (Bennett and Hacker 2003, pp. 83–84)

declaring that their research will show the way to the holy grail of educational transformation? The answer here is clear: we do not. In fact those at the new frontier are very aware of the limitations of their work and of the propensity of less skilled disciples to mislead the rust of us" (ibid., p. 228). This may be the case for some, in general I do not think that this is a truthful picture of what the educational researchers working in this area aspire to. Here are some examples:

In the introduction to a special issue of the *International Journal of Science and Mathematics Education* (2014, 3) Anderson, Love & Tsai write:

> Perspectives on possible future approaches and challenges in reaching the goals of a neuroeducational theory are presented, including applying new techniques such as eye-tracking. EEG, and fMRI analyses to further understand individual differences in student brain functions while performing some typical cognitive functions in math and science learning, such as problem solving, self-directed learning, and interaction with digital-based learning environments. (p. 468)

And introducing the article by Liu Chang in that issue they say that these authors "…offer science educations some neuroscience-backed information as a foundation to develop results-oriented curricula and teaching methods" (Anderson et al. 2014, p. 471). And his own article in the special issue Anderson writes: "The opportunity for merging neurosciences with modern digital technology design theory and best delivery practices is clearly significant and likely to be highly productive in advancing the efficacy of these learning environments" (Anderson, 2014, p. 476). Of course, he starts from "There is much to be gained by beginning with an assumption that the human brain is a functional systemic unit (though modular based) in processing and responding to complex information" (ibid., p. 482)—which embraces precisely what was criticized above (i.e., a confusion at the conceptual level). For him it is all very clear: "The more we understand the physiological bases for individual differences in learning, the more likely we can develop effective ways of maximizing the individual learning potentials of our students." (ibid., p. 488). Others focus on what neuroscience insights can do for teachers, thus for example Hook & Farah argue in *Neuroethics* "Our evidence indicates that educators use neuroscience to maintain patience, optimism and professionalism with their students, to increase their credibility with colleagues and parents, and to reinforce their sense of education as a profession concerned with shaping students' brain development. None of these motivations presupposes an unrealistic view of neuroscience or neuroeducation" (Hook and Farah 2013, pp. 339–340). And in the *Educational Researcher* Dubinsky, Roehrig & Varma argue that: "… teachers benefit from additionally understanding the neuroscience of learning and memory. … Neuroscience has the unique feature that it provides the neurobiological basis for learning, thus allowing discussions about student learning to occur within a scientific, psychological, and pedagogical context" (Dubinsky et al. 2013, p. 320). For these authors "Knowledge of the biological basis of learning and memory and the inherent plasticity of this intricate system gave teachers a more positive attitude towards each student's ability to change and learn" (ibid., p. 324) and moreover "… teaching neuroscience to students can increase their self-understanding, self-efficacy, motivation and metacognition" (ibid., p. 327).

Let me summarize: there are many problems with the un-qualified message or promise of neuroscience related to educational research and the educational field, first of all at the level of the concepts that are used ('brain' versus 'mind'). Further, though there may exist a correlation between some mental phenomena and neurophysiological states, the latter are neither necessary nor sufficient for the phenomena, what we need instead if one wants to pursue this line of research is an explanation in terms of the mechanism (or mechanisms) that is/are at stake, in other words a causal explanation. Harré and Tissaw (2005) distinguish first person expressive talk (for example thinking, believing, happiness etc.) from third person descriptive talk (for example brain activity) and label and categorize the distinction between the grammar of first-person expressive talk and third-person descriptive talk as the asymmetry principle. This is ignored when one speaks about and localizes the former (psychological terms, intentional terms and sensations) 'in the brain'. Another way to identify what is happening may be called the transgression from the mentalist mind-body approach to the materialist brain-body approach. Moreover, according to its own paradigm (means-end) clearly, there are hardly studies which show educationally relevant effects (not to mention the underdetermination problem). And finally, there are quite a few decisions (for example ethical) educators have to take for which neuroscience cannot deliver the necessary insights. All of this may lead to the conclusion that there is not a lot to be expected from the so-called knowledge exchange between the disciplines of education and neuroscience, i.e. if one accepts that there is a difference between on the one hand causality/probability/contingency and freedom/choice/responsibility/regret/remorse on the other hand. We should I think do away with talking about 'brain behaviour' or consciously perceive and alter one's own brain processes to give just two examples; and perhaps also with mustering evidence and rationale of neuroscience research to funding agencies traditionally supporting educational research.

