Chapter 5

Cognitive Neuroscience

In their seductively titled book ‘Can neuroscience change our minds?’ Rose and Rose (2016) point to how the prefix of ‘neuro’ has entered the lexicon and become attached to a variety of human endeavours such as aesthetics, marketing, ethics, politics and culture. Our interest in this chapter is in the application of neuroscience to education, referred to variously as educational neuroscience or neuroeducation. There are now research centres and university courses dedicated to educational neuroscience throughout the world such as the Centre for Educational Neuroscience at the Institute of Education/ University College London; the Brain and Learning project at the OECD’s Centre for Education Research and Innovation, and the many educational neuroscience departments located variously in Cambridge, London, Melbourne, Harvard, Leiden, New York, San Francisco and Wisconsin (see Morris and Sah, 2016). In addition to neuroeducation research being published in educational and neuroscience journals, there exist dedicated journals such as *Trends in Neuroscience and Education* and *Educational Neuroscience*. Education scholars have mined this material for its application to teaching and learning (see Taylor and Marienau, 2016, for an example applied to adult learning). This interest in educational neuroscience is clearly part of a broader interest in neuroscience in both the scientific community and among the general population. The allure of neuroscience for educators is twofold: firstly, it offers the possibility of confirming, at the neuronal level, the benefits of existing educational practice; secondly, it offers the possibility that neuroscientific knowledge can be used productively in educational settings.

The marketing materials for courses in educational neuroscience clearly set out the scope and promise of applying neuroscience to education. For example, the Teachers College at Columbia University offers a Masters of Science in Neuroscience and Education where one of the objectives is “to prepare a new kind of specialist: A professional with dual preparation able to bridge the gap between research underlying brain, cognition and behavior, and the problems encountered in schools and other applied settings.” (Teachers College, Columbia University, 2019:1)

Similarly the University of Melbourne offers a Professional Certificate in Educational Neuroscience where the aim is to ‘Explore the science of learning and how the brain works ……..how this emerging and exciting field can be successfully translated to improve classroom teaching and learning……..This cutting edge course is built around the work of national and international leaders in the fields of neuroscience, psychology, educational science, and philosophy’. The Handbook entry for this course states: ‘Specifically, students will learn how neuroscience and psychology can, and cannot be, successfully translated into classroom practice.' (University of Melbourne, 2019)

Most of the general descriptions of courses and programs of research tend to foreground neuroscience as delivering basic research outcomes which are then translated into educational or clinical practice via the discipline of cognitive psychology. This is also the explicit view set out by Bruer in his influential publication *Education and the brain: a bridge too far* (1997) whereby cognitive psychology is seen as the link that allows for the translation of neuroscientific findings to educational practice. But while there is much energy and optimism about the application of neuroscience to education, there are also warnings about the significant challenges of such an enterprise. Before considering these challenges it is useful to outline the approach of neuroscience and its application to education.

The project of educational neuroscience

De Vos (2016) provides perhaps the best statement of the project of neuroeducation:

To begin with, the neuroeducational approach demonstrates how neurological research attempts to bridge two problematic fields: on one plane, the mind and its psychology; and on the other, the brain and its physiology. …….The crucial thing to note, here, is that the principal rationale of such research is to establish a parallel between the mind and the brain, between psychological variables and brain regions. (De Vos: 133)

The typical neuroscientific investigation in this area is to map regions of the brain being activated and the temporal changes evident when undertaking a task. Ganasana *et al*. (2017) and Williams and Henson (2018) provide an overview of neuroscientific techniques but for the most part the link between behaviour and cognitive process and brain functioning has been made through non-invasive techniques such neuroimaging using functional magnetic resonance imaging (fMRI) and measures of electrical activity such as electroencephalography analysis (EEG) and electro-/magneto-encephalography (E/MEG). It is worth noting that fMRI is an indirect measure of brain activity in that is measures the ratio of oxygenated and deoxygenated blood (blood flow is greatest in regions of the brain that are active). EEG is a more direct measure of the electrical activity of neurons as they 'fire' – it is useful for providing temporal detail but it cannot accurately identify the regions of the brain being activated (although MEG has the potential to provide better spatial resolution). There seems to be no limit to the types of tasks undertaken while mapping brain functioning: memory, attention, performing calculations, logical reasoning, problem solving, hand eye co-ordination, reading, writing, empathy, spatial awareness, interpersonal perception and more – all mapped against the neural regions being activated (see Shearer and Karanian, 2017). Complementing this mapping exercise are investigations that target the neural basis of learning difficulties (e.g. dyslexia, dyscalculia) the effect of interventions of various kinds (e.g. cognitive training, feedback and testing while learning, the role of physical activity), and even the impact of culture on neural functioning (Han *et al*., 2013).

