Research for Teachers

Neuroscience

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What is known about how the brain develops and how does teaching and learning need to take account of this?

Improvements in brain scanning technology and the use that scientists make of it means that our understanding of the learning process is continually developing. While understanding the functions of the brain has many implications for teaching and learning, it is a complex and dynamic field of study that can seem daunting. The fast moving nature of our understanding of how the brain works has also led to a widespread acceptance of 'neuromyths': simplistic and sometimes incorrect interpretations of more subtle findings from the research. Another reason for 'myths' taking roots is the nature of science itself and its constant development and moving forward: theories appear, modify, get confirmed or refuted.

We have chosen a study for this TLA research summary which reviews the findings of existing research on the brain and learning, and sets these out for a practitioner audience. The study also identifies and corrects the myths about brain functions, such as the idea that the right hemisphere predominates when it comes to creative activity. The study was carried out by the Centre for Educational Research and Innovation (CERI) and is titled *Understanding the brain: The birth of a learning science*.

In this summary we look at four themes emerging from the study, including:

- the plasticity of the brain - its ability to adapt over time and in the face of barriers to learning
- how neuroscience can inform language, literacy and numeracy learning
- the importance of the environment (including learning environment) on brain development
- the importance of healthy lifestyles on brain development and ability to learn.

Within each of the themes we connect messages from the research with teaching, learning and practice. For example, the plasticity of the brain has important implications for the way we organise learning for dyslexic students. On the other hand, the patterns of brain development in early childhood suggest the importance of play

in learning. Play equips the learner to develop social skills to deal with current and future difficult situations.

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Overview

What is known about how the brain develops and how does teaching and learning need to take account of this?

Why is the issue important?

Improvements in brain scanning technology and the use that scientists make of it means that our understanding of the learning process is continually devloping. While understanding the functions of the brain has many implications for teaching and learning, it is a complex and dynamic field of study that can seem daunting. The fast moving nature of our understanding of how the brain words has also led to a widespread acceptance of "neuromyths": simplistic and sometimes incorrect interpretations of more subtle findings from the research.

What did the review find out?

This literature review shows how neuroscientific research can contribute to education, for example:

- lifelong learning - one of the most powerful sets of findings related to the brain's 'plasticity' - the ability to adapt and grow and to also prune itself. The demands made on the individual and on his/her learning are key to plasticity - the more you learn, the more you can learn
- holistic approaches to education - the report showed the key part played by emotions in the functioning of the brain - especially important for education was the report's analysis of fear and stress, which showed how thy reduce analytical capacity and vice versa, how positive emotions open doors within the brain
- development and learning in early childhood and adolescence.

How was this achieved?

In this RfT, we look at three themes emerging from the study:

- the importance of the environment on the developing brain
- the plasticity of the brain - its ability to adapt over time and in the face of barriers to learning
- the importance of healthy lifestyles on brain development and the ability to learn.

Within each of the themes we illustrate the overarching message with specific areas of teaching and learning. Learning which includes role play, on the other hand, equips the learner to develop social skills to deal with current and future difficult situations.

How was the research designed to be trustworthy?

The review had two parts. The first and larger part was "The learning brain" and was based on a wide range of research and other literature. Much of the literature focused on scientific and clinical studies, such as those reporting on imaging technologies that offer the opportunity for observation fo the working brain, and provide insights into perceptual, cognitive, and emotional activities relevant to education. The second part of the review included three articles (each written by an expert) about the 'learning brain' in early childhood, adolescence and adulthood, respectively.

What are the implications?

The review showed the importance of:

- acknowledging and making use of the range of different opportunities for learning and brain development throughout life
- supporting children and young people's emotional development along with their brain development
- using the findings of neuroscience to devleop genetically-destined brain structures into literacy and numeracy skills by providing appropriate experience and learning opportunities and triggering the innate potential.

What do the case studies illustrate?

The case studies show, for example:

- how phonics and thinking skills can support young children's literacy development
- how to use a multi-sensory approach to aid teaching mental arithmetic
- how you can teach children to use pretend play
- how important a creative curriculum for teenagers' learning and development can be
- how physical exercise can promote children's learning and development.

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Study

What messages does the study have for teachers about the brain and how it works?

Neuromyths:

- 'We only use 10% of our brain.'
- 'I'm a "left-brain", she is a "right-brain" person.'

The study provides insights into the structure and functioning of the brain which may help educators assess their underlying assumptions about teaching and learning. Importantly, a strong message emerging from the evidence is that of the brain's plasticity - its ability to change significantly over the lifespan in response to learning experiences.

The plasticity of the brain arises from the ability of its nerve cells or neurons to make and break connections with each other. The connections between nerve cells are called synapses, and the establishment and strengthening of synapses between multiple neurons is what enables the brain to carry out specific tasks, such as recognising objects. The more the brain carries out a particular task, the stronger the synapses between neurons become. If the brain ceases to carry out that task over a period of time the synapses weaken or may break altogether (pruning).

The majority of brain cells are present from birth, but the way they are connected to each other - the neural networks - continues to be modified throughout life. The important implication for educators from this is that learning, appropriately organised, can happen successfully at any stage in life.

The other implication of understanding the brain in terms of functional organisation is that even apparently simple tasks such as 'seeing' an object are the result of a complex process of information exchange and analysis. In the case of 'seeing', our brain synthesises the data from many specialist areas, each 'responsible for' only one aspect - recognising colour, shape, motion, etc. Functional organisation of the brain does not mean, however, that some areas might be inactive at a certain point in time. The recent research shows that the brain is 100% active, even when no movement, sensation or emotion is observed.

Some functions are present from birth, for example, the ability to distinguish words in speech by focusing on intonation and rhythm. Other functions, such as an ability to read, take a lot longer to develop. This is because the neural networks required for these skills can only function once a number of specialised areas have been connected and their activities co-ordinated.

