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The Learning Sciences and the Core Content Framework for Initial Teacher Training

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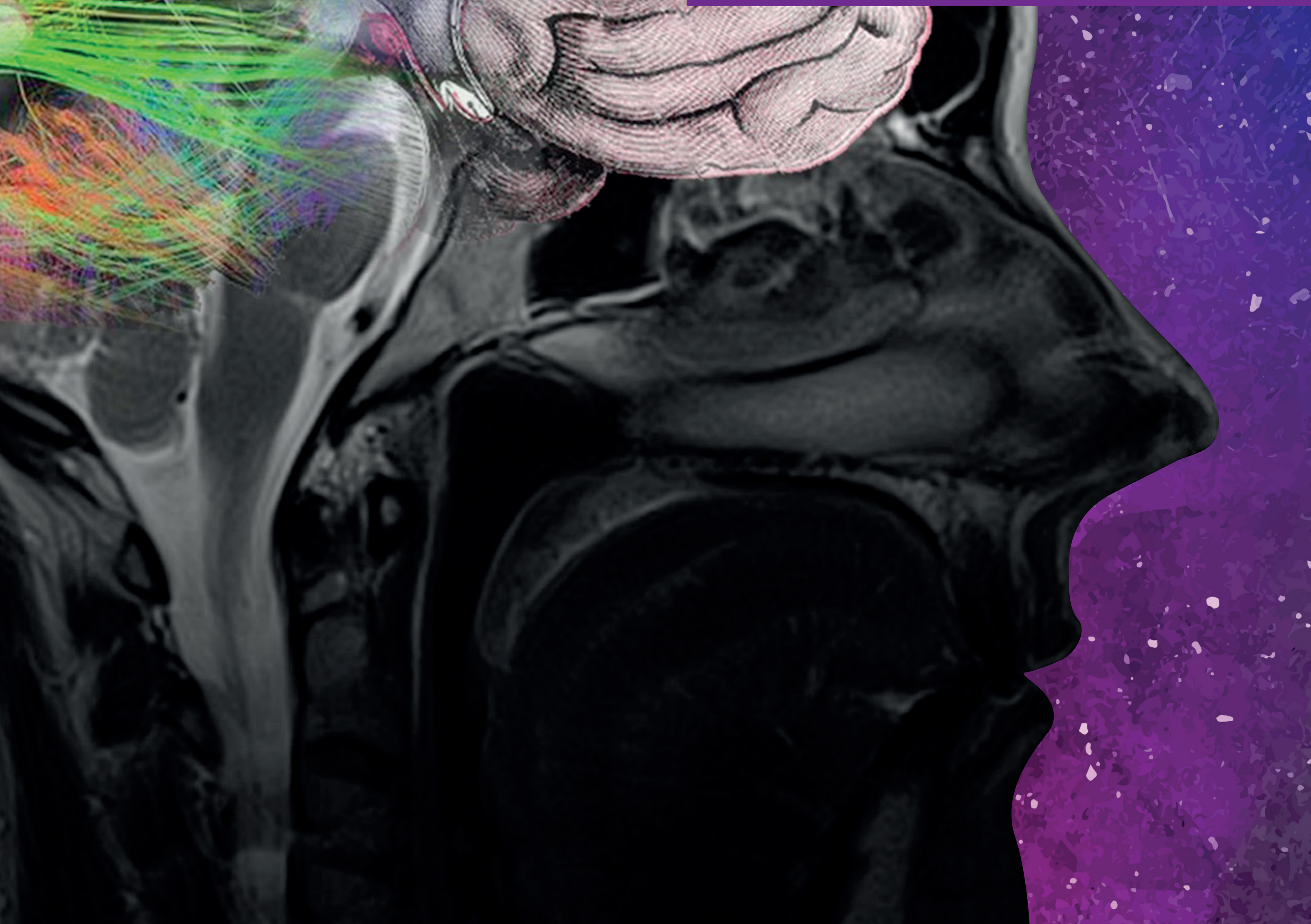

Introduction

This document is an outcome of the project The Learning Sciences in Initial Teacher Education based at Bath Spa University (2019-2020) and funded by the Wellcome Trust. Our intention is to support teacher educators in responding to the 2019 Core Content Framework for Initial Teacher Training by exploring the underpinning research from the 'Learning Sciences'.

We have identified 28 statements in the 'Learn that' column of the Core Content Framework for Initial Teacher Training (CCF) that could be understood using a 'Science of Learning' lens. For each of those statements there is an interpretation of it, often identifying cognitive psychology we think the statement may be derived from. We also explore connections with relevant CCF 'Learn how to' statements, showing these in italics. We provide links to external sources such as video clips which we think teacher educators will find helpful in making sense of these underlying ideas.

Then, under the heading 'Going Further', we have expanded the interpretation of the statement, making further links to psychology, neuroscience or educational literature to locate the statement within a broader viewpoint, as a step in the direction of drawing together the 'learning sciences'. In doing so we are not seeking to replace educational perspectives, but to expand possibilities for understanding learning. This is inevitably a limited selection of ideas and we welcome feedback on the document for future versions (email: k.mcmahon@bathspa.ac.uk).

This resource is aimed at a teacher educator audience (rather than trainee teachers). It could be read as a whole, or by dipping into sections.

This document is the outcome of dialogues within the project team that consisted of: tutors on initial teacher education courses, education researchers, a social neuropsychologist, a biological psychologist, and specialists in educational neuroscience.

Table showing aspects of the Core Content Framework for Initial Teacher Training that we have examined through a 'Learning Sciences' lens.

Click on the code number for a hyperlink to that section.

Code	Core Content Framework LEARN THAT:
	High Expectations (Standard 1 – 'Set high expectations')
CCF 1.1	1. Teachers have the ability to affect and improve the wellbeing, motivation and behaviour of their pupils and this in turn affects learning
CCF 1.2	2. Teachers are key role models, who can influence the attitudes, values and behaviours of their pupils.
CCF 1.3	3. Teacher expectations can affect pupil outcomes; setting goals that challenge and stretch pupils is essential.
CCF 1.4	4. Setting clear expectations can help communicate shared values that improve classroom and school culture.
CCF 1.5	5. A culture of mutual trust and respect supports effective relationships.
CCF 1.6	6. High-quality teaching has a long-term positive effect on pupils' life chances, particularly for children from disadvantaged backgrounds.
	How Pupils Learn (Standard 2 – 'Promote good progress')
CCF 2.1	1. Learning involves a lasting change in pupils' capabilities or understanding.
CCF 2.2	2. Prior knowledge plays an important role in how pupils learn; committing some key facts to their long-term memory is likely to help pupils learn more complex ideas.
CCF 2.3	3. An important factor in learning is memory, which can be thought of as comprising two elements: working memory and long-term memory.
CCF 2.4	4. Working memory is where information that is being actively processed is held, but its capacity is limited and can be overloaded.
CCF 2.5	5. Long-term memory can be considered as a store of knowledge that changes as pupils learn by integrating new ideas with existing knowledge.
CCF 2.6	6. Where prior knowledge is weak, pupils are more likely to develop misconceptions, particularly if new ideas are introduced too quickly.
CCF 2.7	7. Regular purposeful practice of what has previously been taught can help consolidate material and help pupils remember what they have learned.
CCF 2.8	8. Requiring pupils to retrieve information from memory, and spacing practice so that pupils revisit ideas after a gap are also likely to strengthen recall.
CCF 2.9	9. Worked examples that take pupils through each step of a new process are also likely to support pupils to learn.

Code	Core Content Framework LEARN THAT:
	Subject and Curriculum (Standard 3 – 'Demonstrate good subject and curriculum knowledge')
CCF 3.1	1. A school's curriculum enables it to set out its vision for the knowledge, skills and values that its pupils will learn, encompassing the national curriculum within a coherent wider vision for successful learning.
CCF 3.2	2. Secure subject knowledge helps teachers to motivate pupils and teach effectively.
CCF 3.3	3. Ensuring pupils master foundational concepts and knowledge before moving on is likely to build pupils' confidence and help them succeed.
CCF 3.4	4. Anticipating common misconceptions within particular subjects is also an important aspect of curricular knowledge; working closely with colleagues to develop an understanding of likely misconceptions is valuable.
CCF 3.5	5. Explicitly teaching pupils the knowledge and skills they need to succeed within particular subject areas is beneficial.
CCF 3.6	6. In order for pupils to think critically, they must have a secure understanding of knowledge within the subject area they are being asked to think critically about.
CCF 3.7	7. In all subject areas, pupils learn new ideas by linking those ideas to existing knowledge, organising this knowledge into increasingly complex mental models (or "schemata"); carefully sequencing teaching to facilitate this process is important.
CCF 3.8	8. Pupils are likely to struggle to transfer what has been learnt in one discipline to a new or unfamiliar context.
CCF 3.9	9. To access the curriculum, early literacy provides fundamental knowledge; reading comprises two elements: word reading and language comprehension; systematic synthetic phonics is the most effective approach for teaching pupils to decode.
CCF 3.10	10. Every teacher can improve pupils' literacy, including by explicitly teaching reading, writing and oral language skills specific to individual disciplines.
	Classroom Practice (Standard 4 – 'Plan and teach well structured lessons')
CCF 4.1	1. Effective teaching can transform pupils' knowledge, capabilities and beliefs about learning.
CCF 4.2	2. Effective teachers introduce new material in steps, explicitly linking new ideas to what has been previously studied and learned.
CCF 4.3	3. Modelling helps pupils understand new processes and ideas; good models make abstract ideas concrete and accessible.
CCF 4.4	4. Guides, scaffolds and worked examples can help pupils apply new ideas, but should be gradually removed as pupil expertise increases.
CCF 4.5	5. Explicitly teaching pupils metacognitive strategies linked to subject knowledge, including how to plan, monitor and evaluate, supports independence and academic success.
CCF 4.6	6. Questioning is an essential tool for teachers; questions can be used for many purposes, including to check pupils' prior knowledge, assess understanding and break down problems.

