The optimum context for learning; drawing on neuroscience to inform best practice in the classroom

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Aims: As our understanding of neuroscience and the developing brain continues to grow, there is a worldwide move to use this information to inform educational practice. This paper attempts to draw together several convergent but complementary ideas in neuroscience to produce a model outlining the optimum context for a child to learn in a classroom.

Method: A general outline of brain development is presented, highlighting key areas of brain functioning and cell connection. The positive cycle of learning shows how brain circuits are formed which require the child to be engaged in ‘doing’ a task.

Findings: Two key situations which mitigate against a child entering the positive cycle of learning are highlighted: where the child is stressed, and where they are not at their achievable challenge level. Both situations might emphasise activity in the midbrain, which is believed to reduce connections to the forebrain (primarily considered the ‘thinking brain’, which is essential for learning). The importance of a student’s beliefs and mindset are also described which are strong contributors to learning behaviour. Finally, the importance of maintaining a developmental perspective within education is outlined, given what is known about stages of brain development and in particular given the significant changes that take place during adolescence in terms of brain reorganisation. A final model is proposed to guide teacher’s behaviour as a model to be empirically tested in the future.

Limitations: Although an emerging area, this field is in its infancy. Many of the studies included in the model have yet to be replicated and the degree to which a cohesive model such as this can offer a testable means for approaching individual needs is unknown. Merging paradigms from different fields such neuroscience, attachment research and education is a fairly recent endeavour and will require further empirical investigation in a collaborative manner.

Keywords: neuroscience; brain development; education; learning; mindset; teacher-student relationship; attachment.

What can we learn from the developing brain in education?

There is a movement across the world to integrate neuroscience into formal education, but there continues to be a debate in the field about how fruitful a relationship this might be (Ansari, Coch & De Smedt, 2011). Some researchers posit potential in the integration of neuroscience and education to ensure a teacher knows how to work most effectively with a student and reduce wasted energy on intervention without effectiveness (Willis, 2008); others are more sceptical (Cuthpert, 2015).

One of the problems has been the rise and wide acceptance of so-called ‘neuro-myths’ which are ideas about how to engage an individual (and their brain) that sound plausible but are incorrect (Geake, 2008). Examples might include the 10 per cent myth (a belief that people only use 10 per cent of their brain), left brain/right brain thinking and the unsupported science behind programmes, such as BrainGym (Dekker et al., 2012; Howard-Jones, 2014). Geake (2008) argues that we need to be careful of over-simplifying the neuro-level description and interpretation of neuro-radiological investigations, and urges researchers to resist temptations to draw
firm conclusions about brain changes in response to interventions given the inaccuracy of neuroradiological measurement currently. This has led researchers to be rightly sceptical about how useful it is to know that a certain brain region changes if there is no behavioural correlate found (e.g. Bishop, 2013).

This paper is written in full recognition of how early we are in our journey to fully understand learning and the brain. However, there are certain key features of the brain and established facts about brain development and brain functioning that are informative for educators, to help them work in an optimal way with children and maximise learning in the classroom. This paper will outline some of the key aspects of brain architecture and functioning, and explain how this development might affect a child’s learning. The authors will then suggest several educational implications of the recent findings about adolescent brain development and the importance of social interactions on brain function and learning in particular.

**Brain development**

Genes and environment both play a part in developing the brain. The term ‘brain plasticity’ refers to the fact that a brain changes and adapts to its environment. Every time we carry out an action, a cell fires, and changes become wired into the brain and are strengthened when cells are simultaneously activated many times. This action causes neural circuits to form in the brain. The stronger the circuit, the greater the skill. The theory was originally described by Donald Hebb (1949) and later coined into the phrase ‘cells that fire together wire together’ by Carla Shatz, (1992) which is a helpful image in thinking about connectivity. Although present throughout life, brain plasticity in childhood is more effective than plasticity in adulthood (Lillard & Erisir, 2011). An individual’s brain is particularly ready for learning during childhood, and while we can learn new skills throughout our lives, it is much easier to learn skills during childhood. The brain is chemically predisposed to be modified by experience during the developmental period until it reaches maturation which is now thought to be completed sometime during an individual’s third decade of life (Sowell et al., 2003; Spear, 2013).