Research into the composition of neural networks has also helped overturn the myth that people can be

divided into 'right brained' and 'left brained' individuals. The myth arises from the fact that the two hemispheres of the brain tend to specialise in different functions (functional asymmetry):

the left hemisphere in carrying out language, mathematics and logic tasks, and
the right hemisphere in spatial awareness, emotions and synthetic thinking.

Some educationists have worried that, with its emphasis on language and mathematics, western education is designed for 'left brains' to the detriment of 'right brains'. On this basis they have advocated a broadening of teaching methods to include role-playing, music and drawing.

While the reviewers in this study see the educational benefits of a wider range of teaching methods, they argue that labelling children 'right brained' and 'left brained' has no basis in scientific evidence. Neuroscience has shown that despite functional asymmetry, the picture is more complex and the two hemispheres in fact work together, contributing to overall integrated brain activity. Evidence for this includes the fact that both hemispheres are involved in activities such as decoding written words, identifying numerals, and encoding spatial relationships.

How can knowledge about brain development over a lifetime inform teaching and learning?

Neuromyth: 'There are critical periods when certain things must be taught and learnt.'

The brain's plasticity means that while children are more capable of learning certain things than adults, there is no reliable evidence to date of "critical periods" in brain development. That is to say, there do not appear to be exclusive windows of opportunity for learning particular skills which cannot be learned at other stages in life. The authors of this review talk instead about "sensitive periods" - that is that there are optimum moments for learning certain skills.

Aspects of language recognition and production provide a good example of skills more easily developed within a sensitive period. Babies can distinguish all sounds, even those not occurring within their parents' native language. This ability diminishes as children grow, and adults have more difficulty distinguishing unfamiliar sounds making them more likely to have a foreign accent when speaking a different language.

In order to understand brain development in more detail the authors distinguish between experience-expectant plasticity and experience-dependent plasticity. Experience-expectant plasticity refers to adaptations the brain is genetically programmed to make based on exposure to specific stimuli, such as sound structures in language. Experience-expectant learning best occurs during sensitive periods early in life. For example, researchers have found that it is easier to learn grammar up to the age of 16.

Experience-dependent plasticity on the other hand refers to the modifications the brain makes over the lifespan based on exposure to complex environments. Experience-dependent learning does not occur within sensitive periods. This is true, for instance, for the capacity to learn vocabulary, which actually increases with age.

The authors also discussed evidence showing that once a sensitive period has passed, the brain adopts different strategies to acquire particular skills. In the example of grammar acquisition, research found that for late learners both hemispheres of the brain are activated. This contrasts with what occurs in younger learners, where only the left hemisphere is involved in grammar learning. There is a cost to later acquisition, however, research shows learners have greater difficulty in using grammar correctly. Nevertheless, the brain's plasticity means that grammar learning is still possible beyond the sensitive period.

How can neuroscience inform teaching language and literacy?

Neuromyth: 'A young child's brain can only manage to learn one language at a time.'

In today's global world, an ability to speak more than one language is generally considered valuable. Yet many people still believe that learning a foreign language early can impede native language acquisition. The review suggests the opposite: children can learn a second language without detriment to the first. In addition children who master two languages understand the structure of each language better and apply it in a more conscious way.

The reviewers in fact advocate learning a second language at an early age, as this is when children are most effective at learning many aspects of a language. However, they do emphasise that teaching foreign languages to young people must be done in an age appropriate way. For example, they claim rule-based methods for older students would not be effective for younger learners. Learning a second/foreign language early, the researchers conclude, has only positive effects on a child's language development, including their competency in the first/native language.

While language learning is something that comes naturally, learning to read and write is much more dependent on well planned and conscious teaching. Through the process of evolution the brain is primed to acquire language - to process certain stimuli according to universal language rules already wired into the brain when we are born. In contrast to language learning, there are no brain structures designed by evolution to acquire literacy. Literacy is often seen as being "on top of" language. As Vygotsky metaphorically described it, language structures provide scaffolding for literacy to be constructed in the brain. You can find more about Lev Vygotsky's work in our earlier RoM.

As far as teaching reading is concerned, the reviewers suggest that the evidence supports the so-called "dual route" theory. This theory states that the brain processes words along one of two complementary pathways, either by:

- converting letters/words into sounds, or
- via direct transfer of the whole word/phrase into meaning.

In the debate over whether children should be taught reading by focusing on phonetic skills or whole language text immersion, dual route theory implies the importance of both. The researchers in this study believe the evidence would back up such a balanced approach. More information about teaching literacy can be found in a case study. You may also be interested in the findings of the Rose Review on developing children's reading skills (Please see Further Reading section for more details).

Development of literacy in the brain is mainly determined by experience, but biology has its own important part to play. Atypical features of their brain architecture can mean that some children struggle to learn to read and write. They are said to have developmental dyslexia, which used to be seen as a specific learning disability that is not related to other intellectual abilities and persists despite effective teaching. Recent research and teaching practice suggest that rather than being a disability, dyslexia is an alternative developmental pathway, for which effective teaching interventions have been developed. You might want to find out more in our earlier RoM about dyslexia.

How can neuroscience help teachers structure students' numeracy development?

The review highlighted how numeracy (like literacy) is created in the brain through a synergy of biology and experience. As with literacy, there are structures in the brain that are designed for numeracy. But as with literacy, the genetically-destined structures cannot support mathematics development on their own. The activities of these structures have to co-ordinate with those of supplementary neural circuits that are not specifically destined for numeracy, but are shaped to fit this function by experience. The review's findings have implications for both teaching and assessing mathematics, including the importance of:

- linking number and space in teaching mathematics
- assessing in a way which gives the teacher an insight into the learning and reasoning process, rather than simply

looking for the right answer.