Code	Core Content Framework LEARN THAT:
CCF 4.7	7. High-quality classroom talk can support pupils to articulate key ideas, consolidate understanding and extend their vocabulary.
CCF 4.8	8. Practice is an integral part of effective teaching; ensuring pupils have repeated opportunities to practise, with appropriate guidance and support, increases success.
CCF 4.9	9. Paired and group activities can increase pupil success, but to work together effectively pupils need guidance, support and practice.
CCF 4.10	10. How pupils are grouped is also important; care should be taken to monitor the impact of groupings on pupil attainment, behaviour and motivation.
CCF 4.11	11. Homework can improve pupil outcomes, particularly for older pupils, but it is likely that the quality of homework and its relevance to main class teaching is more important than the amount set.
	Adaptive Teaching (Standard 5 – 'Adapt teaching')
CCF 5.1	1. Pupils are likely to learn at different rates and to require different levels and types of support from teachers to succeed.
CCF 5.2	2. Seeking to understand pupils' differences, including their different levels of prior knowledge and potential barriers to learning, is an essential part of teaching.
CCF 5.3	3. Adapting teaching in a responsive way, including by providing targeted support to pupils who are struggling, is likely to increase pupil success.
CCF 5.4	4. Adaptive teaching is less likely to be valuable if it causes the teacher to artificially create distinct tasks for different groups of pupils or to set lower expectations for particular pupils.
CCF 5.5	5. Flexibly grouping pupils within a class to provide more tailored support can be effective, but care should be taken to monitor its impact on engagement and motivation, particularly for low attaining pupils.
CCF 5.6	6. There is a common misconception that pupils have distinct and identifiable learning styles. This is not supported by evidence and attempting to tailor lessons to learning styles is unlikely to be beneficial.
CCF 5.7	7. Pupils with special educational needs or disabilities are likely to require additional or adapted support; working closely with colleagues, families and pupils to understand barriers and identify effective strategies is essential.
	Assessment (Standard 6 – 'Make accurate and productive use of assessment')
CCF 6.1	1. Effective assessment is critical to teaching because it provides teachers with information about pupils' understanding and needs.
CCF 6.2	2. Good assessment helps teachers avoid being over-influenced by potentially misleading factors, such as how busy pupils appear.
CCF 6.3	3. Before using any assessment, teachers should be clear about the decision it will be used to support and be able to justify its use.
CCF 6.4	4. To be of value, teachers use information from assessments to inform the decisions they make; in turn, pupils must be able to act on feedback for it to have an effect.

Code	Core Content Framework LEARN THAT:
CCF 6.5	5. High-quality feedback can be written or verbal; it is likely to be accurate and clear, encourage further effort, and provide specific guidance on how to improve.
CCF 6.6	6. Over time, feedback should support pupils to monitor and regulate their own learning.
CCF 6.7	7. Working with colleagues to identify efficient approaches to assessment is important; assessment can become onerous and have a disproportionate impact on workload.
	Managing Behaviour (Standard 7 – 'Manage behaviour effectively')
CCF 7.1	1. Establishing and reinforcing routines, including through positive reinforcement, can help create an effective learning environment.
CCF 7.2	2. A predictable and secure environment benefits all pupils, but is particularly valuable for pupils with special educational needs.
CCF 7.3	3. The ability to self-regulate one's emotions affects pupils' ability to learn, success in school and future lives.
CCF 7.4	4. Teachers can influence pupils' resilience and beliefs about their ability to succeed, by ensuring all pupils have the opportunity to experience meaningful success.
CCF 7.5	5. Building effective relationships is easier when pupils believe that their feelings will be considered and understood.
CCF 7.6	6. Pupils are motivated by intrinsic factors (related to their identity and values) and extrinsic factors (related to reward).
CCF 7.7	7. Pupils' investment in learning is also driven by their prior experiences and perceptions of success and failure.
	Professional Behaviours (Standard 8 – 'Fulfil wider professional responsibilities')
CCF 8.1	1. Effective professional development is likely to be sustained over time, involve expert support or coaching and opportunities for collaboration.
CCF 8.2	2. Reflective practice, supported by feedback from and observation of experienced colleagues, professional debate, and learning from educational research, is also likely to support improvement.
CCF 8.3	3. Teachers can make valuable contributions to the wider life of the school in a broad range of ways, including by supporting and developing effective professional relationships with colleagues.
CCF 8.4	4. Building effective relationships with parents, carers and families can improve pupils' motivation, behaviour and academic success
CCF 8.5	5. Teaching assistants (TAs) can support pupils more effectively when they are prepared for lessons by teachers, and when TAs supplement rather than replace support from teachers.
CCF 8.6	6. SENCOs, pastoral leaders, careers advisors and other specialist colleagues also have valuable expertise and can ensure that appropriate support is in place for pupils.
CCF 8.7	7. Engaging in high-quality professional development can help teachers improve.

CCF 1.1

Teachers have the ability to affect and improve the wellbeing, motivation and behaviour of their pupils and this in turn affects learning.

Interpreting the Statement

This is a complex statement - but the key message from a science of learning perspective is that emotions and cognition are not separate but intertwined.

Children have to learn to govern executive functions - the ability to work fluidly (working memory), how to inhibit inappropriate behaviour, and how to regulate their motivation and emotions (Nigg et al., 2017). Children have to learn how to be motivated and where to attend, and one way of achieving this is by gradually increasing rewards for learning and/or good behaviour. The best thing teachers can do to achieve the aim of this statement is be consistent throughout the time a child is with them. Demonstrating consistency and making rewards tangible to a child gives them the executive function a child requires to thrive in their lifetimes. More than this, executive functioning helps children learn how to learn, and to deal with emotions such as frustration (Blair, 2016). A teacher's consistency may do much to help every child, but especially help those with developmental delays such as ADHD or ASD. Never assume a child is getting consistent parental behaviour. As the origin of most mental health problems is tied to the 0-20 age range, the value of developing strong executive functioning in early life is profound.

Attention is a disputed concept in psychology, but can be considered to be focus on a specific stimulus for a set time. Attention is a limited resource - we can't easily focus on more than one thing at a time. So one of the roles of a teacher is to help children to manage their attention to sustain engagement. Humans are complicated - what motivates one child to sustain attention might not be the same as motivates another. Young children may not yet understand motivation and what motivates them. Teachers need to foster and implement rewards to help them do so. Developing the brain's built-in motivational processes (Di Domenico and Ryan, 2017) is something which helps a child's lifelong learning.

Planning a curriculum that is engaging and well-paced for a particular class supports attention and motivation. The CCF says that belief in the potential of all pupils is communicated by setting 'tasks that stretch pupils, but which are achievable, within a challenging curriculum' and that trainees should have mentoring to help them learn how to do this.

Motivation is developed by using consistent rewards over a period of time. Motivational skills help every child, including those on the autistic spectrum (Prata et al., 2018). Learning more about a particular age group, class and individual children and what motivates them could be achieved through trainees learning how to 'Seek[ing] opportunities to engage parents and carers in the education of their children (e.g. proactively highlighting successes) with support from expert colleagues to understand how this engagement changes depending on the age and development stage of the pupil.'

External links:

Paul Howard-Jones: Engagement (12 mins)
The Learning Scientists: Situational vs. Well-Developed Interest (11 mins)
Antonio Damasio The quest to understand consciousness (18 mins)
Daniel Kahneman The Riddle of Experience vs memory (20 mins)
Michael Hobbiss - Attention and the Classroom (podcast) (23 mins)

Going Further

Neuroscience supports the ideas that emotions and cognition are not separate. There are different parts of the brain that are often associated with emotion, (such as the hypothalamus, hippocampus, and amygdala) and other parts with cognition (typically the frontal cortex). However, rather than viewing the brain as having separate compartments, it is increasingly understood as a complex integrated system. The hippocampus is also associated with the formation of memories and it certainly plays a key role in this function. Our memory is most influenced by the emotional-charged events (e.g. Immordino-yang, 2015) and an interesting finding of cognitive psychology is that our memory is most influenced by the last part of an experience.

Parts of the brain associated with emotions should not be considered as evolutionarily primitive (see summary in Howard-Jones, 2018). The wonderfully titled article 'Your brain is not an onion with a tiny reptile inside' (Cesario et al., 2020) explains that this misconception is often sustained by textbooks. Emotions are not unhelpful problems to be crushed by the rational forebrain, but are essential in directing motivation and sustaining attention and also for decision making (Damasio, 1994). Neuroscientist Damasio also goes on to propose that feelings are the basis of consciousness (Damasio, 2021).

Teachers, especially primary teachers, share the time and space of the classroom with pupils; to some extent they share the experience and they are certainly part of it. But what memories do people have of the experience? Nobel prize winning psychologist Daniel Kahneman suggests that we have two selves - an experiencing self and a remembering self. Perhaps when asked to think about learning as memory, we might consider how to reconcile the value of the experience itself and of the trace (memory) it leaves. Educators often have a negative reaction to the idea of learning as memory. Some of this is about associating the word memory with memorization that is rote learning without meaning. But perhaps another part of educators' concern, a part that is more difficult to articulate, might be about the emphasis on creating the self that remembers, because it undervalues the time spent as the self that experiences.

Questions for practice

How can we talk about emotion as deeply interconnected with thinking (not presenting emotions as a problem)?

How might we focus on wellbeing in the present moment as well as to support learning outcomes?

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CCF 1.2

Teachers are key role models, who can influence the attitudes, values and behaviours of their pupils.

Interpreting the Statement

To a psychologist all learning is active - you have to give something attention in order to learn it (there is no such thing as 'passive learning'). But there is 'implicit learning' - learning we don't try to do - and most cultural norms are learned this way. This means that we all have biases, they could be called cognitive biases - such as sexism, racism, and ageism.

Teachers affect the implicit learning of the children in their class through the values they express and the language they use. For example, behavioural studies have shown the transfer of anxiety from teacher to student (Beilock, Gunderson, Ramirez & Levine, 2010) and the connection between positive teacher attitudes and improved academic achievement (Ker, 2016). The CCF says trainees should 'Learn how to' use 'intentional and consistent language that promotes challenge and aspiration.'

External links

The Learning Scientists Active vs. Passive vs. Implicit Learning (7 mins)
Kahneman on thinking fast and slow and cognitive biases (1 hour)

Going Further

Social neuropsychology may help offer insights into how we create cultures in schools and classrooms. It provides material and behavioural evidence that could illuminate the Vygotskian theory that humans create a shared 'intermental plane' in which ideas, knowledge and attitudes are created and held between people and then individuals 'internalize' cultural ideas into their own 'intramental plane' (Vygotsky, 1978).

One set of theories is around the role of mirror neurons. Mirror neurons were originally discovered in monkeys, specifically macaques (Rizolatti & Craighero, 2004). Mirror neurons are a particular type of neuron (brain cell) that activate both when an action is taken (e.g a macaque breaking a peanut) and when an action is observed in another individual (e.g. seeing another macaque break a peanut). They are believed to be important in understanding the actions of others and learning by imitation. Although some neurophysiological and brain-imaging experiments claim to indirectly prove the existence of a mirror-neuron system in humans, there is a lack of direct evidence (Rizolatti & Craighero, 2004). Although no research has been done on mirror neurons in human children, the use of mirror neurons to understand others is thought to be acquired through socialization - it is learned within a culture rather than being innate (see Bonn, 2019).