An individual’s brain can be sculpted to respond to need, and require an influencing environment to be changed. The term ‘Experience-expectant plasticity’ (Greenough, Black & Wallace, 1987) refers to the fact that a brain is predisposed to receive certain experiences at certain times, but without that experience the development will not take place. So a brain has sensitive periods or windows for growth (Greenough, Black & Wallace, 1987). During these periods a brain becomes highly sensitive to specific experiences. There is thought to be a preprogrammed order of development within the cortical and subcortical brain (Gogtay et al., 2004) which may be associated with genetic, environmental or neurophysiological factors (Schmitt et al., 2014). This order and trajectory may differ for individual children depending on neurodevelopmental progress (Fox, Levitt & Nelson, 2010; Gilliam et al., 2011).

**The Triune Brain**

An individual’s brain can be considered as having three intimately integrated parts, described as the Triune Brain (MacLean, 1990), which means ‘three in one’. This is shown in Figure 1. This is a simple description of a brain and useful in considering how learning may be affected by evolutionary development. If a brain is cut down the midline we would see three core structures: the hindbrain, the midbrain and the cortex. The **hindbrain** is in evolutionary terms the oldest part of the brain and ensures survival. The **midbrain** also known as the limbic system houses emotion processing (the amygdala), long-term memory (the hippocampus) and the reward system (the nucleus accumbent) among other structures. The **cortex** is situated
on the exterior of the brain and the frontal regions of the cortex in association with other areas subserve higher-order functioning (for instance, language). The cortex is well developed in humans compared to all other mammals, with a significantly larger prefrontal cortex (PFC) than any other species.

Early models of neuropsychology focused on mapping out the modular systems within the brain, in an attempt to show which areas of the brain serve which functions (for example, Broca’s area for language functioning). While there is value in understanding the modularisation of the brain, neuroscientists are now calling for us to shift focus from modularisation to interaction, with a greater focus on mapping functional connectivity given what we now know about the importance of connectivity in a developing brain (Geake, 2008). In particular the emphasis is now on connectivity between the various brain regions (Koziol, Budding & Chidekel, 2011).

A preprogrammed order to brain development
Recent research (Knudsen, 2004) has added to understanding of a sequence of development in the brain. Broadly, the cortex develops from posterior (rear) to anterior (front) (Lenroot & Giedd, 2006). The regions underlying sensory processes come online first. The last part of the brain to fully develop is the PFC which is thought to facilitate the most complex behaviours (e.g. planning, organisation, and decision-making) often described as the ‘executive functions’ in the brain (Kolb et al., 2012). We do not yet understand fully the development of highly complex culturally transmitted knowledge such as reading (Bruer, 1997). It is likely that literacy skills result from maturation and connection of distributed brain regions, rather than one area. In particular, reading is likely to be subserved by many regions which underlie language, visual skills and the connections between these areas as the child learns to decode phonics.
The jury is still out as to how ‘critical’ these periods of brain development are. Early animal research and more recent research on humans has highlighted the limiting effects of early deprivation on visual and auditory processing, showing that if input is not received (via the environment) during the early years, the pathways for developing these skills may never fully develop (Kral et al., 2001; Maurer, Mondloch & Lewis, 2007; Wiesel & Hubel, 1965). However, recent conceptually opposite paradigms stress the power of environmental enrichment on brain plasticity (Sale, Berardi & Maffei, 2014). No doubt the story will unfold in the coming years, but what we do know is that the brain is adaptable and highly sensitive to environmental experience.

**How learning happens at the cellular level**

Understanding brain maturation at the cellular level can be informative, as it offers a way to visualise cell connection and skill development. An immature brain is not necessarily one with fewer neurones; rather, it is one with fewer connections between neurones (Nowakowski, 2006). When a baby is born their brain contains billions of neurones but only a small minority are connected (Couperus & Nelson, 2008). The process of connecting neurones and connecting parts of the brain and making pathways is how the brain develops and thus underpins behavioural development.