Arzi *et al*. (2014) provide an overview of the achievements of cognitive neuroscience. At a general level, the finding that the brain has a degree of plasticity supports the efficacy of educational, training and behavioural intervention. The finding of individual differences points to the possibility of personalised clinical interventions, such as psychoactive drug prescriptions in psychiatry (explained by differences in neural networks and brain metabolism) and the rehabilitation of brain injured patients through the better characterization of their injury using imagery techniques.

Arzi *et al*. also mention a range of interventions and applications being developed such as the use of video/digital games for 'brain training', the optimization of neural networks through physical exercise and cognitive training, biofeedback and neuro feedback technologies providing feedback on psychological and physiological states during training, the use of transcranial direct current stimulation in modulating cognition in a range of health contexts, the development of brain-machine interface technologies and their application to motor deficits and vision impaired, and the expansion of research possibilities with subjects in naturalistic settings (such as education) because of the development of a range of technologies measuring and even controlling neural activity.

It is important to note that as neuroscience has advanced there is a growing recognition that the brain is networked, which means that a simple mapping of behaviour to dedicated regions of the brain is now seen as too simplistic. Arzi *et al*. (2014) make the claim:

Just as it has become clear that no individual brain region performs a single cognitive function, a wealth of recent work also suggests that cognition is supported by the dynamics of large-scale networks of brain regions.

(Arzi *et al*.,2014: 1074)

Wexler (2019) draws attention to some established observations of brain activity. Firstly, how neuronal activity changes in multiple brain areas when undertaking a simple cognitive operation. Secondly, how the same cognitive task performed at different times may have different patterns of brain activation. Thirdly, how, as people age, the same task may involve different brain activation patterns. And finally how a cognitive task often produces different brain activation patterns when it is embedded in a larger task than when it is undertaken separately from any larger task. His overall observation is:

> Such mental operations are ..properties of functional systems that perform the same function through different means or components in different circumstances or at different times The functions are properties of the system, not of specific anatomic locations.

Wexler (2019:81)

In a similar vein Grossberg (2018), in his model of neural architecture, shows how the functional properties of different pre-frontal cortex areas, with their distinctive psychological functions, (e.g. cognitive-emotional interactions, spatial working memory) emerge only by interacting with other brain regions. Neuroscientific studies of the ageing brain indicate that older adults are affected by neural degradation (which is connected to cognitive decline) but that this is partially compensated by increases in prefrontal activation through a process of 'compensatory scaffolding' (Park and Reuter-Lorenz, 2009). Furthermore prefrontal activation appears to be strengthened by cognitive engagement, exercise, new learning, specially designed cognitive training: and life course /lifestyle effects such as participation in social, leisure and community activities (Reuter-Lorenz and Park, 2014); and potentially weakened by poor nutrition and hypertension (Rodrigue and Kennedy, 2011).

The finding that there are individual differences in regions of the brain being utilised while undertaking various cognitive tasks, and the proposition that the brain is networked, substantially complicate the translation of neuroscientific findings into educational interventions. This is not to say that it can't be done, only that the process and nature of the translation needs to be carefully examined.

Lost in translation

There is ample discussion in the literature about the possibility and limitations of translating neuroscience into educational practice. The advocates of such a translation typically use medicine as a parallel case. Spitzer (2012) is representative of this line of argument. He argues that education, like medicine, is an applied science. As such it is similar to the translational path from pure biochemistry to say, the development of therapeutic drugs. But the translation from pure biochemistry to applied medicine is not direct, it relies on intermediate steps that bridge the gap, including controlled trials and clinical research. In an analogous way the bridge between neuroscience and education is claimed to be cognitive psychology (following Bruer,1997). The idea is that neuroscience informs cognitive psychology, which in turn informs applied educational research and educational practice.