Cognitive psychologists have identified many cognitive biases, for example the Gambler's Fallacy, the Present Bias, and Confirmation Bias. The Gambler's Fallacy is the tendency we have to think that the probability of something happening in the future is affected by past events (e.g. 'if I flip a coin and it lands on heads four times, the next time it will definitely land on tails'). The Present Bias is the tendency to over-value rewards that occur nearer to the present - we settle for smaller rewards sooner, than to wait for larger rewards in the future, when presented with a trade-off situation. We might also be aware of the 'availability heuristic' - we tend to accept what we see or hear frequently. All of these biases, and more, can have an impact in the classroom. Teachers have to act too fast for every decision to be made carefully and thoughtfully (Korthagen, 2014); they often act on intuition using 'fast thinking' rather than slow, deliberate, effortful thought (Kahneman, 2011) and so inevitably draw on their biases. All humans do this. Confirmation bias means that when reading this text you are more likely to focus on evidence that supports your existing ideas, than on any points that contradict or challenge them.

Questions for Practice

How can teachers' language influence the attitudes, values and behaviours of learners?

How might scientific perspectives help illuminate social processes of learning?

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CCF 1.5

A culture of mutual trust and respect supports effective relationships.

Interpreting the Statement

How engaged and successful pupils are seems to be tied up with their sense of belonging, as found in a recent meta-analysis looking at research between 2000 and 2018 (Koerpershoek et al., 2019). A positive sense of school belonging has been found to have a positive impact on student motivation, self-esteem, classroom behaviour and a small but significant correlation with academic achievement. This sense of belonging can be fostered by developing good relationships, and appears to be built when pupils feel individually and personally supported, accepted, respected and included. There is evidence that the relationships between students and teachers, and students and their peers, were important. Hence the emphasis on building effective relationships across the whole school.

Making a link with one 'How to' statement was quite difficult here. Perhaps 'Creating a positive environment where making mistakes and learning from them and the need for effort and perseverance are part of the daily routine' is the best match and for Initial Teacher Education (ITE) this is about ensuring that schools and ITE institutions in which trainees are learning have a supportive culture and ethos for pupils and trainee teachers.

External Links

Sense of belonging Columbia MOOC (7 mins)

Going Further

Much educational research is underpinned sociocultural theory in which cultural norms and values are internalized (Vygotsky, 1978) or appropriated (Rogoff, 1990) when a person participates in a social group. The CCF document offers Bandura (1986) as a reference to the social basis of learning. The emphasis on culture and mutuality in this statement also resonates with the first three of the five principles of dialogic teaching: that is it collective, reciprocal and supportive (Alexander, 2017).

Another reference cited in the CCF is Zins et al. (2007). They reviewed research into the impact of interventions in the form of social emotional learning programs (in the USA) and noted the benefits as: building skills linked to cognitive development, encouraging student focus and motivation, improving relationships between students and teachers, creating school-family partnerships to help students achieve, and increasing student confidence and success. This book uses the term "social, emotional, and academic learning," or "SEAL" that became familiar in many primary schools.

Questions for Practice

How might the developing understanding of interactions between different brain networks (emotions and motivation, social cognition, cognitive control, memory and language) help teachers to get better at establishing cultures of mutual trust?

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CCF 2.1

Learning involves a lasting change in pupils' capabilities or understanding.

Interpreting the Statement

We can distinguish between implicit learning (like the way we pick up social norms, or early language learning) and explicit learning. Both kinds of learning will be going on in our classrooms, but this statement is referring to the kind of formal, explicit learning we aim for in schools, which is not the same as the implicit, informal learning that we naturally do all the time. One definition is that 'learning is any relatively permanent change in behavioural potential which accompanies experience…' (Kimble 1961). Some learning is visible but other learning is invisible and it can be a challenge to try and see how our pupils' learning is progressing. For learning to have occurred the change needs to be more than just a fleeting change, it needs to be a sustained change. There is no direct correspondence between this overarching idea and any one 'Learn how to' statement.

External Links

Memory and Learning MOOC (7 minutes)
The Learning Scientists Forgetting (7 minutes)
Paul Howard Jones Neurons and Learning Brain (3 minutes)

Going Further

Changes in capabilities could be physical (balancing, catching a ball, the fine motor control for handwriting) or cognitive - being able to do a task they couldn't before. This kind of learning can be seen in behaviour. A change in understanding is harder to describe and conceive - it involves the learner having a sense of something being more meaningful in that it has connections with ideas that were not previously connected. The depth of understanding could be viewed as the extent to which ideas are held in relation to other ideas (which links with statement CCF3.7). Neuroscience supports a constructivist view of learning and knowledge by showing how connections between brain cells are changed by experiences.

Our first physical experiences are the basis for all subsequent concept building. Movement and touch create experiences in the interaction between our bodies and the environment. Sometimes called 'embodiment' this physical, sensory interaction with the environment is a vital part of young children's learning. In this way, neuroscience supports the value of hands-on learning and active participation in our environments, much as Piaget (1952) argued. We 'grow our own brains' - all the action we take in our environment leads to changes in our brains. The constant changing of the brain is called neuroplasticity.

If learning is defined as relatively permanent changes, the brain has no need for neuroplasticity. You would learn until the store was full. Yet the brain is very plastic. Any change in the experience of the learner is represented by changes in the relationships between neural connections (Hebb, 1950) regardless of whether that change is good or bad. New ideas are grafted onto previous knowledge. Change in experiences or of environment will change the relationships between neurons somewhere in the brain. If those changes are to be 'relatively permanent' then that learning event needs repetition in either approximately the same environment or in a completely different one.

We know that retrieval from memory is enhanced when a test is given in the same environment as when the material was learned or reinforced in a new environment (Anderson and Schooler, 1991). Learning is intractably linked to the place of learning. Memory for place is thought to be a major function of the hippocampus (O'Keefe and Dostrovsky, 1971; Epstein et al, 2017), which suggests that the classroom piggybacks onto a feature evolved to help us to remember where good or bad resources are located. This extends to the things a child is learning - if their experiences are positive then good learning occurs (Kervinen et al., 2020). If negative, then the child learns that school is a bad place (Roth and Lee 2007). Plasticity ensures that moving a child to a new location will change their relationship with learning. Long term learning refers to anchoring facts and experiences. This is achieved by reinforcing the things children already know, and then extending the knowledge base. Every time a teacher goes over that material in class or if that message is given consistently within the child's life, those facts/experiences become more tangible in the brain. Conversely, if someone gives a child a different message (say learning another way of multiplying numbers), plasticity means that the first message becomes weaker. The brain treats facts and experiences in the same way if they are to be remembered. It is the salience of the information that determines if the brain is to change.

As educators we tend to label change in connections between brain cells as 'learning' when they are connections we see as desirable. When experiences lead to links we see as undesirable we might label the change as 'developing misconceptions', or 'bad habits' or even 'trauma' or 'emotional damage'.

Questions for Practice

In what ways might a physical view of learning as changes in the connections between brain cells impact on our understanding of learning?

How does the concept of neuroplasticity relate to constructivist views of learning?

How might knowing about neuroplasticity be helpful for children?

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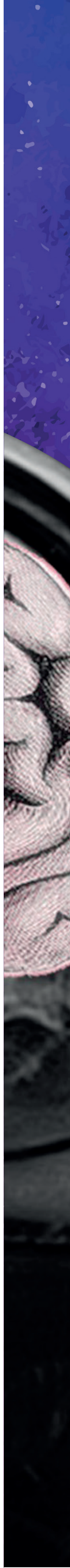

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CCF 2.2

Prior knowledge plays an important role in how pupils learn; committing some key facts to their long-term memory is likely to help pupils learn more complex ideas.

Interpreting the Statement

All new learning connects in some way with what the pupil already knows, so that what is already inside the learner will have a profound impact on the new learning that can be achieved. Until new learning is consolidated it is difficult to apply and vulnerable to loss (Howard-Jones, 2018). Willingham (2008, p.18) explains that: 'memories are formed as the residue of thought'. Luckily, not every thought you have leaves a trace; memory is the trace of salient thought. Thought becomes salient through being marked as important or significant and/or by repeated rehearsal.

In order to be processed effectively, new knowledge needs to be used in some way, such as by applying it in different contexts (Howard-Jones, 2018). This might be accelerated through low-stakes testing, requiring pupils to recall information and enabling it to be stored in the brain in different ways (Howard-Jones, 2018). As knowledge becomes easier to recall and use, learning becomes automatic, which frees up capacity for new learning to take place.

Prior knowledge will include feelings, skills and beliefs as well as factual knowledge. It is the active interaction between long term memory (prior knowledge) and the new information that is important for new learning. The CCF refers to avoiding overloading working memory by receiving clear, consistent and effective mentoring in how to take into account pupils' prior knowledge when planning how much new information to introduce.

External Links

The Learning Scientists - the importance of prior knowledge (12 mins)
Connecting Prior Knowledge | Memory and Learning MOOC (10 mins)
Neurons and Learning Paul Howard-Jones (3 mins)

Going Further

Since the connection of new learning to prior knowledge involves the prefrontal regions of the brain which are still developing in children (Brod, Werkle-Bergner & Shing, 2013), pupils may need support to activate available prior knowledge depending on their developmental status (Shing & Brod, 2016). It is worth noting that the successful functioning of this area of the brain can be impacted by high levels of stress, fearfulness and anxiety (Howard-Jones, 2018). If connections cannot be made with prior knowledge, whether or not this aligns with new learning, it is unlikely that new knowledge will be remembered (Howard-Jones et al., 2020).

Educational research and theory has a long history of exploring the role of prior knowledge, for example there is Ausubel's frequently quoted statement that: 'The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.' (Ausubel, 1968: vi). Piagetian theory is based on the brain having schemas, frameworks of concepts, to which new experiences can be assimilated or, if the pre-existing schema doesn't work for the new experience, the schema will be changed in the process he called accommodation (Piaget,1952).

Declarative statements (of facts) are one form of prior knowledge (e.g. Paris is the capital of France). Another form might be the sensory knowledge we gain from handling physical objects (e.g. stroking a cat's fur or feeling the pull of a magnet). Another form of knowledge might be the patterns of stories we build up (e.g. by being read to, by reading or by watching TV). We develop knowledge of what our own bodies do (e.g. balance, breathe, taste, excrete) by living in them. These kinds of prior knowledge also play an important role in how pupils learn. Knowledge can also be differentiated as 'spontaneous concepts' developed through everyday living and 'scientific concepts' - more abstract knowledge that you don't generally encounter through everyday life and which is often the focus of schooling (Vygotsky, 1987). Although learning both spontaneous and scientific concepts are both culturally mediated, such as through language, the development of these scientific concepts probably need some form of systematic teaching/instruction.