Making use of the biological pathway

It was long believed that babies were born without any quantitative abilities - that they found out about the world simply through exploring it. But research included in the review showed that the baby's brain is equipped with the ability to count and distinguish large from small quantities. So, young children have a substantial foundation of numerical understandings prior to formal education. The studies suggested that mathematics teaching should build upon children's informal and intuitive numerical understandings. You may like to read case study 3 of our earlier RoM about Jerome Bruner's work which explores ways of developing children's division strategies. The researchers also suggested that it is important that teachers use children's natural numerical understandings as a rich source of scaffolding. You can find out about approaches to scaffolding in our earlier RoM about Lev Vygotsky's work.

The importance of experience

The review found that different teaching methods create neural pathways of varying effectiveness: the neural pathways developed through drill learning (e.g. memorising that 10 plus 10 equals 20), for instance were shown to be less effective than those developed through strategy learning (e.g. applying the strategy of double-digit addition). The review also found that as the neural circuits for number and space are intertwined, teaching methods that link number and space, such as number lines, blocks, rods, and board games make powerful teaching tools. Work started by teachers from a small infant school in Sussex which is now widely used, particularly in the teaching of Downs Syndrome children, offers a powerful example of such an approach. To find out more about multi-sensory approaches to teaching mental arithmetic, follow the link to this case study.

The importance of assessing the learning process underlying students' answers

The review's findings have important implications for assessment too. The review indicated that correct/incorrect measures of assessment are inadequate for assessing understanding as they cannot differentiate between, for example, knowledge which has been encoded as fact and knowledge encoded through strategy. To assess underlying understanding requires approaches which explore learning pathways, rather than focusing on correct or incorrect answers. In the approach mistakes are used as opportunities to identify learning gaps and develop understanding. There are some links here with particular approaches to Assessment for Learning (AfL). You can find out more in our earlier RoM about putting AfL into practice.

What do teachers need to know about early learning to help them recognise challenges and structure learning?

Neuromyth: 'There is no time to lose as everything about the brain is decided by the age of three.'

The early years are a period of rapid development of neural networks. Synapses (connections between nerve cells) in newborns are relatively low in number but after two months of growth, the synaptic density of the brain increases and exceeds that of an adult, peaking at ten months. The number of synapses then reduces gradually, reaching adult levels around age ten. The implication of this is that the very early years provide a special opportunity for learning, in which many neuronal paths are created. The reviewers, however, draw a distinction between this and the claim that children's brains must be constantly stimulated in the early years to improve longer term learning capacity. They found little evidence to support such a claim.

On the other hand, the researchers point to evidence which shows that deficits in a child's early years environment can have a negative impact on development. Negative factors include:

- ongoing discord and conflict, for example when an adult scapegoats a child for things that are not going well
- a lack of individual contact with a carer
- a lack of reciprocal conversation and play

- negative social ethos.

The evidence is that children experiencing early negative environments are highly likely to suffer long-term consequences. Research into the development of Romanian orphans found that the majority of them developed profound social and emotional problems. On the other hand, research also suggests that early neural damage due to institutional deprivation is not deterministic: outcomes for the individuals in one study varied widely. The reviewers conclude from this that it is important for those surrounding young children to try to build reciprocal relationships. One way to achieve this is for early years providers and schools to encourage parents to interact with their children. You may like to read case study 3 of an earlier RoM to explore examples of ways of increasing parental involvement in education.

The importance of play in early childhood

Relationship building and human interactions are also fostered through play. The review found that well-run, play-based early childhood programmes had a positive impact on:

- intellectual development
- social achievements
- self-esteem
- task orientation.

Specifically, one study found that children who experienced learner-centred environments developed better listening skills. A further study pointed to the importance of adults' attitude towards play as important in child development. The researchers found that the extent of children's engagement in play varied according to culture and the extent to which adults were prepared to invest the time and energy to actively encourage it. Practitioners may like to read more about how to encourage and organise children's play in a case study which explores different types of play and how teachers helped children develop more sophisticated skills through play.

What do teachers need to know about structuring learning for the teenage years?

Neuromyth: "The brain is largely a finished product by the age of 12."

The adolescent brain is a "work in progress": brain volume and myelination (maturing of neurons, resulting in increased speed of transmitting information between the neurons) continue to grow until the young adult period. Several parts of the brain continue to grow during teenage years. The changes in the areas of the brain regulating motivating reward behaviour may steer the teenagers to risky, high reward behaviours. Another area that continues to grow and develop is the cerebellum. The cerebellum is responsible for posture, movement and balance; it also influences other parts of the brain responsible for motor actions and is involved in cognitive functions, especially language. Finally, the prefrontal cortex, which governs cognition amongst other functions, is pruned during adolescence. Recent studies suggest that the way the prefrontal cortex develops during this period could have an impact on teenagers' ability to regulate their emotions.

Teenagers have rather well developed cognitive capacity but are emotionally immature, which the researchers metaphorically described as "high horsepower, poor steering". Emotional development during adolescence affects social awareness and character and is partly due to the surge of hormones in the brain. Sex hormones are important in the emotional centre of the brain; they influence serotonin and other neurochemicals which affect mood, and thus play an active role in teenagers' intense emotions and thrill-seeking behaviour. Difficulties with regulating strong emotions can affect teenagers' learning capabilities. Emotional regulation is an important skill of effective learners, helping them to focus attention and solve problems.

The review found positive emotions trigger motivation to learn. They argue that the brain responds very well to the "enlightenment", illumination that comes with the understanding of new concepts. Helping children and young people realise how pleasurable learning can be is a way of improving motivation and engaging disaffected learners. Practitioners may like to read a case study of how introducing creative elements into the curriculum helped teenage pupils realise that learning can be fun and improved their learning, motivation and

behaviour.

Latest research findings suggest that teenagers' decision-making functions are usually not fully developed. Some studies connect this immaturity in making decisions with, for example, a much higher rate of teenage drivers involved in fatal car accidents. Considering it is in their adolescent years most people make important decisions, such as career choice, the researchers recommend the education system takes this into account and plans for a broader range of formal and informal learning opportunities for people to switch course later in life. You might want to learn more about how teacher beliefs and aspirations for children and young people affect their pupils' learning in the Behaviour for learning RoM anthology.