Clearly, neuroscientific explanations have a particular seductive character. Evidence for this can be found in a 2008 article by Weisberg, Keil, Goodstein, Rawson, and Gray who discuss an experiment they have set up concerning the seductive allure of neuroscience explanations. Explanations with logically irrelevant neuroscience information had a particularly striking effect on non-expert's judgments of bad explanations. So why is it then that neuroscience is so attractive? Interestingly, one may be tempted to find an answer in the discussion this field offers itself when discussing certain so-called neuromyths of which examples are that one only uses a fraction of one's brain, namely 10 %, or that people are rather right- or left-brained. There is even a specific label coined for this: neurophilia (the appetite for neuroscience). Pasquinelli (2012) discusses several issues of neuromyths (the misconceptions about the mind and brain functioning) such as the origin, persistence and potential side-effects in education. There is according to her in the media "the tendency to offer irrelevant information, sensationalism, and the omission of relevant information" (Pasquinelli 2012, p. 90). She also refers to the biasing effect of images: “because neuroimages appear as compelling as eyewitness, they are persuasive” (Pasquinelli 2012, p. 91). Thus she argues: “The ignorance of basic facts about the making–of of brain images can mislead the layperson into believing that an image of the brain is sufficient to prove the existence of a mental state—an attitude described as ‘neurorealism’” (Pasquinelli 2012, p. 91). And she refers to the blossoming of projects, reports and studies on the social, political, and educational implications of neuroscience, looking in the latter field for guidelines and/or easy fixes for education. She talks about the example of Brain Gym (based on the idea that when different parts of the brain do not work in coordination learning can be impaired), and argues that though there is no evidence that its exercises are effective, they are globally well received in the domain of education (Pasquinelli 2012, p. 92). It is therefore really disappointing to find towards the end of the paper as an answer to the question what actions one can take, *only* that “knowledge must be pursued, conveniently disseminated, and taught” (Pasquinelli 2012, p. 93) ending with the mantra “From this collaboration [an effective interbreed between science and applicative domains (such as education)], compelling theories and practices can see the light that are at the same time true of science and meaningful for educators” (Pasquinelli 2012, p. 94).

Granted, neuroscientific studies can eradicate mistaken views about how the brain works. But that does not go very far to justify a legitimate educational interest not to mention what needs to be done in educational contexts. It does not justify the direction a lot of educational research has taken, not to mention the amount of money that is made available. It may be a field that merits interest on its own strengths, surely there are so many areas which are interesting. But it should not be ‘sold’ as highly relevant for education. Indeed, something very remarkable is going on there: never mind the possible problems, we are aware of that, so let’s continue ‘business as usual’, and therefore the mantra sounds ‘a lot may be expected from this field!’ It is easy so see how educators may be tempted to find an easy fix for educational problems, overwhelmed by neurorealism and the aura of doing real science offering the prestige that goes with it and the so-called expertise demanded for by educators and no less by parents. My arguments have been directed against such a neuromyth, which I offer as a reminder that education, including educational research and the discipline of education, should reclaim its territory.

References

Aldrich, R. (2013). Neuroscience, education and the evolution of the human brain. *History of Education, 42*, 396–410.

Anderson, O. R. (2014). Progress in application of the neurosciences to an understanding of human learning: The challenge of finding a middle-ground neuroeducational theory. *International Journal of Science and Mathematics Education, 12*, 475–492.