The neurone is the main cell in the brain with a cell body, axon and dendrites. When an action is performed, a signal is sent down one neurone and a neurotransmitter is used to connect it to another neurone; a connection is made. Then when the activity is repeated, the same circuit is fired. Every time it fires, a layer of fat is wrapped around the circuit, insulating the circuit to make it work more quickly and efficiently. This process is called myelination and these connections are described as white matter. The more the activity is performed, the more the circuit is fired and myelinated, and the more efficiently the skill is carried out. Myelination increases the efficiency, co-ordination and balance between cells (Fields, 2005; Zatorre, Fields & Johansen-Berg, 2012). So it is important to encourage children to perform actions to build the circuits and fine tune skills. The circuits link different parts of the brain, thereby integrating the brain resulting in a more mature integrated brain. The rate at which a particular circuit is myelinated is affected by the preprogrammed order of development, so when in a ‘sensitive period’ that circuit stabilises or is ‘joined up’ more quickly and efficiently.

Towards the end of the sensitive period or opportunity for growth, a final stage of development happens which is called ‘pruning’ (Petanjek et al., 2011). The brain loses connections that are not considered useful for the environment in which the brain is developing. The brain keeps connections that are useful to it (that are being used), thus finalising the period of developmental plasticity. During adulthood it is more difficult to alter the circuits and learn complex behaviours. Although not impossible, it just may take longer and require more focused determined practice than during childhood.

In summary, the brain has a period of intense ‘developmental plasticity’ during the first 25 years or so of life. There is a preprogrammed order of brain development when the brain is ready to learn certain skills, but the environment is crucial to facilitate this. The brain learns by linking neurones together to make pathways or circuits, integrating the brain regions. Towards the end of a sensitive period of development, connections that are not linked are pruned away. This presents both risks and opportunities to children which may be of relevance to teachers.

**The Positive Cycle of Learning**

Given what we know about the brain, it is essential that every child engages with a task or as we refer to it enters the ‘cycle of learning’ in the best possible way, as shown
in Figure 2. The brain learns through action, so getting the child ‘doing’ is crucial in order for them to learn. Within the classroom, in order to support the development of brain circuits, each child needs to enter this cycle.

A positive cycle of learning is most likely to take place when the child experiences success in their action. Success in the form of task completion and/or positive feedback from the teacher will engage the reward systems in the brain. Dopamine is one of a number of neurotransmitters that connect neurones together, by carrying messages across the synaptic gap from one neurone to another. Dopamine is released when an experience is rewarding and drives the individual to repeat the action; it increases motivation and with it, attention. Dopamine can even be released in anticipation of a reward based on memory and experience (Sharo et al., 2009).

In terms of applying this process in the classroom, we may use the example of a Maths lesson. If the experience of learning Maths was positive previously, a child is likely to feel positive towards that lesson and be more attentive and engaged. The child is then ‘doing’ the skill with greater motivation and attention, and they are therefore building connections in the brain. The more the child repeats the activity, the greater the myelination of that circuit and the more efficient they will become at that skill, leading to a greater experience of success. The child is then in the positive cycle of learning.

Children who struggle with learning are not accessing the positive cycle of learning and it is important for educators to know why. Indeed, children may find other ways to release dopamine and feel ‘successful’ in the classroom, such as promoting themselves as the class ‘clown’ or challenging the teacher.

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**Figure 2: The Positive Cycle of Learning.**

- **Engage in task**
- **Experience success, sense of achievement, positive feedback leads to dopamine release**
- **Want to do it again, anticipation leads to dopamine release**
- **Activity connects neurones and builds circuits**
- **Myelination of circuits makes for efficiency and leads to competence**
- **Competence leads to feeling of success and desire to …..**

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to elicit peer admiration. The opposite of a positive cycle of learning results in the Matthew effect (Merton, 1968). An example of the Matthew effect is found in children who slow down in progress with language skills because they lose an interest and motivation in reading and therefore fail to build vocabulary skills at the rate of their reading motivated peers (Stanovich, 1986). Therefore, these children progress less well overall than their peers.