Horvath and Donoghue (2016) argue strongly against the appropriateness of applying a medical analogy. They identify four possible bridges between the two fields of neuroscience and education, each with a different purpose. Firstly there is a *prescriptive bridge* which "attempts to specify practices to be undertaken at the educational level on the basis of evidence derived from the neurophysiologic level. In other words, prescriptive translation aims to instruct an educator and learner on *what* to do and how to do it" (p.2, 2012). This seems most closely allied to what happens in medicine. Secondly, there is a conceptual bridge, which is basically the application of broad neuroscience concepts to understand, interpret or explain the success or otherwise of an educational intervention. For example, neuroplasticity is a concept that could be invoked in a classroom setting, but it in no way directs educational practice. Thirdly there is a functional bridge, whereby neuroscientific knowledge may constrain or set limits on learning. For example, students with attention deficit disorders may take drugs that have an impact on neural functioning which will improve attention, but once again there are no direct implications for the practice of teaching. Finally there is a diagnostic bridge, whereby it may be possible to identify the neural origins of say, a learning difficulty, by neural imaging of the student's brain activation patterns. But just knowing that a certain region of the brain normally associated with say, mathematical calculation, is failing to activate, will not inform classroom practice (whether it informs clinical practice is another issue). Horvath and Donoghue (2016) claim that transdisciplinary research in neuroeducation is primarily concerned with prescriptive bridges. However they argue that neuroscience only translates via conceptual, functional and diagnostic bridges and that, in principle, 'findings at the neuroscientific level are irrelevant to and cannot be prescriptively translated to classroom behaviors" (2016:2). Their argument is complex, but basically they make the case that neuroscientific knowledge and educational practice are incommensurable in that the questions they ask, the tools they use, the data they gather and the criterion of success are all very different. As they put it , they are at incommensurable levels of organisation. As such they dismiss the view that it is simply a matter of time before an increasing neuroscientific knowledge may bridge the gap between neuroscience and education.

Quite apart from Horvath and Donoghue's analysis, there is a range of other reasons for challenging the medical model as a good fit for neuroeducation. Firstly, from a constructivist perspective, education is conducted in a social, cultural and historical context and, as such, is not reducible to individual neural functioning. The aim of education is not solely about learning in the cognitive psychology sense, it is about the formation of persons. Importantly, the aims of education change in response to social and cultural changes. This of course is not necessarily the view held by neuroscientists who by and large would be trained in a realist epistemology, where reality can be empirically studied and is not subject to the vagaries of historical, social and cultural variation. With different, and seemingly incommensurable epistemologies, how can neuroscientists and educators work together in interdisciplinary teams? The answer, according to Palghat *et al.* (2017) is for interdisciplinary researchers to discuss their epistemological positions. They will at least understand each other better and perhaps come to an agreement on what is and what is not translatable. For example, the translatability of neuroscientific research may depend on the issue being investigated:

…moving from brain imaging studies of a perceptual task to psychological discrimination theories does not require a distal inference to be made. However, trying to integrate cellular mechanisms for memory with prescriptive policy recommendations is vastly more difficult. Anderson(2002) referred to the possibility of making such distant inferences as a 'seven orders of magnitude problem'. There is inherent difficulty in attempting to infer from a phenomenon that occurs in a small part of the brain over millisecond time periods to the education of a professional, for example, that takes many years and occurs in a complex social milieu. The complexity of this translation task results in confusion and possible conflict stemming from differences in language, methods and motivation at each of the layers of interpretation between the brain and broader society.

(Palghat et al, 2017: 206)

Palghat *et al*. (2017) expound on particularly pertinent issues for neuroeducation: the nature of the relationship between mind and body (or brain in this instance) and what they term the 'hard problem of consciousness'. Simply put, these issues relate to whether we consider mental states and subjective experience to be reducible to physical/chemical states in the brain, or whether there are reasons to consider mental states and subjective experiences as phenomena in their own right and therefore not reducible to physical/chemical states in the brain. Given that there is no watertight argument for supporting either position, Palghat *et al.* (2017) recommend that collaborative researchers in the field of neuroeducation at least attempt to talk about their epistemological positions when discussing methods, results and interpretive language.