Anderson, O. R., Love, B. C., & Tsai, M.-J. (2014). Neuroscience perspectives for science and mathematics learning in technology-enhanced learning environments. *International Journal of Science and Mathematics Education, 12*, 467–474.

Bakhurst, D. (2008). Minds, brains and education. *Journal of Philosophy of Education, 42*, 415–432.

Bennett, M. R., & Hacker, P. M. S. (2003). *Philosophical foundations of neuroscience*. Malden: Blackwell Publishing.

Davis, A. (2004). The credentials of brain-based leaning. *Journal of Philosophy of Education, 38*, 21–35.

Davis, A. (2013). Neuroscience and education. At best a civil partnership: A response to Schrag. *Journal of Philosophy of Education, 47*, 31–36.

Dubinsky, J. M., Roehrig, G., & Varma, S. (2013). Infusing neoroscience into teacher professional development. *Educational Researcher, 42*(6), 317–329.

Elliott, J. (2006). Educational research as a forum of democratic rationality. *Journal of Philosophy of Education, 40*, 169–185.

Geake, J. (2008). Neuromythologies in education. *Educational Research, 50*, 123–133.

Glock, H.-J. (1996). *A Wittgenstein dictionary*. Oxford: Blackwell Publishers.

Goswami, U. (2008). Principles of learning, implications for teaching: A cognitive neuroscience perspective. *Journal of Philosophy Education, 42*, 381–399.

Hardiman, M., Rinne, L., Gregory, E., & Yarmolinskaya, J. (2012). Neuroethics, neuroeducation, and classroom teaching: Where the brain sciences meet pedagogy. *Neuroethics, 5*, 135–143.

Harré, R., & Tissaw, M. (2005). *Wittgenstein and psychology*. Burlington: Ashgate.

Hook, C. J., & Farah, M. J. (2013). Neuroscience for educators: What are they seeking, and what are they finding? *Neuroethics, 6*, 331–341.

Jensen, E. (2008). *Brain-based learning: The new paradigm of teaching*. San Diego: Corwin Press.

Liu, C.-J., & Chiang, W. W. (2014). Theory, method and practice of neuroscientific findings in science education. *International Journal of Science and Mathematics Education, 12*, 629–646.

Narvaez, D., & Vaydich, J. L. (2008). Moral development and behaviour under the spotlight of the neurobiological sciences. *Journal of Moral Education, 37*, 289–312.

Pasquinelli, E. (2012). Neuromyths: Why do they exist and persist? *Mind, Brain, and Education, 6*, 89–96. AU3

Patten, K. E., & Campbell, S. R. (Guest Eds.). (2011). Educational neuroscience. *Educational Philosophy and Theory, 43*(1).

Purdy, N., & Morrison, H. (2009). Cognitive neuroscience and education: Unravelling the confusion. *Oxford Review of Education, 35*, 99–109.

Schrag, F. (2011). Does neuroscience matter for education? *Educational Theory, 61*, 221–237.

Schrag, F. (2013). Can this marriage be saved? The future of 'neuro-education'. *Journal of Philosophy of Education, 47*, 20–30.

Sigman, M., Peña, M., Goldin, A. P., & Riberio, S. (2014). *Nature Neuroscience, 17*, 497–502.

Smeyers, P., & Depaepe, M. (Eds.). (2013). *Educational research: The attraction of psychology*. Dordrecht: Springer.

Tommerdahl, J. (2010). A model for bridging the gap between neuroscience and education. *Oxford Review of Education, 36*, 97–109.

Wagemans, J. (2011). Weg met de psychologie? [Away with psychology?]. *Karakter. Tijdschrift van Wetenschap, 36*, 14–15.

Weisberg, D. S., Keil, F. C., Goodstein, J., Rawson, E., & Gray, J. R. (2008). The seductive allure of neuroscience explanations. *Journal of Cognitive Neuroscience, 20*, 470–477.

Wittgenstein, L. (1953). *Philosophical investigations/Philosophische Untersuchungen* (trans: Anscombe, G.E.M.). Oxford: Basil Blackwell.