Although there may be many reasons why children do not enter the positive cycle of learning. Two common situations that often occur are:
1. The child feels stress or is emotionally overwhelmed.
2. The task is not with their achievable challenge level.

**Causes of the brain functioning in the limbic region (emotional processing) at the expense of engaging the cortex (‘thinking’ brain)**

*Finding a child’s achievable challenge level*

Individuals differ greatly in their ability to learn. The achievable challenge level is the point where the task is neither too easy nor too difficult for the child, and s/he can engage fully with learning. This is equivalent to Vygotsky’s notion of ‘The Zone of Proximal Development’ (Vygotsky, 1978) Some individuals struggle in specific areas (for instance, literacy, numeracy) and others struggle in all domains (intellectual disability). The field of behavioural genetics has demonstrated that there may be genetic influences on learning capacity (Plomin & Kovas, 2005). For some children, they only need to be shown that the ‘a’ makes an ‘a’ sound a handful of times for it to be firmly consolidated in their lexicon. For other students, they may need to be shown the relationship between phoneme and grapheme hundreds of times to encode it fully. Genetic predispositions can be moulded and modulated through nurture, which is the environmental influence of education and this has been shown by positive response to intervention (Brooks, 2013). The challenge is to identify a student’s specific barriers to learning and find ways to overcome the challenges (RSA, 2011). A teacher’s ability to find the child’s achievable challenge level for each subject for each child is key. If the task is too easy the child will become bored, or if the task is too hard and the child may become stressed; this can also lead to the hindbrain (automatic systems focused on survival) being dominant and ultimately inhibiting learning (Willis, 2008).

In other words, children differ in how much input they need to build a robust sense of mastery and therefore the required brain circuit to develop a skill. Some brains need greater environmental inputs than others, in the form of repetitions to build circuits. This is not only in relation to specific skills taught in the classroom such as learning to read, but also to broader abilities that impact on behavioural and emotional regulation and, therefore, a child’s ability to engage in classroom learning, such as the Executive Skills (inhibitory control, working memory and attention control: see Cantin, Mann & Hund, 2012).

**The ‘switching’ station in the brain – the Midbrain**

The brain comes hardwired to recognise and respond to threat. It has an emotional filter system which is necessary in order primarily to ensure the individual is safe. Information comes through the five senses and then is processed within the limbic system, where the amygdala (involved in emotional processing) and the hippocampus (which facilitates memory) are housed. This set of brain systems evaluate information and assess the safety of a given situation based on current and past experience. If a threatening situation is perceived, the amygdala becomes aroused and sets off an alarm system which puts the brain in survival mode. Processing is taken up by the midbrain and entry to the prefrontal cortex for higher order decision making is blocked — after all, there is no
point in problem solving if the individual is not safe. Willis describes this process in detail and refers to the midbrain as the ‘switching’ station in the brain, ensuring safety before thinking or developing higher order circuits (Willis, 2009).

The ‘switching station’ highlights the importance of emotions in education, as the neurology of learning and memory is interwoven with the primitive survival circuitry dedicated to stress, arousal and fear. When in a state of stress, activation in the active learning part of the brain (the frontal lobes) is significantly reduced as the brain prioritises emotional processing (activating the amygdala and related limbic regions) to ensure safety and survival (Le Doux, 1996; Pawlak et al., 2003). A degree of stress can act to focus our attention and increase our strength, as the body gets ready to protect us in an emergency. However, an overwhelming level of stress or a stress that threatens our survival can compromise effective brain functioning.

So what might cause stress in the classroom? If the child perceives the teacher as consistently angry or negative, this could cause them to experience undue stress. The impact of this stress will work against entering the positive cycle of learning in the classroom. Children who are still strengthening the Executive Skills necessary to learn in formal education – such as the ability to attend and focus on the teacher for long periods of time, to resist impulses and to regulate their behaviour and emotions – can be perceived as perpetually ‘naughty’ or disobedient. A teacher’s response of punishing these children acts to reduce that child’s ability to learn, by putting the child in a state of stress, thereby reducing communication to the thinking brain (forebrain) and the larger associated network. For young children, positive regard from an adult is essential to performing well, hence the importance of a consistent and nurturing relationship between the child and their teacher (Birch & Ladd, 1997).