How can teachers help children monitor and regulate their emotions in the classroom?

Evidence from the fields of neurobiology and education suggests that learning occurs not only as the result of thinking processes, but that emotions and physical exercise also play a central role. Emotional competency or intelligence has been described as "one's ability to self-regulate - that is, to restrain one's impulses and instincts, but also includes the capacity for compassion, and the ability to engage in co-operation."

Much of the research into the development of emotional self-regulation has taken place among children in their early years. The outcomes suggest a link not only between children's ability to learn to monitor and control their emotions and their ability to create and maintain positive relations with peers, but also between social competence and later academic outcomes. The latter was demonstrated, for example, in a study in which four-year-old children had the task of resisting the temptation to eat one marshmallow in order to receive two later on. The researchers found that those children who resisted the impulse longest were more likely to be the ones who enjoyed later academic success.

Research also shows that high levels of stress can have a detrimental effect on learning. When faced with negative emotions such as fear and stress several processes kick in to mediate the effect. This includes increased heart rate, perspiration, increased adrenaline levels, and the release of stress hormones. While a small amount of stress can lead to improved learning and adaptation to a changing environment, beyond low levels it can be damaging both mentally and physically, and can block learning. In the school environment children may experience stress when confronted with bullying students, aggressive teachers, or learning materials that are difficult to understand.

One way of helping children develop a more robust temperament for dealing with stress over the long-term is through more physical activity. Research has shown that sports people respond to stress by exhibiting less anxiety and greater calmness. Other research among adults has shown a link between increased aerobic exercise (in this case walking) and improved brain functioning. Further studies have found a link between physical activity and improved motor co-ordination and control. You might want to read a case study to learn more about the impact of a physical exercise programme on children's concentration and behaviour, fine and gross motor skills and reading accuracy.

Other forms of exercise which can be carried out in the classroom also have the potential to improve learning. In a project led by Alan Watkins with the support from the Southampton LEA, for example, teachers have introduced rhythmic breathing as part of an emotional literacy programme. The effect is to regulate the heart rate, thus stabilising the physiological state, and in turn the child's emotional state. (Please see OECD, 2003 in the Further Reading section for more details)

Communication training is another approach that has helped children deal with negative emotions in ways that are more positive socially. The Rosenberg method (Rosenberg, 1999 in Further Reading section), for example, is a non-violent communication process which has been taken up in several countries. The core feature of this approach is to help individuals become aware of their basic needs and develop their communication skills so they are in a better position to articulate these needs.

What is the role of memory in learning?

Neuromyths: 'Improve your memory!'

Memory and learning are interdependent: memory is built on learning while the benefits of learning can be 'stored' and developed thanks to memory. During the learning process, traces are left by the processing of information. Memory is a cognitive process that allows us both to reactivate these traces and to further develop them when acquiring new information. Memory, being tightly connected with learning, can be influenced by the same factors as learning, for example strong emotions, high motivation or increased attention.

Contrary to some popular urban myths, memory is not infinite, because the number of neuronal networks, where the information is stored, is enormous but finite. Research has also shown that the capacity to forget is necessary for building up an efficient memory. The researchers argue that many of the impressive performances, where people demonstrate, for example, memorising long lists of numbers or playing several games of chess blindfolded, should be seen as a specialised way of thinking rather than a specific type of visual memory.

The researchers question some of the current teaching methods and student evaluation approaches that rely too much on memory. Development of neuroscience, they argue, suggests there should be more emphasis on comprehension and learning how to learn in modern education.

How was the research designed?

In 1999 the "Learning Sciences and Brain Research" project was launched by the Centre for Educational Research and Innovation. The project was aimed at reviewing potential implications of recent research findings in brain and learning sciences for policy-makers and all those involved in education as parents, teachers, researchers, policy makers and learners.

The second phase of the project (2002-2006), reported in the study, channelled its activities on the following issues: Literacy, Numeracy, Lifelong Learning and Emotions and Learning. The content of the report derived from literature reviews, three trans-disciplinary and international networks and a focus activity, in which cognitive neuroscientists were challenged to tackle questions relevant to teaching and learning.

The project was run and supported by various institutions in the countries-members of the Organisation for Economic Co-operation and Development (OECD), particularly the USA, Japan, Denmark, Finland, Germany, France, Spain and the UK. DfES, the Lifelong learning Foundation and Cambridge University were amongst the British organizations contributing to the project.

What are the research implications?

Teachers may wish to consider the following implications of the findings of this research:

- The review showed that learning a second/foreign language early has many positive effects on a child's language development, including their competency in the first/native language. If you have bilingual or minority ethnic children in your class, how could you encourage them to develop their language skills in their home language? Could the parents of bilingual children be encouraged to help them develop reading skills in their home language, or could you link up with complementary institutions such as a community centre or mosque to discuss home language provision?
- Researchers in the study emphasised that teenagers often experience difficulties with regulating strong emotions, which can affect their learning. You might like to reflect on your recent lessons and consider how you support your pupils in developing strategies for managing their emotions in learning situations. Would you find it helpful to work with a colleague and your students to build a bank of examples of the ways in which emotions can inhibit and enhance learning and decision making, and a bank of strategies for managing such situations?

- The review showed that the quality of interaction with their parents is crucial to young children's development. Could you give parents and carers more guidance on activities that they could do at home that connect with their children's development, such as reading books, singing songs and nursery rhymes, painting and drawing, playing with numbers and letters or using pretend play, perhaps using a similar approach to that described in case study 3?
- Based on the finding that the neural circuits for number and space are intertwined, the researchers recommended using teaching methods that link number and space, such as number lines, blocks, rods, and board games. Could you reflect on how often you use these and similar teaching tools? How effective do you find them in your context?