Secondly, there are very few prescriptive actions that teachers can learn and apply to their practice without considerable adjustment to the realities of the classroom. Even the outcomes of applied educational research, for the most part, cannot be taken prescriptively. This is because of the very fluid and contingent nature of the relationship between teachers and learners. Teaching is an interactive process where the actions of the teacher need to be constantly modified to take into account the reactions of the group.

Thirdly, the relationship between educational practice and neuroscience does not fit the standard translational research paradigm of basic research, then applied research, followed by implementation in practice. It is often the case that this relationship is reversed where neuroscientists are guided in their research by the outcomes of educational/psychological research. For example, prior to the advent of neuroscience as a field of research, there was a wealth of research on the educational benefits of distributed practice. Gerbier and Toppino (2015) point to the 100 years plus of research demonstrating that retention in memory of material is better with spaced practice (also referred to as distributed practice) than with massed practice. They then proceed to discuss the different theoretical explanations of the phenomenon using evidence from brain imagery studies of neuroscience. After exploring different hypotheses they recommend that students adopt a spaced interval study program with testing. In this instance neuroscience is simply providing another source of support for what is a longstanding finding in psychological studies of retention and the practical knowledge of teachers.

More generally De Vos (2016) makes a strong case that neuroscientific research draws heavily on established psychological concepts. They argue that most attempts to apply neuroscience to education do so within a psychological framework for understanding learning. The example they offer is the connections made in the literature between social cognition and the medial prefrontal cortex (MPFC) and the finding that adolescent groups have more MPFC activity in a range of tasks such as understanding irony, thinking about one's intentions, thinking about character traits and emotions such as guilt or embarrassment, and identifying emotions. The point made by De Vos is that the concepts being examined are psychological in nature and are the subject of psychological theory.

> …the point of departure for neurological research is inevitably still psychology and its assumptions, which serve to provide the initial material and research base for neurology. Hence, also, the tautological risk: psychology is supposed to underpin neurological research while the latter is more and more evoked as the final proof of the scientific validity of the psychological theories themselves.
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> (De Vos:134)

Given the above positions, are there circumstances in which neuroscience can contribute to a prescriptive translation of research? Well certainly the findings on the benefits of spaced practice offer an example, but only in the sense that neuroscientific findings support the prescriptions already identified in the educational literature. Another pertinent example is that of Hale *et al*. (2016) who bring a neuroscientific lens to the debate on whether learning difficulties (academic and cognitive deficits) are best addressed through educational intervention focused on compensation or educational intervention focused on remediation. It is clear that they support the remediation side of the debate:

"We now have the ability to link observable behaviours, psychological processes, and neuroimaging findings (De Souza *et al*., 2012), and results have revealed two facts from this large evidence-base often ignored in education. First, disability is indeed different from typical learning and behaviour, but symptoms of clinical interest are dimensional in nature. In other words , learning and behavioural difficulties occur, but they should be considered on a continuum of functioning from good to poor. Second, remediation of cognitive and academic weaknesses normalizes dysfunctional brain patterns in many children with learning and behavioural difficulties warranting clinical attention, so that disability is not necessarily permanent. This does not mean that all disabilities can be eradicated with evidence-based intervention, but suggests disability can be ameliorated in some cases and mitigated in others."(2016: 46)