At the brain level we can look to Social Baseline Theory (Beckes & Coan, 2011) to see how important this relationship might be. Social Baseline Theory proposes that humans are hard-wired to use social proximity as a default strategy for regulating emotional stress. In a series of experiments, Coan and his colleagues have shown that being with another person to whom we have a secure attachment affects brain processing in a way that conserves brain energy (Coan et al., 2006). Not only does an individual register less distress in threatening situations when with a secure attachment figure, but the world is perceived as less daunting and thereby engages a broader network of brain regions in problem-solving. When accompanied by a securely attached person, an individual does not have to invest energy regulating distress as they seem to ‘outsource’ stress regulation to the other person. The more secure the individual feels within the relationship, the less effort the individual’s brain has to invest in reducing stress. Research into Social Baseline Theory needs to be replicated in children and ideally applied to a teacher/child relationship, but the findings are intriguing and suggest that relationships in school may be important determinants of learning.

As shown in Figure 1, a secure relationship between teacher and student is the lowest level of the hierarchy of needs within the classroom to ensure optimal brain functioning. If the child feels respected, accepted and cared for by the teacher, their emotional brain can get on with the job of learning at school. In a similar vein to Maslow’s hierarchy of needs (Maslow, 1943), if these needs are not met, the individual will struggle to move up the hierarchy and higher cognitive functioning will be inhibited.

Emotions have traditionally been thought of as irrational and beyond our control, with no place in a learning environment (Immordino-Yang & Damasio, 2007). However, given what we now know about how interwoven emotional and learning processes are at the brain level, it is clear that
considering the child’s affect during learning is essential. Negative emotional states work against learning and memory, and, by contrast, positive emotions can support both processes. When the amygdala is in a good state it is calm and can strengthen the ‘staying power’ of information presented in a lesson (Willis, 2009).

The importance of students’ beliefs and mindset
Hattie’s (Hattie, 2013) extensive meta-analysis of research into educational outcome has found that the factor that most robustly produces the biggest effect size in terms of impact on the learner is ‘student expectations’. Similarly, the expectations a teacher has for his or her students, based on their beliefs about students as learners, has the greatest impact in the classroom. Even if unspoken, it seems that the teacher’s beliefs about a student are communicated; teacher expectations affect the student’s self-concept as a learner, which in turn influences student approaches to learning (Trouiloud et al., 2002, 2006).

Research evidence has accumulated regarding the impact of children’s mindset on learning (Dweck, 1988; Yeager, Scott & Dweck, 2012). Dweck (passim) and her colleagues have carried out extensive investigations and found that what people believe about themselves affects their motivation, their ability to achieve goals and accomplish tasks (Dweck, 2006, 2007, 2012). The key idea is that children who have a fixed mindset about their intelligence, in that they see intelligence as an inherent trait, inhibit their learning, as they become increasingly concerned about maintaining their status as an ‘intelligent’ person and are less likely to take risks and attempt work they believe they will not be able to master. Children with a growth mindset, on the other hand, believe that intelligence or abilities can be learnt through effort and persistence. Such children seek critique and good mentoring, take on challenges and thrive in the face of difficulty. Dweck has shown that a child’s mindset has an impact on their behavior, particularly with regards to effort and resilience.

This belief and attribution underpinning learning could draw on the findings in neuroscience that show the way in which the brain develops through connection when new skills are learnt. It may be helpful for children to know this evidence. Every time a student tries and persists with a task, neurones fire and new connections are formed and circuits myelinate. For everyone, even people who achieve great things, they have had to work hard, persist, fail and try again (Dweck, 2010). Programmes such as Brainology (Dweck, 2008) aim to change children’s behaviour towards learning by changing their mindset and teaching children about how a brain learns. Similar findings regarding the attributions of learning have been shown in mathematical learning by Pinxten and colleagues (Pinxten et al., 2014).