School leaders may wish to consider the following implications from the study:

- The research showed that language acquisition and the development of language skills were strongly dependant on experience. Do you have a whole school strategy for developing your pupils' language skills, for example vocabulary? Could the opportunities provided to the young people at school be increased by working collaboratively with their families?
- The researchers questioned some current teaching methods and student evaluation approaches, pointing out that they rely too much on memory. Students' ability to reproduce facts is easier for teachers to measure than assessing the degree to which they understand a problem or the ways they go about solving it, and some subject areas may be more sophisticated in their approach to assessment than others. Would it be worth exploring your colleagues' repertoire and understanding of approaches to assessment, for example as a focus for cross-school CPD?

Filling in the gaps

Gaps that are uncovered in a field of research also have a useful role in making sure that future research builds cumulatively on what is known. But research also needs to inform practice, so practitioners' interpretation of the gaps and follow-up questions are crucial. The researchers highlighted several areas of research which were not explored by the project:

- better understanding of optimal timing - "sensitive periods" - for learning, especially in relation to adolescents and older adults
- the role of interaction with others and cultural differences in learning
- multi-dimensional pathways to competence, for example reading
- understanding different brain activity - neural networks, role of cognitive function and memory - among "experts" as compared with average learners and those with genuine problems. This could inform both the identification of successful learning and of effective, targeted teaching methods
- the impact of emotions on learning, in particular how the adolescent's emotional brain interacts with different kinds of classroom environments.

Do you think that research exploring these questions would help you inform your practice? Which issues are of most interest to you?

What is your experience?

Do you have any evidence regarding the development of the human brain over a lifetime and how that links with approaches to learning? Do you have action research or enquiry based development programmes running that explore, for example, children with atypical literacy or numeracy development? We would be interested to hear about examples of application of neuroscience to develop learning in and outside the classroom, which we could perhaps feature in our case study section.

Your feedback

Have you found this study to be useful? Have you used any aspect of this research in your own classroom teaching practice? We would like to hear your feedback on this study. Email research@gtce.org.uk to share your views with us.

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Case studies

We have chosen five case studies to illustrate different aspects of the 'consulting pupils' project featured in our RfT summary.

Case study 1 is an example of a school that consulted pupils about a specific issue identified by the school - target setting. Case study 2 relates the experiences of two teachers who tried implementing their pupils' suggestions for teaching strategies. The third case study describes how a teacher trained a group of ten-year-old pupils to enable them to conduct their own research and the fourth case study is an example of a school which evaluated the impact of students participating in research projects on their learning. Finally, we have summarised the different approaches for consulting pupils developed through one of the network projects.

Supporting young children's literacy development

Here we present two vignettes which illustrate different aspects of teaching literacy to primary children. The first vignette suggests how teachers can support children's literacy development by targeting the two different pathways of transferring visual information into meaning. The teachers in the case study developed children's phonetic skills as well as teaching them to grasp the meaning directly from the visual image, which, as dual route theory suggests, is the optimal approach to teaching reading. The second vignette shows how the use of thinking strategies can contribute to children's understanding of a written text.

Example 1: Phonics and teaching literacy

The staff at one primary school undertook a project aimed at raising attainment in literacy by introducing the Letters and Sounds programme, based on the recommendations of the Rose Review. The programme involved all children up to and including Year 2, their teachers and support staff.

The programme focused on the teaching and application of word recognition skills. Some of the examples of the various activities used within the four parts of a daily lesson included:

Part 1: Revisit and review - for example 'Noisy Letters' where the children are given a GPC (Grapheme Phoneme Correspondence), or a word or sentence containing that GPC and asked to locate their partner with the same GPC, e.g. c representing /k/ as in cat or oy representing /oi/as in boy.

Part 2: Teach - for example using words with the focused GPCs in them, showing the children how to separate the phonemes through robotic speaking and adding sound buttons to each GPC, e.g. the word 'feet' would be robotically spoken as 'f-ee-t'.

Part 3: Practice - when children are encouraged to practice blending, reading, segmenting and spelling words with new GPCs. Activities might include children using magnetic letters to make words.

Part 4: Apply - children read or write words or sentences using high frequency words and words containing the new GPC. Activities involve GPC relays, where children get parts of words and put the correct GPC in the gaps within a specified time limit; silly sentences, where children are asked to read a sentence, see if it makes sense and then make a written or verbal response.

Daily 20 minute phonics sessions were introduced in school as part of the programme. All children were assessed and grouped in appropriate phases, often in mixed year groups, even across Key Stages, for phonics sessions.

The teachers observed increased attainment in personal, social and emotional development, improved motivation of SEN children and inclusion. They also noticed that children became more confident when writing and the standards in the Foundation Stage generally improved.

Reference

Miller, K., & Rainford, J. *Implementing the 'Letters and Sounds Programme' in the primary school.*

Example 2: Using thinking skills strategies in teaching literacy

A primary teacher set out to improve Year 1 children's comprehension of literacy texts and encourage wider

participation within the class through speaking and listening. She also wanted to explore the use of thinking skills strategies when teaching literacy.

During the first - pilot - phase of the project the teacher tried two thinking skills strategies. The first thinking skills strategy was Community of Enquiry, following the Philosophy for Children programme devised by Matthew Lipman. The children shared a selected text by having the book read aloud to them. Then they generated questions, arising from their understanding of that shared text. These questions were then used as a basis for a communal debate. Techniques such as evidence-based comments were encouraged, such as 'I agree with ... because...'

The second strategy was the odd one out strategy, which is based on the skill of categorisation and comparison. The children listened to a story and then selected three main characters. They then identified similarities and differences between the characters, first working in pairs and then sharing their ideas with the whole class ('think-pair-share').

After the pilot phase, the teacher decided to use the odd one out strategy as this had produced a wider range of participation. Ten sessions of odd one out thinking strategy were carried out and the results compared to standard literacy teaching, which does not employ thinking strategies, in the control class.

The teacher researcher found that:

- the children could learn how to take turns in a discussion and give feedback within a structured activity, but these skills needed to be taught explicitly, they were not simply picked up through the everyday activities in the classroom
- young children, aged 5 and 6, were able to compare and contrast characters in stories, identifying a range of characteristics through the odd one out strategy
- using adults to scribe for young children enabled them to articulate their thoughts explicitly.