The recent emphasis on cognitive psychology has been accompanied by an emphasis on a 'knowledge rich curriculum' (see for example Sherringham, 2018) in part due to the argument by authors such as Willingham (2010) about the importance of prior knowledge. For Willingham (2010), the value of any particular knowledge is about its utility in enabling pupils to access and learn more. So, for example he argues that when a person is reading there is knowledge that a reader is assumed to have, and acknowledges that this is going to be the knowledge of the culturally powerful. Following Hirsch, he argues that the quickest way to bring about change is to provide that knowledge to those children who don't have it so that, for example, they are able to understand what they are reading (Willingham, 2010). Others would take the position that the knowledge deemed important should be made representative of society as a whole, not its more powerful members. The debate here is about the means of provoking social change. Young (2009) distinguished between 'knowledge of the powerful' and 'powerful knowledge' with transformative power as a human right; there are different kinds of power in action in this distinction, though perhaps the two are always intertwined. A concern of pedagogy is how to introduce the knowledge of others without alienating the learner and devaluing their existing knowledge.

Questions for Practice

How might a deeper understanding of the processes through which prior knowledge affects new learning help practitioners?

What different kinds of prior knowledge might be important to learning?

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CCF 2.3

An important factor in learning is memory, which can be thought of as comprising two elements: working memory and long-term memory.

Interpreting the Statement

Working memory is very brief and has limited capacity. There is a great deal of sensory information available to us at any one point - much more than we would ever be able to process - so only some of this will be moved to long term storage. There are elements of both conscious and unconscious processing involved in deciding what moves into long term memory, and what will be forgotten. It is important that the pupil engages and actively processes new learning, moving it from short term to long term memory, because otherwise it is lost. This in itself is useful to understand and might help teachers to deal with their own frustration when a child seems to have no memory of something taught and the teacher is thinking 'but we did that yesterday!'.

What is going on in a person's working memory is related to their control of attention and what is salient (relevant/significant) in the environment. Rather than being a passive recipient of all sounds, sights, smells and feelings, the brain is always selecting what to attend to based on a kind of hypothesis of 'what matters here' based on previous experiences. Working memory is an active process, at least partly under the control of the learner. Teachers then can think about how to support children in focussing their attention and coming to a shared understanding of 'what matters' in different learning situations. There are no 'how to' statements that are closely linked with this theoretical understanding. However, this key idea underpins other 'know that' and 'know how to' statements in the CCF.

External Links

The Learning Scientists: short term memory vs. working memory (4 mins)
Columbia MOOC Understanding how memory works (12 mins)

Going further

Historically, memory has been categorized by psychologists in different ways. Sometimes 'short term memory' is used as a synonym for working memory, although some consider the two to be different - working memory involves the short-term retention and use of information, whereas short term memory is a slightly longer-term process involved in retention (a sort of stepping-stone to long-term memory). Tulving (1972) suggested that there are three different types of long term memory - semantic (which stores general knowledge and information about the world), procedural (which stores memories about motor skills) and episodic (which stores information about events we have experienced in our lives).

Camina and Guell (2017; np) summarise the current scientific view of memory thus:

'The three major classifications of memory that the scientific community deals with today are as follows: sensory memory, short-term memory, and long-term memory. Information from the world around us begins to be stored by sensory memory, making it possible for this information to be accessible in the future. Short-term memory refers to the information processed by the individual in a short period of time. Working memory performs this processing. Long-term memory allows us to store information for long periods of time. This information may be retrieved consciously (explicit memory) or unconsciously (implicit memory).'

Working memory not only plays an important role in the formation of long term memories but has also been associated with other executive functions, with research suggesting strong links between working memory, attention and inhibition (Melby-Lervåg & Hulme, 2013). These conscious and effortful processes have particularly been associated with the prefrontal cortex in the brain (Kane and Engle, 2002), a region which is relatively immature in children (Brod, Werkle-Bergner & Shing, 2013).

This association between working memory capacity and higher cognitive function has led to a number of companies developing commercially available programmes claiming to 'train' working memory to improve achievement in other areas, such as reading, attention and processing speeds. A meta-analysis of studies of working memory training suggests that training has some effect on similar working memory related tasks but that any effects on wider cognitive functioning are small and unsustainable, concluding that this does not have any 'practical benefits for learning or, more generally, education' (Schwaighofer, Fischer & Bühner, 2015, p.156). Another meta-analysis also found that working memory training does not improve academic performance or cognitive skills in typically developing children, and that evidence for 'far-transfer' effects are inversely correlated with the quality of the experiment design (Sala & Gobet 2017). As yet, there is little convincing evidence that such working memory training has any lasting effects on cognition or general benefits to learning. However, that does not mean that working memory is fixed.

From a clinical neuroscience perspective, the two-part view of memory in the CCF statement is useful. Clinical neuropsychology has a different focus to cognitive neuroscience as it is all about function – behaviour. Rather than looking at the workings of bits of the brain or trying to map cognitive models into the brain, the brain is considered more holistically and pragmatically. From this perspective then, behaviour emerges from development and while children/teenagers are at school or even university, their brains are still developing. One thing that is developing is working memory. The links between the frontal and parietal areas of the brain follow a template but are constructed experientially. Children's capacity for information processing is something they grow. School plays a pivotal part in giving children the raw material to nurture their (still plastic) adult brain.

The brain can be understood as interacting with the environment in a way that is analogous to a scientist making and testing hypotheses or beliefs. The hypotheses are formed to plan future action. It can be mathematically modelled as a kind of continuous probability generation in which information gathering occurs to avoid surprises, to reduce uncertainty and thus make safe decisions. From this view, Parr and Friston (2017) have argued that working memory is a process of evidence accumulation, updating beliefs towards either the existing ones or to incoming sensory information in order to inform action choices. To an educationalist this has echoes of Piagetian assimilation or accommodation.

Questions for Practice

What mental pictures are we creating of 'working memory' and 'long term memory' and how do these compare with how different scientists view them?

Should we see working memory capacity as a fixed attribute of the child?

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CCF 2.4

Working memory is where information that is being actively processed is held, but its capacity is limited and can be overloaded.

Interpreting the Statement

Cognitive Load theory is based on the premise that before entering long-term memory and forming knowledge structures ('schemas' e.g. mammals are furry animals or slices of cake are parts of whole) information from the senses must first be processed in a kind of mental holding space known as the 'working memory'. The working memory has limited capacity. It is often described as being able to hold 5-9 chunks of information. Individuals seem to vary on this. Demands on this capacity are called the 'cognitive load'. If the working memory is overloaded with too many 'chunks' at once then the next step of forming long term memories (encoding) will not happen (Kirschner et al, 2006). In other words, information won't be remembered, and concepts won't be formed.

For teachers one implication of this is they might aim to reduce distractions that take attention away from what is being taught. The way the task is presented might encourage focus on the most important aspect of the work so judgements have to be made about whether resources provided support or distract. In the CCF there is a 'Learn how to' statement that trainees should discuss 'with expert colleagues how to reduce distractions that take attention away from what is being taught (e.g. keeping the complexity of a task to a minimum, so that attention is focused on the content)'.

Teacher judgments of the complexity of a task in relation to a learner or group of learners could be explained in terms of cognitive load theory. The 'Intrinsic cognitive load' is the inherent difficulty of the material itself. This is different for a particular group or individual learner as it depends on their prior knowledge, but the subject matter may also present inherent challenges depending on how abstract or complex it is. This might involve trainees learning how to: 'break complex material into smaller steps (e.g. using partially completed examples to focus pupils on the specific steps)'.

Some cognitive psychologists distinguish intrinsic cognitive from 'Extraneous cognitive load' which depends on how the material is presented. A third category used is 'germane cognitive load' - this is about making connections with existing ideas so the new information becomes integrated with existing knowledge - so it is the necessary or valuable cognitive load. Educationalists might consider cognitive load in Vygotskian terms as identifying and working within the Zone of Proximal Development (Vygotsky, 1978).

External Links

3 Minute Ed Theory Cognitive Load Theory - an Introduction (3mins)
Paul Howard Jones Building New Knowledge (6 mins)
Columbia MOOC Working memory (11 mins)
Impact Chartered College Cognitive Load Theory and its application in the Classroom (article)

Going Further

It is worth noting that working memory isn't a single clearly identifiable structure in the brain; MRI scans show that many different parts of the brain connected by white matter tracts are active when people are given tasks requiring working memory. (Working memory activates the fronto-parietal brain regions, including the prefrontal cortex, cingulate, and parietal cortices and, according to more recent findings, some subcortical regions (the midbrain and cerebellum) are also involved as well as regions specialized for processing the particular representations (e.g. numbers, sounds) to be maintained in working memory (Chai et al, 2018; Eriksson et al, 2015). Working memory can be understood as a network of detectably interconnected areas of the brain. So working memory is a model of what our brains are doing when we are working on the problem that requires some kind of reasoning.

Interestingly, another detectable network of interconnected areas of the brain, the Default Mode Network (DMN), becomes less active when people are consciously working on a problem. The DMN is measurably more active when people are replaying autobiographical memories, letting their minds wander, or imagining future possibilities. It is involved in social interaction through emotion perception and theory of mind. Teachers are helping children grow their task active capacity and 'strengthening the boundary' between the two networks. Default Mode (DM) will do its own thing; you cannot prevent it doing that. All a teacher can do is make it less likely that children drift in DM (when bored or left behind). You can't avoid DM - it wouldn't help the child if you did. We can picture the teacher's role as helping learners to manage which brain networks are most active depending on what the task requires. One of the difficulties experienced by people with mental health issues is that the separation between the task active brain networks and the DMN becomes blurred. People with ADHD also have less distinct boundaries between task activity and default mode.

Baddeley and Hitch (1974) produced a model in which working memory is a limited capacity system that allows temporary storage and manipulation of information necessary to perform complex tasks such as understanding, learning, and reasoning. They proposed three subsystems within short-term memory: the central executive, a phonological or articulatory loop and a visuospatial sketchpad. The phonological loop consists of an auditory store (which decays rapidly), and an articulatory rehearsal system which allows memory traces to be kept intact. The visuospatial sketchpad holds visual information; these two systems can work simultaneously to deal with audiovisual information, without each affecting the other's processing. Both systems are considered 'slave' systems to the central executive, a coordination system to regulate and control cognitive processes. Later, Baddeley (2000) included a fourth subsystem, the episodic buffer, which acts as a temporary storage for the other systems, linking them with long-term memory.

The clinical neuroscience view is that we can't find an articulatory loop or a visuospatial scratchpad in the brain! Again, a working memory and some form of long term storage that could be called long term memory is enough.

Questions for Practice

What are the implications for practice of knowing that working memory is brief and has a limited capacity?

What mental pictures are we creating of 'working memory' and 'long term memory' and how do these compare with how different scientists view them?

Can all our thought processes be attributed to the working memory network?