Sensitive periods in development – the case of the Adolescent Brain
Early brain research showed that the brain has ‘critical periods’ for the development of sensory and motor regions. These appeared to be windows of opportunity after which the development of full functioning in that area became reduced (Weisel & Hubel, 1965). This led to the belief that the early years of a child’s life, particularly before the age of 3 years, offered the greatest, if not the only, opportunity for brain development. Post-mortem research in the 1970s began to reveal differences in the frontal cortex of adolescent brains compared to the brains of younger children (Huttenlocher, 1979), opening up the possibility that brain development may be longer than previously thought (Blakemore, 2006). While we are still a long way from being able to track sensitive periods in most brain regions that might inform us about primary education, the past 15 to 20 years has seen an explosion of interest and research in the area of adolescent brain development, in this country led by Blakemore and colleagues.
The most significant finding is that certain areas of the brain undergo reorganisation and development during the latter part of childhood, triggered it seems by puberty. This has significant implications for education; the more teachers understand these developmental drives and this functional reorganisation, the more they will be able to work with the brain rather than against it during secondary education. For example, given what we know about the social reorientation during adolescence, teachers could be taught to: (1) make use of the social brain; (2) avoid social pain; (3) understand social sensitivities of teenagers; (4) Create the conditions for the development of higher order functioning; and (5) Understand heightened sensitivity to rewards.

Make use of the social brain
Adolescence is a time of heightened social importance where peer relationship and acceptance become fundamental to experience and self-worth. This is thought to be related to the significant development that goes on in the social brain during adolescence (Somerville, 2013).

Research by Lieberman and colleagues (Leiberman, 2012) has found, through brain scanning studies, the importance of what they refer to as the ‘mentalisation network’ or ‘default mode network’, the aim of which is to keep track of another person’s beliefs that are different from one’s own. This system involves activation in several regions: medial prefrontal cortex, temporoparietal junction, posterior superior temporal sulcus and anterior temporal cortex in the forebrain (Mills et al., 2014). Humans can mentalise explicitly from the age of 4 years onwards but it is likely that these skills are developing well before then (Frith & Frith, 2003). Importantly, when people are free to think as they please and are not engaged in a competing task, the mentalisation network is more active. One problem for education, Lieberman points out, is that the mentalisation network competes with the parts of the brain involved in analytic processing and general intelligence (frontoparietal regions). It is a balance: the more one region is activated, the less another one is activated. When an individual is engaged in Maths, for example, the thinking brain is involved but if this process ceases, the social thinking reliably comes online. In other words, when we are thinking about the social world our learning brain turns off, and vice versa.

Rather than telling adolescents to leave their social brain outside the classroom, Lieberman advocates leveraging on this social bias in the brain to change how we educate to include a social element in the classroom (Lieberman, 2012, 2013). He refers to this as the Social Encoding Advantage.

The way in which the Social Encoding Advantage could be used in the classroom is yet to be explored and researched fully, but early suggestions include focusing on the social drama in history to engage social thinking, encouraging mind to mind transfer of knowledge in English, and using the social motivation of teaching peers in more content-led classes (Leiberman, 2012). Indeed, there is evidence from an experimental study that participants who were told to memorise information because there would be a test later did less well than a group who were told to form an overall impression of the person who read the information (Chartrand & Bargh, 1996). The aim of the task for the more successful group was, therefore, a social one rather than a memorising task. A later study found different patterns of brain activation between the two groups, with the Social Encoding Group thought to be using the regions within the mentalising network drawing on the prefrontal cortex (Mitchell, Macrae & Banaji, 2004). This phenomenon has yet to be explored in children and adolescents, but it is an avenue worth pursuing when exploring how to make the best of young people’s social interest in the classroom. Peer tutoring is another avenue that needs further investigation, especially as a recent meta-analytic review on a number of single-case experiments had yielded prom
ising results (Bowman-Perrott et al., 2013). Given the massive social reorientation during adolescence, the approach is likely to be most effective during this particular developmental period.