This is a valuable contribution to the compensation vs remediation debate in education, but it doesn't really settle the debate, and the prescriptions it offers remain open to other points of view. Indeed there are no unequivocal examples of prescriptions for educational practice arising solely from neuroscientific research. However neuroscience does offer clinical interventions that can assist those with learning difficulties and it should be noted that neuroscience has had an impact well beyond the issue of specific research translation into education. For example there are neuroscientists who have embarked on the quest for the origin of consciousness, emotion and selfhood, the most influential or whom is Antonio Damasio. Damasio's (1999) treatise titled *The Feeling of What Happens: body, emotion and the making of consciousness* is ground-braking in the sense that it addresses questions previously seen as outside the scope of neuroscience. He addresses the problem of consciousness, which has two parts: how we form images of objects or the 'movie in the brain' , and how the brain 'engenders a sense of self in the act of knowing' (p. 9) and 'the sense that there is a knower and observer for that movie' (p.11) . He develops a neurobiological account of the self but he specifically disavows the idea of an homunculus, an observer or spectator. His self-schema comprises the proto-self (the neural circuitry mapping the state of the organism in response encounters with objects that produce ‘felt images’), core self (the sense that there is an owner of images and emotional states-a bodily felt self) and autobiographical self (a sense that the self exists over time and not just in the moment). His work is significant in that it has influenced thinkers in the humanities and social sciences, who have incorporated the ‘turn to neuro’ and biology within their thinking (e.g. Fonagy, 2002; Blackman, 2008; Hunt, 2013). As expressed by Hunt and West (2009), the role of language and culture in the formation of selves is seen against the ‘backdrop of a well-developed and fundamentally important bodily felt self, without which consciousness extended by language would not be possible.’(p.73) Damasio is also significant in the central place he gives to the body and emotion in cognition and meaning making.

We now turn to the question of whether it is useful to apply a neuroscientific mindset to educational practice. The next section covers how such a lens has been applied and misapplied in various ways in different educational contexts, and how it might be applied productively in the future.

Neuro myths and neuro-mindsets

There exist a number of critiques of neuroscience and its various applications. The most notable of these is that of Rose and Rose (2016) who locate the whole neuroscientific enterprise within its historical, political and social context. The authors frame the rise of neuroscience as one of the technosciences which are coproduced with the neoliberal political economy. In this sense, neuroscience supports the central tenets of neoliberalism: individualism rather than collectivism, market forces rather than state regulation, and privatisation rather than public services. For the uninitiated, this would be seem a long bow to draw, but for those familiar with the literature on the kinds of selves demanded by the neoliberal economy, none of this would be surprising or new (exemplifying this literature is Nikolas Rose’s book *Inventing Our Selves*).

The authors’ point to the illusory ‘imaginary’ of the neurosciences, which:

… can empower us to remake our brains, and hence our minds and our very selves. Personal effort, guided by the neurosciences, can overcome the injuries of poverty and inequality. Plasticity, a property of the brain central to neuroscientific thinking for half a century, has become a quasi-magical term within public policy discourse offering an entirely new solution to problems of child development and poor educational performance, and heralded as the new elixir by self-help manuals.

(Rose and Rose, 2016: 3)

It is certainly the case that commercial products have been developed which trade on the public attraction of neuroscience and there is evidence of the prevalence of neuromyths among teachers (Howard-Jones, 2014). Some myths are based on a simplification of the science, such as the findings on hemispheric differences leading to the myth that people are right brained or left brained and require training to balance the hemispheres. In other instances a neuro explanation is used inappropriately, such as linking information about the development of the prefrontal cortex to the risk factors for drivers under 25. There are also highly commercial products that appeal to neuroscience such as Brain Gym and some of the learning style instruments.

Serious researchers are at pains to identify the neuromyths in circulation. For example the Centre for Educational Neuroscience (2019), University College London has developed a web-based resource on neuromyths *Neuro-hit or neuro myth*. This site examines the status of certain claims made in the name of neuroscience, most notably the status of research on left brain versus right brain thinkers, gender differences in cognitive abilities, learning styles, the cognitive impact of learning a second language, and the idea of critical periods in development. They are mainly concerned with correcting any overapplication of findings – especially where some 'truth' becomes the 'whole truth'. For example inferring that a 'critical period' of development means that if we fail to learn something in a critical period then it is not possible to learn it at a later time.