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CCF 2.5

Long-term memory can be considered as a store of knowledge that changes as pupils learn by integrating new ideas with existing knowledge.

Interpreting the Statement

Our working memory is considered to be very short, a matter of 20-30 seconds; anything that lasts beyond this can be considered to have moved into what is described as our long term memory. This is a mechanism inferred by cognitive psychologists, and has been influenced by the development of computers, with their hard drives being seen as analogous with human long term memory. Of course, as humans are animals and not machines, what we move into and store in our long term memory will be influenced by many factors such as existing knowledge, emotions, social factors, necessity - and this is a constantly changing situation. Things that we need to use regularly, or for our own safety, such as our own address, how to read, how to drive, the necessity of avoiding snakes, may become automatic, deeply embedded. Knowledge, such as the capital cities of Europe, may become automatic if it is important to us and used regularly, or may become harder to retrieve if it is used less. One way to help make things easier to move into, and recover from, our long term memory is the building of connections between this and other things already there.

The CCF states that trainees should 'Learn how to: build upon pupils' prior knowledge by discussing and analysing with expert colleagues so that pupils can secure foundational knowledge before encountering more complex content.'

External Links

Paul Howard Jones Building New Knowledge (6 mins)
Paul-Howard Jones: Consolidation (7 mins)
The Learning Scientists - Sleep, Learning and Self Care (podcast) (21 mins)

Going Further

Like other forms of memory, long term memory isn't a box in the brain - it is made up of more durable connections across the brain. Long term memory can be retrieved consciously or unconsciously. Memory is not fully understood. Neuroplasticity means that the traces of experience on the material of the brain (probably as connections between neurons) can be 'overwritten' or reinforced. But it wouldn't be helpful if our brains were too plastic - having to relearn to walk every morning wouldn't be convenient. Once we have learned to read we can't stop ourselves from reading.

A neuroconstructivist view of learning unifies a Piagetian approach to cognitive development with an understanding of brain development (Thomas, Mareschal and Dumontheil, 2020). At the cellular level, neurons (brain cells) form connections and increasingly complex patterns of interconnections, based on activity. The activity is a child's ongoing embodied interaction with the environment; 'Neural activation patterns are generated by sensory inputs, and therefore the functioning of the sensory organs has a highly constraining effect on the construction of representations in the mind.' (ibid: 44). The social environment is also seen as vital in affecting the activity, though arguably this part of neuroconstructivism needs further articulation.

Knowledge (patterns of connections) can only be formed by building on existing knowledge (existing connections). The connections will be stabilised or lost based on ongoing activity and use of those connections. So from this viewpoint we can see long term memory as the formation of stable patterns of connections between brain cells.

A strong emotional experience is also more memorable - makes more durable connections. (This makes sense in terms of evolution - that we have evolved to remember the berry that made us vomit). We also 'remember' things that didn't actually happen but we have thought about. A famous case of this involves American news anchor Brian Williams, who was criticized in 2015 for claiming that a military helicopter that he had been travelling in during the Iraq War was shot down by a rocket-propelled grenade. In fact, he had been travelling in a separate group and was not involved in that incident. However, overtime people unintentionally conflate and merge different memories, and misremember events, believing that the most up-to-date version of their recollections is still accurate.

Different factors affect the formation of long term memories. Although hopefully not relevant for most school pupils, drinking too much alcohol inhibits the processes of long term memory formation. Sleep is essential for consolidating memories (e.g. Mazza et al. 2016) and teachers could work with the wider school community to support good sleep habits.

Questions for Practice

How does the view of knowledge as a long term memory store relate to the constructivist view of building knowledge? How might this be explained in lectures/ seminars on theories of learning?

How 'fixed' are long term memories?

What factors affect the integration of new ideas with existing knowledge?

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CCF 2.6

Where prior knowledge is weak, pupils are more likely to develop misconceptions, particularly if new ideas are introduced too quickly.

Interpreting the Statement

Teachers often use analogies, phrases or examples to help explain new concepts, but if the pupil does not understand the analogy/phrase/example then this can build further misconceptions - for example, saying the earth is round relies on the pupil understanding that this means round in a 3D spherical sense and not round like a hoop. It is really important to check for shared understanding, and avoid assumptions of sound prior understanding. A related CCF ‘Learn how to’ statement says that expert input from colleagues should focus upon identifying ‘possible misconceptions’ so that these can be addressed and prevented from forming and that trainees should practice ‘Encouraging pupils to share emerging understanding and points of confusion so that misconceptions can be addressed’.

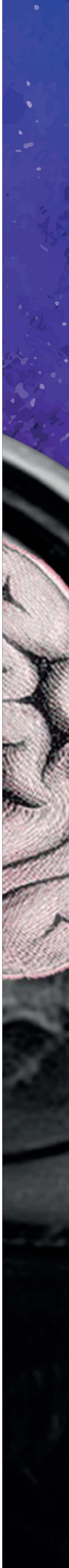
Maths is an area that is often seen as building up from basic to more complex concepts, and it can be easy to assume that children have mastered the basic concepts when they haven’t. In addition, we are - as we know - not empty vessels - we all have a desire to fit new knowledge with old knowledge. The sensation when we are having to assimilate new but conflicting information has been described as causing cognitive dissonance, and can be very uncomfortable. We tend to try to find ways to reduce this discomfort, so it is important that new ideas are linked to accurate prior knowledge, or our drive to make sense of the world can perpetuate new misconceptions. This has to be done sensitively, because there is some evidence that we are prone to something described as the ‘backfire effect’, in which sometimes new knowledge that challenges our deeply held current beliefs results in us clinging harder to our original beliefs. Humans are not machines, all of our learning is filtered through the accumulated impact of our previous experiences. This is reflected in the statement that trainees should ‘Learn how to: link what pupils already know to what is being taught (e.g. explaining that content builds on what is already known)’.

External Links

The Learning Scientists blog: How to help Students overcome misconceptions
Willingham : Teaching Content is Teaching Reading (10 mins)

Going Further

Bombarding learners with new knowledge quickly can result in cognitive overload, meaning that new information either isn’t retained, or is combined together in ways which result in misunderstanding. When we experience new things, we don’t simply store this as isolated memories - we try to integrate new knowledge into our existing understanding of the world. Prior knowledge therefore has an influential impact on our ability to store new information. When memories are stored as detailed, specific events or ‘episodes’ the brain area called the hippocampus is involved. When memories are integrated into schemas, the details of the event are not kept in the same way and this involves areas of brain cortex (the medial prefrontal cortex).



We know from educational practice as well as psychological experiments that very strong schemas can lead to misconceptions in which experiences are inappropriately integrated into existing schema. This suggests that we should aims for: 'robust schemas that are on the one hand strong enough to help to remember and predict, but also malleable enough to avoid such undesirable side effects' (van Kesteren & Meeter, 2020: np). van Kesteren and Meeter (2020) go on to argue that a useful memory for educational purposes will both establish key features that contribute to overarching meaning and enough detail to make it distinctive to the context. We might consider how teachers could support this.

Science education has been good at identifying the existing ideas that children have about the world and that these can be quite different from scientific ideas (e.g. the sun and the moon change places for day and night). Constructivist-based theories of science education have focussed on how teaching can help children to build on or replace their existing ideas with others that are more in line with how scientists understand the world. Neuroscience supports the idea that learning is about building connections - associations - between existing ideas to form new concepts. However neuroscience is also modifying our understanding: changing children's concepts is not about replacing naive ideas and misconceptions with new ideas but about inhibition of the old ones - suppressing them with alternatives. The neuroscience studies that lie behind this shift in thinking looked at what happens when physics experts and novices were presented with counterintuitive situations (heavy and light objects falling). They found that the experts showed significant activity in brain areas associated with inhibition and concluded that the physics experts' misconceptions were still there, but were being suppressed. We can only help children to build new ideas and reinforce and strengthen these and help them recognise the need to suppress previous ideas (Bell and Darlington, 2018).

Questions for Practice

How do constructivist views of learning relate to neuroscience views on how concepts are formed?

How might a neuroscientific view on the process of conceptual change inform our practice?

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CCF 2.7

Regular purposeful practice of what has previously been taught can help consolidate material and help pupils remember what they have learned.

Interpreting the Statement

New learning requires us to use our limited working memory capacity, so to free up space it is necessary to practise using and recalling newly learned information to make it more permanent. As we consolidate our new learning, it becomes easier and quicker to access. For new learning to happen, new information must be connected to prior knowledge. The younger the learner, the more support is needed to make these connections. As well as drawing on input from the senses, working memory can be working on long term memories. This involves 'retrieving' them from the long term memory into the working memory. There is something about the effort involved in retrieving the memory that strengthens it. The CCF says that 'Learn how to: Increase likelihood of material being retained, by: Observing how expert colleagues plan regular review and practice of key ideas and concepts over time (e.g. through carefully planned use of structured talk activities) and deconstructing this approach'. And that trainees should work to 'improve at balancing exposition, repetition, practice and retrieval of critical knowledge and skills'. Human memories are not fixed like in a book or a computer - memory is 'reconstructive' - so every time you retrieve a memory you are changing it.

External Links

Paul Howard-Jones Consolidation (7 mins)
The Learning Scientists - Study Strategies: Elaboration (1.5 mins) Audience secondary pupils
Deans for Impact practice-with-purpose pdf download
Deans for Impact - Deliberate practice
Teach First Deliberate Practice
Mike Hobbiss Blog Constructivism is a theory of learning not a pedagogy

Going Further

The use of the term 'purposeful practice' may be drawing on the concept of 'deliberate practice' (see for example, Deans for Impact, 2016). Deliberate practice has five principles: push beyond one's comfort zone, work towards well-defined specific goals, focus intently on practice activities, receive and respond to high quality feedback and develop a mental model of expertise. This provides a broader context for the practice activities themselves.

Ericsson et al (1993) claimed that expert performance in the vast majority of fields may be explained by differences in the quantity and quality of practice. The idea is attractive because it seems meritocratic; innate talent is overrated and anyone can make it, and argue that genetic effects account for a small amount of variance (Ericsson and Harwell, 2019). It is worth noting that Ericsson and Harwell (ibid) dissociate their work from the 10,000 hour rule promoted by Malcolm Gladwell. The focus of their work has been how musicians become experts.

Their claims have been challenged by Macnamara and Maitra (2019) who replicated aspects of their studies and found that though practice did have a substantial effect it was much smaller than claimed by Ericsson et al (1993) suggesting that other factors were important too, particularly among the elite violin players studied.