The teacher summed up that the main benefit of using thinking strategies was that the children realised that discussing a story helps understand it better.

Reference

Anderson, B. *Can thinking skills offer a framework to support young children's comprehension in literacy?*

A multi-sensory approach to teaching mental arithmetic

We chose this case study because it shows how multi-sensory teaching activities developed mental arithmetic capability in children from nursery through KS1. It illustrates nicely an approach to numeracy teaching that combines number and space, an approach the research suggests is more effective than drill learning in developing neural pathways.

The study took place in an infant school on the south coast of England, serving a mixed catchment area with one in three pupils on the special needs register. In each class in Key Stage 1, six children were chosen. To give a balance of age and gender, in each group of six, there were three boys and three girls who were autumn, spring and summer born, otherwise the children were randomly chosen resulting in a spread of ability.

The focus was to construct multi-sensory teaching activities to develop mental arithmetic capability in children from Nursery through KS1. The teacher-researchers wanted children to develop an understanding of number that relates numbers to each other, relational understanding, which could be generalised to solve new problems.

Teaching and learning with the programme of activities

All classrooms and the nursery created a visually rich mathematics environment giving number a high profile so that children could see number being used. For example, drawers were numbered as well as labelled, storage pots were marked to show how many pencils they should contain. Teachers were encouraged to take

opportunities to use clocks and calendars and to show numbers in daily use in data handling sessions.

Visual structured apparatus was used throughout the school in a daily mathematics lesson. The activities were predominantly practical and multi-sensory because they involved the children seeing and feeling the structured images, whilst they were hearing and saying connected mathematical language. The tendency to move into formal symbols was resisted.

Teachers were encouraged to make connections between classroom teaching activity using the structured apparatus and the 'real world.' For example, if the children were working on addition, they would be invited to make up their own addition story to apply the number bonds they had learnt.

The programme of activities was carefully designed to scaffold children's learning so they were not expected to take on too many new ideas at a time. Each activity built on and extended previous learning. The activities were very simple, for example, to practise addition children might throw a number die and then feel in a 'feely bag' for two shapes that made that number.

How successful was the programme?
The Year Two children's scores in the National Tests at the end of KS2 showed dramatic improvement over previous cohorts' scores. They had developed a range of strategies to solve arithmetic problems, seeing numbers as related 'wholes' and generally did not solve arithmetic problems by counting. Many were able to apply their arithmetic to solve problems.

With very few exceptions children had developed confident and positive attitudes to maths. Children were drawn to the images and enjoyed working with them. Children benefited from frequent opportunities to count ever larger sets of objects. This gave them experience of higher numbers and understanding of the structure of the number system.

Frequent reminders to use mental imagery - phrases such as 'let your fingers be your eyes' if they were feeling for shapes in a feely bag and 'try to see the shapes in your mind's eye' when they were doing mental arithmetic - were found to be helpful.

Children were able to write arithmetic quickly and accurately and were only asked to record arithmetic when they had understood arithmetic symbols and knew addition and subtraction facts to ten in practical activities. It was found that it was also important that children developed pencil control before recording their number work so the writing process was not laborious for them. The early work on the multi-sensory approach to teaching mental arithmetic has been further developed and is now known as Numicon.

Reference:
Tacon, R., & Wing, A. (2004) *A multi-sensory approach to teaching mental arithmetic*. London: DFES

Developing children's skills at play

We have chosen this case study because it looks at the ways of engaging children in pretend play and suggests some effective ways of encouraging and organising young children's play to support their brain development. Play as a learner-centred activity was found to be important in terms of children developing their listening skills. In this particular study all of the children had learning difficulties and so particular attention was paid to the stages of developing skills at play, and how teachers might support this process.

Eight primary children aged between five or six years, took part in a programme which sought to teach pretend play. All the children were 'statemented' as having learning difficulties, and five were diagnosed as autistic. The children's understanding of speech ranged between 1 year 8 months and 3 years 5 months. The children with autism had difficulties in participating in classroom activities; for example they usually found sitting and watching the teacher for more than a few moments was difficult.

What is pretend play?

Pretend play is frequently seen in children as they approach two years of age and plays a prominent role in developing flexibility of thought for a number of years. Pretend play is first seen in functional play. In functional play, the child uses an object as it is meant to be used, for example, feeding a teddy bear with a plastic spoon or saying "bruuum" as a toy car is pushed along the table. If the child were to imagine that 'Teddy' had burnt his mouth on the plastic spoon or that the car had made a sudden reverse because of the frightening monster that appeared at the end of the table, it would be considered symbolic pretend play. If the child were to develop both a play scenario and a pretence as a pair, then this would be considered social pretend play. If the child were to develop a play scenario that he had not seen or used before, it would be considered spontaneous pretend play. Three-six year old children, developing normally, might combine all these aspects of pretend playing into a single but very complex play scenario.

Children with autism have an impairment or absence of pretend play. Although many children with autism do use some pretend play, this tends to be narrow, repetitive, functional play. Children with autism are noted for not developing spontaneous symbolic and social pretend play. However the mental abilities that are used within symbolic play are essential for effective learning and provide a foundation for later problem solving, generalising information, creative processes and understanding other people. These are central difficulties for children with autism and undermine most forms of subsequent learning.

What was the teaching process used in this study?
The author wanted to teach the children to use symbolic play acts, to watch the pretence of others, to take turns in pretend play games with other children and ultimately to create spontaneous play scenarios with other children in free-play settings.

Initially an adult modelled a number of play scenarios in front of the children who were sitting in a semi-circle. Children were then asked to use the same materials to imitate and extend the modelled play scenario. Others continued to watch this. Videos of these sessions were shown to the children and the most important aspects were highlighted. As the group became used to the approach, adult intervention was decreased and spontaneous, social and creative acts were encouraged.