Avoid social pain
Social pain is the experience of pain as a result of interpersonal rejection or loss, such as rejection from a social group. Researchers have taken advantage of the technological insights of functional MRI to look at where social pain is registered in the brain. The findings suggest that social pain (in this case perceived rejection) is associated with activation in the same brain region as physical pain (the anterior cingulate and right ventral prefrontal cortices, Eisenberger & Lieberman, 2004; Eisenberger, Lieberman & Williams, 2003). Moreover, there is a correlation, in that participants who report higher levels of social pain also show more brain activation (Eisenberger et al., 2003). If we consider that the purpose of pain is to draw attention to the potentially threatening source of pain, pulling cognitive resources away from other activities, we see the potential impact on learning of social exclusion, bullying and rejection in school. Social pain is unseen and, therefore, more easily ignored or minimised than physical pain. Nonetheless, empathy from teachers regarding the impact of social rejection, and an awareness of the potential devastating impact of social ‘shaming’ in the classroom, is needed to meet the basic brain needs of adolescents.

Understand social sensitivities
Adolescence is a time when the brain learns to process complex emotions such as embarrassment and guilt (Blakemore, 2008) and while teenagers learn these demanding cognitive responses, research has shown a dip in their ability to mentalise (Dumontheil et al., 2010). The implication of this is an increased chance that the young person will misread another person’s ‘mind’, be highly sensitive to social slights and perhaps be hyper-vigilant to social ‘put downs’, particularly from their teacher. At the same time, the PFC is undergoing significant reorganisation, leading to reduced impulse control, emotional regulation and ability to read from the wider context (Casey, Getz & Galvan, 2008). Teachers who understand this aspect of brain development in the children they are teaching are more likely to understand a teenager’s heightened response and sensitivity. Greater understanding will lead to greater tolerance, and without punishment and anger there is a learning opportunity for the young person, where good connections and circuits can be built, linking up the emotional with the thinking brain.

Create the conditions to optimise opportunities for the development of higher order functioning.
Brain development offers both risks and opportunities. Just as the sensory and motor cortices are sensitive to development during the early years as brain reorganisation takes place, so the skills subserved and interconnected with the PFC may also be particularly sensitive to development during adolescence (Blakemore, 2006). If this is the case, then the teenage years – and secondary school education in particular – offer an exciting opportunity for learning higher order cognitive skills such as planning, decision-making, critical analysis and creativity along with behavioural and emotional regulation. Such skills are commonly talked about as being highly valued in the modern economy (Robinson, 2013). Without classroom conditions that allow a child or young person to feel safe, stress-optimal and in a positive relationship with others, the opportunity for the individual and indeed, society to develop these higher order skills is significantly reduced.

Understand heightened sensitivity to rewards
Reward sensitivity is a well established finding in the area of adolescent brain development (Galvan, 2013). Studies using function MRI measures have repeatedly shown
exaggerated neural activation in reward centres in the brain, particularly the ventral striatum (Ernst et al., 2005; Galvan et al., 2006; van Leijenhorst et al., 2010). The Dual System Model (Steinberg, 2008) uses this temporal gap between the early maturing of the reward systems in the brain and the slower maturing cognitive control system, the PFC to explain adolescent behaviours of risk-taking. It is hypothesised that teenagers have heightened reward systems, leading them to experience greater sensitivity and motivation for pleasure while being less able to regulate this. These findings may help us both to understand pleasure-seeking behaviour in the classroom, and perhaps to consider how to make the most of adolescents’ intense interests and passions in education. For example, there is an opportunity to support the development of higher order learning skills while allowing teenagers to study a topic of choice.

In sum, in order to support learning it may be beneficial to have an understanding of brain development and what this means for a young person’s developmental drives, particularly during adolescence when the brain is rewiring and is highly sensitive to certain types of input. Adults need to support the development of salient drives (often social) and take advantage of the opportunity to nurture important skills (higher order processing), while having a framework to understand behaviours that appear extreme or ‘out of sync’ with a situation (social and reward sensitivities and weaker mentalising skills).