Neuroscience provides another way of viewing the value of repeated practice. Constructivist theories of learning (that each individual constructed their own knowledge and understanding of the world based on their unique experiences) are consistent with the neuroscience. However, in his blog (linked above), Hobbiss (2018) reminds us that this does not mean there is also evidence to support pedagogies that are based on constructivism such as 'facilitating' but not providing explicit guidance. He argues that 'Neuroconstructivism' tells us that mental representations made in the brain as a result of experience are always partial, distributed across different brain areas and are always context dependent; they are traces of the whole experience of the learners (including for example how they felt at the time and how important it seemed) not the neat abstractions of knowledge that the teacher may have hoped would be created. Hobbiss (2018) suggests that this means that pupils need to construct multiple, overlapping representations, developed in different contexts and strengthened by rehearsal and retrieval.

Questions for Practice

What kinds of regular practice should we advocate?

How might we provide educational structures that support children in forms of regular purposeful practice that leads to useful and meaningful learning'?

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CCF 2.8

Requiring pupils to retrieve information from memory, and spacing practice so that pupils revisit ideas after a gap are also likely to strengthen recall.

Interpreting the Statement

Three strategies for learning have been particularly highlighted from reviews of cognitive psychology research aiming to identify useful tools for practice; these are retrieval practice, spaced learning and interleaving. A much-cited article summarising the evidence for these is Dunlosky et al (2013).

Retrieval practice is 'bringing information to mind from memory' (Weinstein et al. 2019 p85). We might think of retrieval practice as recapping or revisiting, but the crucial factor is that it is the pupil that does this, and puts in the effort to retrieve the memory. It is not the same as the teacher repeating content or a pupil simply looking at something again. It is important that the retrieval process is 'low stakes', so it could be a quiz, but not a high pressure test, as too much anxiety interferes with memory formation. But, retrieval practice can feel difficult and uncomfortable and children may need support to tolerate this. The CFF document says that trainees should 'Learn how to' employ the strategies of: 'Increasing challenge with practice and retrieval as knowledge becomes more secure (e.g. by removing scaffolding, lengthening spacing or introducing interacting elements)'.

Bath Spa University PGCE Activity for Students - a critical look at retrieval practice

Working memory is also freed up when concepts are so secure in long term memory that they are a single 'chunk' and so take up just one bit of the capacity of working memory. It is this idea that is part of the justification behind the drive for children to create stable, long term memories of key facts. Willingham (2009) gives examples of this: knowing your multiplication tables and letter sounds. The argument made is that: "Each subject area has some set of facts that, if committed to long-term memory, aids problem-solving by freeing working memory resources and illuminating contexts in which existing knowledge and skills can be applied. The size and content of this set varies by subject matter." (Deans for Impact, 2015 p5).

Spaced or distributed practice is that thing that many people had good intentions to do - plan a revision schedule for an exam that involved planning to look at each element for a short time and revisit it at intervals. For teachers, it is about planning to revisit content after a gap in time. The research has shown that if you compare 'massed practice' - studying for a longer block of time, with the same total time, but distributed' then people are better able to remember the content. It isn't entirely clear why this time interval is important - but it is consistent with retrieval practice and consolidating memories. There is a considerable body of evidence from cognitive psychology to support this strategy. It seems in line with existing educational good practices of reviewing and revisiting content at the start of lessons and topics and provides another rationale for doing this. However, it is not clear from the research what the ideal time gap is for any content or group of children, so professional judgment is still needed. One issue to bear in mind is that the research generally involves well defined, narrowly defined chunks of knowledge such as vocabulary lists.

External Links

MOOC Retrieval Practice (11 mins)
The Learning Scientists - Study Skills - Spaced Practice (2 mins) audience secondary pupils
The Learning Scientists - Study Skills Retrieval Practice (3 mins) audience secondary pupils
The Learning Scientists - Why does spacing work? (2 mins)

Going Further

The effect of spaced learning/practice is robust, although there is no one particular theory that explains why. One theory, the 'new theory of disuse', put forward by Bjork and Bjork (1992, 2011), argues that memories have retrieval strength (the ease with which a given memory can be recalled at a given point) and storage strength (the extent to which a memory is securely stored in the mind). The process of studying boosts both of these strengths, but storage is dependent on retrieval, and there is a negative relationship: if information is learned rapidly, a high emphasis on retrieval strength results in a low emphasis on storage strength. Instead, spacing out learning allows for long-term boosts in storage strength. One issue to bear in mind is that the research involves well defined, narrowly defined chunks of knowledge such as vocabulary list and is less convincing for learning complex tasks and knowledge. Others have argued that context is important in learning; research has shown that information learned in a specific environment (say, a classroom) is more likely to be recalled at a later point in that same environment. Therefore, if information is learned over time, a greater and more variable number of contexts will be associated with that information, allowing for a wider range of cues to help subsequent recall (Glenberg, 1979).

Interleaving means switching between work with similar, but different kinds of content, typically maths problems (e.g. finding the area of different rectangles, then triangles), within one session. It is not clear why interleaving has led to better learning outcomes in many studies, particularly in maths and in learning motor skills such as playing a musical instrument (for an accessible summary see Pan, 2015). It may be that the juxtaposition helps pupils to focus on the distinct features of a problem or activity. But it isn't clear where the balance lies between the value of interleaving and the detrimental effects of task switching. Again, professional judgment in applying these ideas in a particular context would be needed.

Questions for Practice

What constitutes 'retrieval practice' beyond the use of quizzes and tests?

What different ways are there of provoking children to retrieve memories?

How do you balance providing sufficient challenge without causing additional anxiety through retrieval practice?

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CCF 2.9

Worked examples that take pupils through each step of a new process are also likely to support pupils to learn.

Interpreting the Statement

As we all have limited amounts of processing capacity, if we move too fast from introducing a new concept to expecting learners to be able to apply it in a novel context, this can lead to cognitive overload, where the learner simply cannot cope. A worked example is a step by step demonstration of how to approach a task or solve a problem. By using worked examples as a stepping stone from the new information to an example of how it can be applied to a problem, the aim is to reduce cognitive load. Teachers are familiar with the sensation of moving too quickly in expecting learners to use their new learning, which can result in frustration for all. Guides and worked examples are thought to support learning because they address the issue of cognitive load.

Cognitive psychologists (see e.g. Willingham, 2009:109; Kirschner and Hendrik, 2020:9) argue that cognition is fundamentally different in novices and experts and thus approaches such as problem-based learning or inquiry learning (without guidance) don't work well for novices, although they do work for experts (this is called the 'expertise reversal effect'). From this perspective, providing worked examples is better for novices than using a problem solving approach. The CFF states that trainees should 'Learn how to: increase likelihood of material being retained, by discussing and analysing with expert colleagues how to design practice, generation and retrieval tasks that provide just enough support so that pupils experience a high success rate when attempting challenging work'.

External Links

Teacher's blog on cognitive load
Dylan Wiliam - Teacher Reflective Practice (4 minute video)
Novices and experts video (4 minute video)
MOOC Cognitive load (7 minute video)

Going Further

Learning via problem solving usually involves presenting pupils with a series of informational statements, along with a goal statement. This can be problematic when prior knowledge is weak; if they do not have understanding of the procedures required to solve the problem, the result can be a reliance on strategies like trial-and-error or means-end analysis. While they may reach the goal, the process carries with it a high cognitive load (through the intense use of working memory), and it doesn't often result in an understanding of how to generally solve such problems in the future. Worked examples, in additionally providing a step-by-step guide as to how to approach the problem, therefore reduce the cognitive load incurred by weaker solving strategies, and as such allow working memory resources to be devoted to constructing a pattern of thought (or 'cognitive schema') that can inform future problem solving (Spanjers et al., 2011). There is some evidence that the way the problem is broken down can also have an impact on learning, with modular examples - those which break down complex ideas into smaller and more understandable elements - reducing cognitive load and improving learning (Gerjets et al, 2004).

Considering the educational aim a single activity and of a series of activities is important in making planning decisions about how worked examples fit within a series of lessons. For example the aim of a single activity might be that learners are able to use a specific approach to address a problem (possible ways to open a story), but an overarching aim might be to select an appropriate strategy to solve a problem in a more meaningful context (writing an engaging story for a particular audience).

Questions for Practice

How does the promotion of worked examples over problem-based or inquiry learning relate to social constructivist concepts of the role of the 'more knowledgeable other' in supporting learners' progress across the Zone of Proximal Development (Vygotsky, 1978) or sociocultural views of 'scaffolding' learning (Wood, Bruner and Ross, 1976)?

Which models of planning can help to identify each step in the learning process and provide a logical progression?

How can sufficient support and challenge be provided for all pupils within and between lessons when children may secure new learning at different rates?

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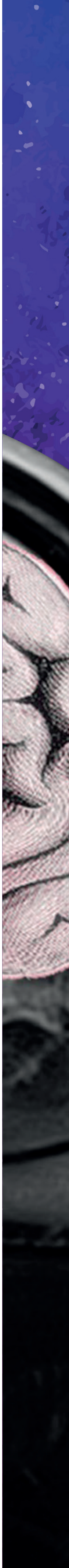

CCF 3.3

Ensuring pupils master foundational concepts and knowledge before moving on is likely to build pupils' confidence and help them succeed.

Interpreting the Statement

There are a number of key ideas here within this one statement. Firstly, it assumes that once foundational concepts are automatic and accurate, more capacity is available for processing new concepts, and thus the learner will be more likely to succeed. An example of this is the idea that children should have instant recall of their times tables, enabling them to solve complex mathematical problems more successfully, because they needn't use any of their limited capacity to work out basic multiplications. It also assumes that knowledge is built in a linear, or pyramid style, progression, with each new idea resting on earlier underlying concepts. Again, this is often the way we view maths learning, and we have all taught children who had very shaky foundations and therefore struggled with later concepts. The CCF says that trainees should 'Learn how to: Deliver a carefully sequenced and coherent curriculum, by:... Observing how expert colleagues ensure pupils' thinking is focused on key ideas within the subject and deconstructing this approach and by providing opportunity for all pupils to learn and master essential concepts, knowledge, skills and principles of the subject.' Finally, there is the assumption that confidence builds success. Whilst there is some evidence to support all of these viewpoints, one equally could argue that this can be rather an oversimplification. The evidence around the correlation between confidence and success is complex, and should be viewed with caution.

External Links

MOOC Connecting Prior Knowledge | Memory and Learning (10 minute video)
Dylan Wiliam - Teacher Reflective Practice (4 minute video)

Going Further

The idea of 'mastery', particularly in mathematics, seems to be based on comparison with East Asia, where other social and contextual factors impact performance on PISA tests. One of the crucial factors is the perception of the value of education to society, with 68% of teachers in Singapore believing that their professional is valued by society, versus 35% in England, based on research cited in the CCF (Jerrim and Vignoles, 2016). This research points out that there are also significant cultural, historical and economic differences between countries, which make it impossible to know what is causing the difference in test scores. There is little evidence that teaching methods are superior, or whether they could be successfully translated into UK schools (Jerrim and Vignoles, 2016).