Typical examples of modelled play scenarios would include:

- pretending to lose a balloon and undertaking a journey to recover it
- pretending to be asleep and waking to find that all your possessions have been stolen
- what can we make out of this old linen sheet?....a roof, umbrella, a hammock or perhaps a jellyfish!

Equipment used for these lessons involved a combination of representational toy materials and non-representational junk material.

The presentation of the pretend play scenarios was crucial to the success of the intervention. To maintain the children's interest in the play of others it was necessary to use exaggerated voice and gesture. This gave the sessions a sense of fun and pantomime. The children seemed to enjoy this approach and laughed at the use of melodrama. Instead of holding the attention for two or three minutes, the children were able to watch for up to 40 minutes.

What were the findings to the study?
Following the intervention, all the children with autism were able to use symbolic pretend play without being prompted.

Improvements in pretence:

- Some children were able to combine several different types of symbolic pretence within each episode of their play.
- The types of play used and the language that accompanied it were similar in the children that did and did not have autism.

Improvements in social play:

- All the children with autism were able to engage and initiate social pretend play after the intervention, more frequently, more purposefully, and using high quality play at the beginning of the programme.
- During the intervention there was a shift in the children with autism engaging their peers in play, rather then playing alone or using confrontational behaviour.

Reference:
Sherratt, D. (1999) *Teaching children with autism to use pretend play.*

The importance of creative curriculum for teenagers' learning and development

We chose this case study because it shows how bringing creative elements into the curriculum can help teenage pupils realise that learning can be pleasurable, which the review found to be an important contributor to motivation to learn.

The project was carried out in three stages. The first stage involved two teachers supported by two artists working with twenty Year 10 pupils; the second stage involved three teachers and three artists and working with 20 different Year 10 pupils; whilst the third stage involved 30 teachers and 24 artists working with 450 pupils. In each of the three stages, pupils and staff completed questionnaires evaluating the impact; photographs and videos were taken to monitor and document the project.

What did the project involve?
During the first stage of the project pupils worked with artists over a four week period to create a range of graffiti artworks based around the theme of future cities. Pupils used materials and techniques that were new to them. The artists worked with the young people individually and in groups to develop their language skills as well as their art skills.

Year 10 pupils, involved in the second stage, worked with the rap artists to devise French rap that was professionally mixed and recorded onto a CD. The young people had an opportunity to work with artists to create the lyrics, improve their understanding of the French language and their pronunciation.

Stage three was focused on language and literacy skills in geography and history. 450 pupils worked with artists, musicians, dancers, illustrators, fashion designers etc over a week to create a selection of artworks and performances which all had the common theme of either VE Day or Japan. Pupils took part in various arts activities that included kimono designing and modern fashion design, Japanese illustration, war make up, war-time and modern music and dance, etc. The aim of the creative workshops was to extend the pupils' understanding of Japan and VE Day as well as improving the pupils' language skills around these subjects.

What were the pupil outcomes?
In addition to the improved language, literacy and subject skills, the researchers recorded positive impact on:

a) motivation. Teachers noted that pupils who had previously been eager to run out of the door when the bell rang volunteered to stay after school for an extra two hours, and even then wanted to continue working and had to be told to go home. The attendance for both the Graffiti art project and French rap project was 100%. The following quotes reflect how pupils found the projects.

"I really enjoyed this week because it made me realise that learning can be fun."

"My best bit was the dancing because everyone from all years were clapping and cheering for one another and it made you feel good"

"I liked learning about Japan and VE day in this way because you learn more than you do if you just look at books."

b) pupils' confidence and self-esteem. For example, a girl with cerebral palsy showcased her spray painting skills in front of a large audience in Manchester city centre. Teachers believed that the project helped her develop independence and increased her confidence in her art lessons.

c) pupils' awareness of the opportunities that are available to them post 16. The artists discussed career opportunities with the pupils and indicated to the pupils what jobs were available in the art world.

Reference:
Furey, B. (2006) Can creative projects improve the language and literacy skills of our pupils?

Ways physical exercise can promote children's learning and development

This neuroscience study found that physical exercise was important in helping children regulate their emotions and so aid their learning. We chose this case study because it shows how beneficial a special programme of physical exercise can be for various aspects of a child's development. The teacher researchers introduced a daily exercise programme and set out to explore its impacts on children's reading.

The study was carried out in two primary schools over a period of nine months. It involved four teachers, 18 Year 3 children (half of them being in the control group) and their parents. The children were selected at the screening stage which assessed their balance and co-ordination. The testing also included visual tracking and sound discrimination.

The control group was from a school in the same area, with a similar catchment and academic profile (based on SATS results). This school was offered the option of introducing the exercise programme the following year.

Why was the exercise programme introduced?
The researchers were looking for new strategies for supporting underachieving children. They wanted to build on a pre-existing school programme Fit for Learning, which linked physical exercise with learning, in the light of the research by Sally Goddard and Peter Blythe from the Institute of Neuro-Physiological Psychology (INPP). The INPP has devised a daily programme of exercises which can be carried out in a school setting. The programme aimed at inhibiting the primitive reflexes which are necessary for early survival but can interfere with later development and learning, for example balance and co-ordination, auditory and visual processing, hand-eye co-ordination. Primitive reflexes can sometimes have a profound impact on child development and lead to learning difficulties, behavioural problems and coordination difficulties.

The teachers designed the project to find out if the exercise programme had an impact upon reading accuracy and comprehension.

How was the exercise programme introduced?
Teachers participating in the project were trained by one of INPP researchers to implement the exercise programme.

The children were given blocks of exercises (six blocks of four exercises) from October to July. They did the exercises every morning for 15 minutes. The exercises were based upon infant movement patterns, following the normal developmental sequence. They ranged from simple head lifts to crawling and use all parts of the body. The movements were performed in a smooth and controlled manner.