The Optimum Context for Learning: A neuroscientific model (Figure 3)
The Optimum Context for Learning model (Figure 3, overleaf) draws together these various hypotheses, illustrating key findings from neuroscience, and placing them in a hierarchy. In a similar vein to Maslow’s hierarchy of needs (Maslow, 1943), the model proposes that if stronger foundation levels are achieved, there is a greater chance of a child reaching the top of the model and succeeding. To reach the top, where learners are passionate and engaged, lower levels need to be firmly established.

**Level 1**
Working from the bottom up first, on Level 1 a child needs to feel safe and be in a stress-optimal environment to ensure there is favourable activation in the higher cortex, rather than overactivity in the limbic region. Strong connections with adults and a climate of acceptance and positive regard are necessary to enable optimal learning in the brain to take place. Moreover, a student’s brain functions optimally when in the presence of someone with whom they have a strong relationship, and to whom they can outsource stress. Once a student feels safe, stress-optimal and connected to an adult, this will enable them to be interested and enjoy the activities in school. Interest and enjoyment may not always follow, but certainly will not be possible without the engagement of Level 1.

**Level 2**
The level of the task needs to be within the child’s achievable challenge level in order that they can engage with the task and not be bored or overwhelmed; both of these may cause dominant midbrain functioning, thereby reducing communication to the thinking brain (forebrain) and the larger associated network.

**Level 3**
The child can then engage in the positive cycle of learning which will begin with an action potential in neurones and result in growth of myelinated circuits. Myelinated circuits correlate with skill and competence which in turn bring success, and so the cycle continues.

**Level 4**
The child’s beliefs about themselves as learners and their learning ‘mindset’ have an impact on their learning behavior. These cognitions determine whether the student is open or resistant to feedback, and confident.
or fearful of trying new challenges in the event of failure. Importantly, positive beliefs will orient the child to embrace challenges, persist in the face of setbacks and demonstrate hard work and resilience.

**Level 5**

With the other four levels in place, a student can begin to be playful in and enjoy their learning, and have ownership of what they are doing; mastery of the skill and knowledge will follow.

**Level 6**

The final stage is for learners to be passionate, interested learners who are fully engaged with what they are doing; this will fuel greater heights of achievement.

**Demands change according to stage of brain development**

As the brain changes and develops, so do the young person’s drives, needs and behaviours. Any solid educational model needs to take into account a student’s changing needs to work with the brain to ensure optimal functioning. As we learn more about how the brain reorganises during development, as we are learning about the adolescent brain, we are able to train teachers to understand emotions and behaviours more fully.

**Limitations to the model**

There are clear limitations to this model. As yet, it is untested in its cohesive whole, and the various paradigms and theories which are proposed have emerged from...
quite distinct and varied backgrounds, which may make it difficult to evaluate. Implementation of the model and its evaluation may also be a challenge given the required collaborations between the various elements such as academic neuroscientists and educators. Importantly, as yet, there is limited teaching and training for all educators on brain development, which might make the translation of this model limited. However, at the same time, if models such as the Positive Cycle of Learning can be tested and found to be effective in promoting learning progress, they might be incorporated into teacher training, thus benefiting students and educators alike. Evaluation of the model will also require rigorous thought. It will be important to consider how to balance the benefits of assessing behavioural versus neuroanatomical change, alongside academic achievement and emotional welling.

**Conclusion**

The Optimum Context for Learning model seeks to draw together several convergent but complementary ideas in neuroscience and education. It looks to use established research in the fields of neuroscience in order to inform and ameliorate educational practice. There is a clear hierarchy which suggests how educators might address learning and motivational issues from a neurological perspective. For example, if a child is disengaged in the classroom or their behaviour is out of sync with expectations, a conscientious teacher can work through the hierarchy from the bottom to ensure that each level is achieved. Ensuring there is safety and a stress-optimal environment for the child will be the primary aim, and the teacher can look to factors in their relationship with the child to check. The next step will be to empirically test out the model and its application in the classroom. Moreover, it will be important to explore how other interventions such as pharmacological interventions (medications for inattention), designed to harness learning potential, interact with and effect each level of the hierarchy in the Optimum Context for Learning.

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References