The Maths Mastery teaching programme has been adopted by many primary and secondary schools in England, and aims to cover less material in greater depth, with every child expected to 'master' one stage before moving to the next. Research in both primary and secondary schools demonstrated a small positive impact on test scores, which is noted by the authors to be similar to that found with other interventions designed to improve basic skills, such as the 'Literacy Hour', and this varied with school 'quality' (Jerrem and Vignoles, 2016). A number of limitations were noted, including testing immediately after the year's intervention programme.

The picture emerging around confidence and success shows that this relationship is less than straightforward. There is some evidence, for instance, that one can stimulate certain areas of the brain (the prefrontal cortex) to induce sensations of confidence, but this does not result in improved perception (Cortese et al, 2016). Conversely, in the phenomenon called 'blindsight', people with lesions in the visual cortex make correct perceptual decisions, but feel no confidence and say that they are 'just guessing' (Weiskrantz, 1996). Thus Cortese et al (2016) argue that there is a dissociation between confidence and success.

Whilst there is evidence that the relationship is likely to be bidirectional, so that success can boost confidence as well as confidence boosting success, for instance in one study of mental maths tasks (Hoffman and Spataru, 2008), one does not guarantee the other.

Questions for Practice

How might teachers support children in developing automaticity?

What factors could impact on learners' confidence and how can teaching help to build confidence and avoid undermining it?

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CCF 3.6

In order for pupils to think critically, they must have a secure understanding of knowledge within the subject area they are being asked to think critically about.

Interpreting the Statement

Critical thinking is not a generic skill that can be applied to any situation, as it depends on background knowledge and understanding (Bailin et al., 1999, Willingham, 2008). For example, thinking critically about a new National Curriculum would require some background knowledge, including the content of the current curriculum and educational theory, and would not mean that you could perform equally well thinking critically about an unfamiliar topic. Background knowledge and understanding of the specific context is crucial for critical thinking to take place. There is general agreement in education that critical thinking is beneficial (Lipman, 2003), although it is contested whether, for example, critical thinking about a scientific concept is different from critical thinking about a poem or a religious belief. This statement emphasizes the view that a 'knowledge rich' curriculum is an essential prerequisite for critical thinking. This underpins the CCF statement that trainees should practice: 'Ensuring pupils have relevant domain-specific knowledge, especially when being asked to think critically within a subject'.

This statement could be aiming at encouraging pupils to be able to identify truth from falsehood and good science from bad science. The persistence of many neuromyths shows that this is not easy, partly because of the desire to over generalise and over simplify. So the idea that we need to know the facts in order to properly evaluate what we are taught has some real value. The tragic recent case of the young American who believed that Covid-19 was a hoax, so attended one of the Coronavirus parties but ended up catching and dying of it, is just one very clear example of why it is so important to be able to tell fact from fiction. Pupils today have access to many sources of information and they do need to be able to evaluate the validity of these sources; one way to help them do this is enable them to have a fund of basic knowledge that is accurate. In addition, pupils need to understand the importance of investigating multiple sources by reading laterally, cross checking and digging deeper than the first few results in a search engine or material promoted by specific groups or organisations (Stanford History Education Group, 2016 and ResearchED, 2020).

External Links

Novices and experts video (4 minute video)
Willingham on thinking critically about internet sources (1 hour long video)
The two Daniels discuss book 'How to Educate a Citizen' by E D Hirsch (25 minute podcast, first part is very relevant)
Neuroscience of creativity (7 min video)

Going Further

Willingham (2008) suggests that teaching critical thinking is difficult because we misunderstand the complexities involved. He argues that, in contrast to views embraced by critical thinking interventionists such as the Philosophy for Children movement (Lipman, 2003), critical thinking is not a separately teachable skill. He says that all critical thinking must be embedded in the unique context in which it happens, so there can't be a universal set of critical thinking skills that can be acquired and used across all contexts. Whilst he agrees that there are some metacognitive strategies that, once learned, make critical thinking more likely (such as looking at more than one point of view), he contends that the ability to think critically in any domain must depend on having sufficient domain knowledge and practice. Without such knowledge, the thinking cannot be sufficiently deep or accurate for meaningful conclusions.

Although creativity is not mentioned in the CCF, the same argument about the need for secure knowledge has also been applied to creativity, challenging viewpoints that learning knowledge stifles creativity (Weisberg, 1998). Creativity, or generative thinking, usually means connecting unrelated or less-related existing ideas to come up with something original and valuable. Research suggests that creativity involves both hemispheres of the brain (Kühn et al., 2014; Sawyer, 2011), with no evidence for the popular belief that creativity is located in the right hemisphere (Sawyer, 2011). Positive associations have been found between bilateral activity in the frontal lobes and creativity (Carlsson et al., 2000), although longitudinal studies are required to determine causal associations (Zhou, 2018). Creativity relies on prior knowledge but means avoiding automatic connections and disrupting some unconscious habits (Howard-Jones, 2002). The default mode network (DMN), associated with mind-wandering and complex unconscious processing, has been linked to creativity (Jung et al., 2010; Kühn et al., 2014). This is more active when completing a familiar, known task, rather than a novel task (Mason et al., 2007) and is easier to do when we are relaxed and/or experiencing disruption to routine behaviours and thinking.

Creativity has been associated with attention, as a wider breadth and efficient selective attention mean that individuals can collect more information to connect and combine, and can inhibit irrelevant information (Kharkhurin, 2011; Martindale, 1999). This assumes that individuals have a store of information from which to draw upon. There seems to be a need to switch back and forth between the default mode network and the executive control network, allowing evaluation of the ideas generated. Being asked to make remote connections has been found to support the generation of ideas, such as creating stories from random words (Howard-Jones et al., 2005), and by broadening the focus of attention (Howard-Jones and Murray, 2003). Therefore, attention training may lead to better creative thinking (Liu et al., 2012; Takeuchi et al., 2013). Studies also show that working memory capability can predict behavioural responses to creative activities (Zhou, 2018). However, there are very limited studies of creativity training that measure behavioural changes and neural manifestations of creative thinking (Zhou, 2018).

Questions for Practice

What constitutes 'secure understanding of knowledge' that could underpin opportunities for critical thinking?

What opportunities does the curriculum present for children to develop critical thinking skills?

How might approaches to critical thinking differ between curriculum subjects/areas?

How does the argument of the need for secure knowledge for critical thinking relate to creativity?

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CCF 3.7

In all subject areas, pupils learn new ideas by linking those ideas to existing knowledge, organising this knowledge into increasingly complex mental models (or "schemata"); carefully sequencing teaching to facilitate this process is important.

Interpreting the Statement

Cognitive psychologists talk about schemata (Gross, 2015); this is the idea that there are knowledge structures that are built from the commonalities across many different experiences. The schemata that are established will have an impact on how new learning is perceived, interpreted and comes to be stored in the long term memory. The process of encoding new information, and linking it to existing memories, is becoming better known, with specific areas of the brain involved, such as the ventromedial prefrontal cortex, the hippocampus and the angular gyrus, however this is still a process that is nowhere near being fully understood; current thinking amongst neuroscientists is moving away from the idea of domain general processes (Thomas et al, 2019), towards the idea that there are specific circuits for specific skills, including memorisation. This means that it is important for teachers to consider the kinds of subject matter they are teaching and consider the kinds of schemata, or mental models, involved and then think about the kind of sequencing of skills and knowledge that will be most beneficial for this particular group of learners - part of this will involve finding out what models the pupils have already developed. In order to 'Learn how to: 'deliver a carefully sequenced and coherent curriculum' the CCF states that trainees should be Discussing and analysing with expert colleagues the rationale for curriculum choices, the process for arriving at current curriculum choices and how the school's curriculum materials inform lesson preparation'. They should also 'practise, receive feedback and improve at: Drawing explicit links between new content and the core concepts and principles in the subject'.

External Links

Columbia MOOC The Science of Learning and Effective Teaching Strategies (3 minute video; new knowledge builds on prior knowledge and the importance of challenge and mindset)
Columbia MOOC Connecting Prior Knowledge (10 minute video)

Going Further

When learning new concepts, sometimes prior understanding has to be somehow circumvented. An example might be the learning of fractions, which tend to be counter-intuitive because the larger the denominator, the smaller the fraction; another example might be scientific concepts about matter, which become ever more complex as learning deepens and earlier ideas have to be supplanted by new ideas. It seems that we learn to do this by suppressing, or inhibiting, older ideas and that this is a necessary skill, with a correlation between effective inhibition and maths success (Gilmore et al, 2015). Evidence from neuroscience supports this idea, showing higher levels of activation in the frontal lobes (which are associated with inhibitory control) when new concepts are being learnt or practiced (Mareschal, 2016). This, in turn, suggests that if we can help children develop inhibitory control, through suitable training, then this may help them learn new concepts more effectively.

Questions for Practice

How might teaching need to be adapted to enable all children to make links between existing and new ideas?

How can teachers elicit children's existing understanding/schemata?

What do teachers need to know about children's existing understanding/schemata?

How can careful planning ensure logical sequencing of learning in the short, medium and longer term?

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CCF 3.8

Pupils are likely to struggle to transfer what has been learnt in one discipline to a new or unfamiliar context.

Interpreting the Statement

In education we generally aim to help learners develop knowledge that they can apply in different contexts, ultimately in the lives beyond school. We may hope that learners can make connections between what they have learned in one context and apply to another within or across different areas of the curriculum. It is the principle behind the use of the word education rather than training. We also want learners to be able to recognise features of a situation or problem that will alert them that they have the 'toolkit' to address it. But learners find this 'transfer' very difficult. Cognitive psychologists use the terms 'near transfer' and 'far transfer' to describe when the application of knowledge is to a similar context or a very different one.

Even in near transfer situations, of course the learner needs to be able to retrieve the particular knowledge required, but on its own that isn't enough. Factors that seem to help are when the learners are able to recognise that this is a situation in which they are being expected to transfer knowledge and that they know how to apply it. Being able to see beyond superficial details to the underlying principles seems to be part of this process. The CCF says that trainees should 'Learn how to: Help pupils apply knowledge and skills to other contexts, by observing how expert colleagues interleave concrete and abstract examples, slowly withdrawing concrete examples and drawing attention to the underlying structure of problems and deconstructing this approach.'

External Links

The Learning Scientists blog page Transfer (blog)
The Learning Scientists with Jared Cooney Horvath: Memorizing facts vs Using Information (Podcast 28 mins).