The exercise programme and its benefits were explained to the parents of the children involved. They also received a copy of the exercises and were encouraged to help the children do the exercises at home.

What were the results?

The teachers found that:

- the average increase in reading accuracy and comprehension for children on the daily exercise programme was 14 months, while the children in the control group made eight months progress in reading accuracy and four months in reading comprehension during the same period
- children's gross and fine motor skills had developed
- the programme appeared to support the children personally and socially
- children's concentration, self-esteem and self-confidence had also improved.

Commenting on improvements in concentration and self-esteem, teachers noted in particular:

"The children's behaviour and work has noticeably improved over the year."

"It is much easier to manage the class. The lively children are more focused and capable of completing work within lessons."

The children enjoyed the programme and said how much it had helped them personally and socially. The following are examples of comments from children:

"I have more self confidence. I have improved my co-ordination, catching skills and handwriting. I have also learnt to ride my bike."

"My work has got faster. I find throwing and catching easier."

"My balance is getting better. I can also write and colour more neatly."

"The exercises have helped me in Maths. I am now a super genius. I am also faster at doing things at home."

"I have more control in the classroom. I can focus on my work."

Reference:
Preedy, P., Wolinski, R., & O'Donovan, C. (2004) *Exercise for Learning*.
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Further reading

What else might I enjoy reading?

Effective early literacy teaching in the first years of school

Effective teachers of numeracy

Strategies for supporting dyslexic pupils

Teaching phonics effectively

Vygotsky's ideas on teaching and learning

Where can I find out more online?

Fostering creative thinking: co-constructed insights from neuroscience and education Howard-Jones, P. (2008)
www.bris.ac.uk/education/people/academicStaff/edpahj/publications/

Neuroscience and Education: Issues and Opportunities. A Commentary by the Teaching and Learning Research Programme. Howard-Jones, P. (2006)
www.bris.ac.uk/education/people/academicStaff/edpahj/publications/

Perceptions of the role of neuroscience in education Howard-Jones, P., Pickering, S. & Diack, A. (2007)
www.bris.ac.uk/education/people/academicStaff/edpahj/publications/

Rose Review: Changes to the teaching of early reading
www.qca.org.uk/qca_13898.aspx

Effects of a Cognitive Acceleration Programme on Year 1 pupils (Updated)
www.standards.dfes.gov.uk/research/themes/thinkingskills/6553/

Literacy Instruction, SES (socio-economic status) and Word-reading Achievement in English-Language Learners and Children with English as a First Language: A Longitudinal Study.
www.standards.dfes.gov.uk/research/themes/English/literacyinstruction/

Pedagogical Dilemmas in the National Literacy Strategy: primary teachers' perceptions, reflections and classroom behaviour
www.standards.dfes.gov.uk/research/themes/English/TueOct151710182002/

Praising the person or what they do - do different types of praise have different effects on pupils' motivation
www.standards.dfes.gov.uk/research/themes/Motivation/praise/

The long-term contribution of early childhood education to children's performance.
www.standards.dfes.gov.uk/research/themes/early_years/WedMar241201102004/

Synthetic phonics website
www.synthetic-phonics.com
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Appraisal

Robustness

This literature review is an output from the project 'Learning Sciences and Brain Research' which was launched by the OECD's Centre for Educational Research and Innovation (CERI) in 1999. The project was set up to encourage collaboration between learning sciences and brain research on the one hand, and researchers and policy makers on the other hand. It aimed to help teachers, policy makers and other education professionals understand how the brain learns and how learning can be fostered through nurture, training and adapted teaching processes and practices.

The content of the literature was gathered through three trans-disciplinary networks set up in 2002 to focus on literacy, numeracy and lifelong learning. In 2004, a fourth activity area on emotions and learning was set up

in parallel to the three networks.

The review has two parts. The first and larger part is entitled "The Learning Brain" and is based on a wide range of research and other literature identified during the project. Much of the literature focuses on scientific and clinical studies, such as those reporting on imaging technologies that offer the opportunity for observation of the working brain, and provide insights into perceptual, cognitive, and emotional activities relevant to education. The second part of the review is structured on three articles about the "learning brain" in early childhood, adolescence and adulthood, respectively. These were written, in each case, by three experts.

The review methods also involved trans-disciplinary meetings of participants from the United States, Spain, Japan, Finland, the United Kingdom, France, Germany and Denmark.

Relevance

Many teachers are fascinated by brain science and its application to learning and it has recently been the subject of a number of media articles. But teachers are not always able to access bona fide research (as distinct from the quick fixes and populist notions that abound), a need which this study aimed to meet. Whilst the review authors acknowledged that their findings cannot generate a universal, prescriptive pedagogical approach they can inform planning for teaching and learning. The review authors suggest neuroscience is already making an important educational contribution: providing new perspectives on longstanding challenges, raising new issues, or reinforcing existing practices.

Applicability

This literature review shows how neuroscientific research is contributing to education, for example:

- lifelong learning - one of the most powerful set of findings relates to the brain's 'plasticity' - the ability to adapt and grow and to also prune itself. The demands made on the individual and on his/her learning are key to plasticity - the more you learn, the more you can learn
- addressing dyslexia and dyscalculia - neuroscience shows that a balanced approach to literacy instruction may be the most effective and that mathematics instruction should build upon students' existing informal understandings
- assessment - many conventional forms of assessment, where success can be boosted by cramming, have been shown to be 'brain unfriendly' with low retained comprehension, and
- development and learning in early childhood and adolescence.

The review also outlines and refutes a number of "neuromyths" including ideas about left-side and right-side thinking, influencing developments in infancy, gender differences, and multilingualism, which are not underpinned by science.

Writing

It is quite a long review although it is well-sign-posted with chapters on the different types of learning activity mentioned above. The language is accessible for the most part with glossaries of key words in the text. Despite its length, the writing is lively and the inclusion of quotes from a number of prominent thinkers adds interest. A basic knowledge of biology, as it relates to the brain and nervous system, is helpful, but not essential.

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