Katzir and Pare-Blagoev (2006) tell the story of a funded program in Georgia, USA, that distributed Mozart CDs to new mothers in the belief that neuroscience research had established that early exposure to classical music enhanced brain development. This finding, called the 'Mozart effect' has since been debunked. Cautionary articles followed from neuroscientists keen to make sure that their research was not misused. Even by the admission of neuroscientists, research is still in its infancy, and we need to be cautious in its application to human behaviour, especially given that some of the core issues have not yet been solved (see Weisberg e*t al*., 2008; Niven and Boorman, 2016; Schulkin, 2016). Schulkin warns us:

> Neuroscience, though exciting, is easy to oversell; we still have not solved core issues in neuroscience. Our expectations are high, perhaps too high … While neuroscience is a new science, we just need to keep in check a vulnerability bias of seeing more and expecting more than there is at this time in neuroscience.
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> (2016: 22)

The existence of neuromyths and their uptake by some educators has now been well documented (Pasquinelli, 2012; Howard-Jones, 2014). Pasquinelli cites the widespread popular knowledge of the Mozart effect as evidence of the persistence of neuromyths in spite of their lack of scientific support. This persistence she attributes to 'neurophilia', the appetite for brain news, a concept well supported in the research of Weisberg *et al*. (2008), in an article titled the *Seductive Allure of the Neuroscience Explanations*. They demonstrate how non-experts value explanations of psychological phenomena more highly when they have irrelevant neuroscience information provided. Thus, the prefix 'neuro' affords a legitimacy to explanations that would otherwise be questioned.

It is important for educators to avoid perpetuating neuromyths in their educational practice. But this does not mean abandoning a neuroscience mindset. The question is whether a neuroscience mindset changes educational practice or just affirms existing practice. An example of 'brain friendly teaching' in the adult learning literature is found in McGinty et al (2013). It turns out that 'brain friendly teaching' is exactly what adult educators have espoused as good practice over many decades. For example brain friendly environments are those that provide 'stimulation, novelty and problem-solving opportunities' in an 'atmosphere of acceptance, encouragement, and support'. Once again, practice precedes any neuroscience findings. This is starkly similar to Taylor and Marienau's (2016) book *Facilitating Learning with the Adult Brain in Mind*. The overall purpose of this book it to illuminate the alignment between various models, techniques and approaches to facilitating adult learning and how the brain actually learns.

It is pretty clear that the brain aware practices outlined by Taylor and Marienau were developed, not in response to neuroscientific research, but in response to the experience of teaching adults. For example they outline various approaches to address the anxieties that adults bring to the their learning. However, even if the neuroscience of anxiety were well known, this would not change the approaches recommended. Arguably teachers are 'brain aware' only in the sense that they have applied *their* brain functioning to their experience and used experience as a guide to practice. But this in no way undermines the 'brain aware' theme, rather it points to the interdependent relationship between experience and the brain.

The idea that the brain can be shaped by experience has been known for many decades through early research on kittens, mice, and ferrets raised under restricted visual environments. For example, when kittens are exposed to vertical black and white lines only, they develop cortical cells that only respond to vertical lines (Blakemore and Cooper, 1970). There is now ample evidence that the human brain changes in response to experience. It is only recently that the area of cultural neuroscience has investigated this phenomenon at a higher level - how the experience of culture shapes neurobiological processes (Han *et al.*, 2013). Cultural neuroscience is interested in the mutual constitution of brain and experience – the way in which the brain both shapes experience is shaped by experience.

Given the interdependent relationship between the brain and experience, the issue is whether the knowledge gained from experience is more useful for informing education than the knowledge gained from a study of the brain. Arguably, it is experience that is the better guide. Cozolino and Sprokay (2006) echo this sentiment in the opening sentence of their monograph titled *Neuroscience and Adult Learning*:

…most effective adult educators may be unwitting neuroscientists who use their interpersonal skills to tailor enriched environments that enhance brain development

(2006: 11)

They go on to illustrate how widely adopted principles of learning are supported by neuroscientific research, but as far as teachers go 'understanding the brain's processes further enhances what they may intuitively already know' (Cozolino and Sprokay p.18) For example, the need for a moderate state of arousal to enhance learning and the need to attend to both cognition and emotion are widely adopted as good practice in the adult education literature. That these practices are likely to enhance neural connections, specifically strengthening orbitofrontal-limbic connections (Cozolino and Sprokay, p. 14-15), means that practice is affirmed rather than changed.

However it should be conceded that, while most teachers attend to emotion and cognition, they may not fully grasp some of the neuroscientific subtleties of the relationship between cognition and emotion. For example Immordino-Yang and Damasio (2016) describe findings that some patients with brain damage are cognitively capable but unable to manage daily life. They could not make judgements about their actions because their emotions had been impaired. In the words of the authors 'Emotions, are, in essence, the rudder that steers thinking'(p. 28). Thus emotions don't just function as *preparation* for learning in the sense that emotions are related to motivation, arousal and feeling comfortable; they are, in fact, an *integral* part of cognition. In the case of patients with brain damage, emotion and cognition are not integrated; as a result they are not able to learn effectively from experience.

As discussed earlier in this chapter, there are significant difficulties in translating detailed neuroscientific findings to specific recommendations for educational practice. However at a more global level there is a clear neuroscientific case for the functionality of emotions in learning. This is the position adopted by Immordino-Yang and Faeth, (2016) who propose three fundamental strategies for integrating emotion and cognition in educational practice:

1.Foster emotional connection to the material
This includes practices such as fostering a participatory approach, relating material to learners' lives, and providing open ended problem solving tasks so that students learn from mistakes. 'It is in the detours and missteps, as well as in refinding the path, that rich emotionality is played out, that valuable emotional memories are accumulated, and that a powerful and versatile emotional rudder is developed'(2016:102)

2. Encourage students to develop smart academic intuitions
This refers to learners being given the opportunity to use experience-based intuitions and to think about the application of knowledge in real life contexts. This takes time and it may seemingly be less efficient but in the long run it is a more effective way to embed knowledge.

3. Actively manage the social and emotional climate of the classroom.
This refers to the importance of trust and respect and social cohesion in the learning environment so that learners feel safe to experiment and make mistakes. Ideally developing positive emotion should not rely on content irrelevant tasks or interventions such as 'icebreaker' exercises or light-hearted jokes 'For emotion to be useful, it has to be an integral part of knowing when and how to use the skill being developed' (2016:104)

All of the above strategies stress the emotional dimension of learning and are aimed at fostering ‘skilled intuition’, which is really shorthand for ‘learning from experience’. Most of these strategies have for many years been advocated by the adult learning literature and taken up by adult educators, and interestingly, they are all consistent with both the humanistic and psychoanalytic approaches to education. Neuroscience thus provides a strong endorsement of existing practice, although with a nuance that strengthens and may subtly change the mindset of teachers (i.e. the strong view that emotion and cognition are integrated).

Somewhat ironically the neuroscientific focus on emotion, intuition and experience suggests that as educators we should trust in experience, and leave our brains to do their work. This is the position of Colvin (2016) who argues that, for now, ‘experience will continue to have the leading role in education research’ (p.3). While this is partly valid, neuroscientific findings and a neuroscience mindset will no doubt continue to influence educational thought and practice in a variety of ways: through providing another form of legitimacy to existing educational practices (including educational and lifestyle interventions for ageing); through identifying appropriate clinical and educational interventions for those with learning difficulties; through scrutinising educational theory, research and practice for existing beliefs about learners and learning that are not justified (included here are neuromyths); and finally, by providing a neurobiological dimension to an understanding the self.

Activity

The Centre for Educational Neuroscience (2019), University College London has developed a web-based resource on neuromyths *Neuro-hit or neuro myth*. The web address is:
http://www.educationalneuroscience.org.uk/resources/neuromyth-or-neurofact/
The website has links to a number of items. Click on each of these items so that you can inform yourself of the status of each claim and adjust your assumptions accordingly.

- Left brain versus right brain thinkers
- Diet makes a difference to learning
- Fish oils improve learning
- Physical exercise enhances learning
- Different children have different learning styles
- Learning two languages gives a cognitive advantage
- Girls and boys have different cognitive abilities
- Most learning happens in the first 3 years of life
- Violent video games make children more violent
- We only use 10% of our brains
- Well-rested children do better in school
- You can train your brain with digital media
- Children do better in school if they were born in the autumn
- Is ADHD on the rise in UK schools?

- [Mindfulness has a place in the classroom]
- [Intelligence is fixed]
- [The future of education is brain stimulation]

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