Going Further

There is a move (in neuroscientific thinking) towards suggesting that we may develop specific brain mechanisms for specific skills, as opposed to domain general mechanisms that work the same across all areas. Part of the evidence for this is the difficulty of creating an intervention that has a transfer effect - an example would be the brain training games that have become popular: although they can be shown to improve the skills needed in those games, there is little convincing evidence that these skills transfer to other situations. Therefore it will be important to clarify connections between knowledge or skills gained in one discipline and another, teaching how it can be applied to the new discipline.

Bath Spa University PGCE Activity for Students - a critical look at brain training

There is also evidence that children and teenagers are still developing the neural circuitry needed to build these links (Quach et, 2020), so adults around them need to remember this and not assume that they will automatically make these links in the way that an adult might - they need to be made explicit.

Since connecting prior knowledge to newly learned information involves the prefrontal regions of the brain which are still developing in children, it is assumed that varying levels of support are needed to activate available prior knowledge according to their developmental status (Shing & Brod, 2016). The exact type of support is difficult to determine, but it seems that the younger the learner, the more concrete support is needed (Shing & Brod, 2016).

Questions for Practice

What kinds of curriculum structures could help to facilitate the transfer of learning across disciplines?

What teaching strategies and learning experiences could help to clarify connections and skills across disciplines and make these links explicit to children?

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CCF 4.1

Effective teaching can transform pupils' knowledge, capabilities and beliefs about learning.

Interpreting the Statement

Howard-Jones (2018) has said that teaching can seem like a super power, because it is clear that effective teaching can, literally, rewire the brain. Of course, all experience is rewiring the brain all the time, but the aim here is to make changes that enhance learning in school contexts. Scans have shown physical changes in the brains of people who have had effective reading or maths intervention (Iuculano et al, 2015), or been taught a new skill such as juggling (Scholz et al, 2009). In this CCF statement an effective teacher will be able to transform pupils' knowledge/capabilities/beliefs by understanding what the pupils currently know, what they need to know next, and how to help them build relevant connections between these. This overarching principle is not related to a specific CCF 'Learn how to' statement.

We know that the brain remains capable of change and growth throughout life, and it is this neural plasticity that gives hope. There is some evidence that teaching children about brain plasticity has a positive impact on their learning.

External Links

Columbia MOOC Student mindset (5 minute video)
Growth Mindset - is really THAT easy? (24 minute blog)

Going Further

It has been suggested that teaching students about brain plasticity can have a positive effect on academic attainment and motivation (Blackwell et al., 2007; Paunesku et al., 2015) and that children who understand that their brains are 'plastic' are more resilient (Dubinsky et al., 2013). There has been global interest from educational settings in Carol Dweck's idea that intelligence is not fixed, but can be developed through a 'growth mindset' (Yeager and Dweck, 2012). In many cases this theory has been simplified, misinterpreted and misapplied by schools; it is emphasised that mindset and effort alone will not assure academic success (Nye et al., 2018), and that we should not lose sight of the goal of learning (Dweck, 2015). It is argued that children need to be challenged, supported to make mistakes and provided with effective learning strategies for this approach to be successful (Nye et al., 2018).

There have also been questions around the research findings in Blackwell, Trzesniewski & Dweck (2007), Mueller & Dweck (1998) and Haimovitz & Dweck (2016), with critics pointing out inconsistencies and errors with statistics. It is also important to note that the original findings from Mueller & Dweck (1998) have not been successfully replicated in a published paper by an independent team.

Bath Spa University PGCE activity for students - A critical look at Growth Mindset

The more recent growth mindset study by Yeager et al (2019) (also Carol Dweck's team) addresses some of the methodological criticism. In this study a short online intervention (2 sessions, less than one hour) to challenge beliefs about intelligence as fixed aimed to investigate whether certain groups (of 14-15 years olds) were more affected than others by the intervention.

They concluded that the intervention improved grades among lower achieving students and when peer norms ‘supported ‘challenge seeking’. However in already high achieving schools the growth mindset intervention did not increase achievement.

Questions for Practice

What evidence is there for the value of particular interventions to promote a Growth Mindset?

How might interventions to change beliefs about learning affect different groups of pupils/students differently?

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CCF 4.3

Modelling helps pupils understand new processes and ideas; good models make abstract ideas concrete and accessible.

Interpreting the Statement

Although it is not clear what underpinning research this statement is based on, it may be based on Rosenshine's Principle of Instruction No.4: Provide models and worked examples (Rosenshine, 2012). There are a number of CCF statements that trainees should 'Learn how to model effectively: by discussing and analysing with expert colleagues how to make the steps in a process memorable and ensuring pupils can recall them (e.g. naming them, developing mnemonics, or linking to memorable stories), by narrating thought processes when modelling to make explicit how experts think (e.g. asking questions aloud that pupils should consider when working independently and drawing pupils' attention to links with prior knowledge)' and by 'exposing potential pitfalls and explaining how to avoid them'. These strategies seem to partly be based on supporting pupil metacognition (CCF 4.5) or using worked examples (CCF 2.9) and partly on the value of giving abstraction a more concrete, visual or physical form. For example, the EEF reports on learning in mathematics emphasise the value of 'manipulatives and representations' (EEF, 2017, 2020).

There are many different ways that we learn from others, including watching or 'observational learning' (Charpentier, Iigaya and O'Doherty, 2020). Human brains, like all bilateral brains, have evolved to translate sensory input into movement output, a process that has been described as the "sense to action" principle (Howard-Jones, 2018, p40). It seems that learning may be enhanced when accompanied by meaningful movement, and that some types of learning can become embodied.

In one example of this, animal names in a new language were remembered more effectively if the children were asked to gesture and act like the animal. This is called the enactment effect. In addition, when a teacher models how to do something, it seems that this can be a powerful way of teaching, especially if it is accompanied by relevant actions and gestures. For instance, teaching people to remember the word 'stack' is more effective if the teacher uses a physical gesture to show what the word means. There is some evidence that we have neurons which, in a sense, copy what is being watched, known as mirror neurons. Thus the relevant areas of the brain activate as if the pupil was actually doing what the teacher was doing, when in fact they are simply watching.

External Links

The Learning Scientists: Study Skills - Concrete Examples (2 mins) audience secondary pupils
Karl Friston on embodied cognition (14 mins)
Lakoff on embodied cognition 2015 (90 mins - long but fascinating and the first 7 minutes alone are useful)
Butterworth talking about number and the brain 2013 (7 mins)

Going Further

There is growing evidence of the embodied nature of learning, so that what may at first appear to be purely cognitive concepts, such as formal maths, can be seen to include a physical element, hence the growing consensus that we need to consider the physical side of learning. One such example is the recent work on finger gnosis, whereby a link has been found between early maths and the ability to identify each finger separately. This is important for teachers as it has the potential to help us consider more effective ways to support children in their learning. Evidence from behavioural studies and neuroscience appears to support the notion of a functional link between fingers and counting. The parietal area of the brain, which is implicated in maths tasks (Dehaene, 1998; Dehaene, Piazza, Spinel and Cohen, 2003) also controls finger movements. One fMRI study found that counting resulted in the activation of the anterior intraparietal sulcus (IPS), which is also activated during finger movements (Krinzinger et al, 2011), concluding that finger counting may mediate the transition from non-symbolic to symbolic and exact number.

Krinzinger et al (2011) looked at young children, 6-12-year-olds, however Butterworth (1999) had found that the IPS of both hemispheres were activated in adults during approximate calculation tasks and the left inferior frontal lobe was more involved during exact calculation; as stated, this is important because the IPS is an important area for controlling hand and finger movements. Butterworth concluded that there could be a functional link between processing number and finger use.

Another study found that tasks that involved the hands interfered with counting ability in 5 year olds, whereas similar tasks involving the feet did not (Crollen and Noel, 2015). In a recent small scale experiment, it was found that a novel intervention explicitly linking fingers, arabic numerals and number words, had a significant positive effect on pre-school children's ability to count and recognise numbers up to 10 (Humphreys and Yau, 2019). This link between physical movement and learning has not been limited to maths. Other studies have indicated an essential link between movement and early language learning (Iverson, 2010; Libertus and Violi, 2016), language cognition (Fischer and Zwaan, 2008) and academic achievement in junior school (Jaakkola, Hillman, Kalaja and Liukkonen, 2015).

We might pause and note that this looks like 'kinaesthetic learning'. Although there is evidence that labelling children as having particular learning styles and teaching them using their one preferred mode is not helpful (see CCF 5.6), teachers may have developed creative kinaesthetic teaching learning strategies are a valuable means of embodied learning.

Questions for Practice

How might good models connect abstract ideas with learners' concrete/sensory experiences?

How might teachers make use of an embodied view of cognition to support learning?

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CCF 4.4

Guides, scaffolds and worked examples can help pupils apply new ideas, but should be gradually removed as pupil expertise increases.

Interpreting the Statement

Guides and worked examples are thought to support learning because they address the issue of cognitive load (Cooper and Sweller, 1987; Sweller and Cooper, 1985). This early research (which has since been replicated in a number of studies: Bokosmaty, Sweller & Kalyuga 2015; Paas & van Merrienboer 1994; Quilici & Mayer 1996; see also this meta-analysis by Crissman, 2006) showed that pupils taught with worked examples learnt more quickly, and were more able to transfer the knowledge to solving novel problems, than pupils who were required to work out how to solve the problems themselves. The theory behind this 'worked example effect' is that undirected problem solving inhibits the ability of the learner because it places a heavy load on working memory, making it harder to transfer it into their long term memory. Worked examples reduce the load on working memory and thus facilitate long term learning.

To learn how to do this trainees should be: 'Observing how expert colleagues break tasks down into constituent components when first setting up independent practice (e.g. using tasks that scaffold pupils through meta-cognitive and procedural processes) and deconstructing this approach' and in their own practice be supported to use 'modelling, explanations and scaffolds, acknowledging that novices need more structure early in a domain'.

Any form of teacher guidance raises the question of how teachers should 'handover' to the pupil to apply the strategies. Kirschner and Hendrik (2020) are in favour of a pedagogical approach that of 'guidance fading' rather than an abrupt switch to independence. In our experience, this is what teachers aim to do and it requires considerable professional judgment.

External Links

Dylan Wiliam - Teacher Reflective Practice (4 minute video)
From concrete to abstract maths (blog)
Ideas for how to reduce cognitive load in the classroom (Australian government guidance)
Research behind cognitive load theory

Going Further

Bruner's idea of scaffolding (Wood, Bruner and Ross, 1976) is familiar to educators, arising from the work of Vygotsky on the zone of proximal development. We know that humans are social learners, and that the support of a more knowledgeable other can help us build new knowledge. Concrete examples can initially be easier to grasp and are a good way of introducing new concepts, however we know it is hard to transfer knowledge from one domain or example to another, and the concrete approach is less flexible than the use of symbols, which, because they are abstract, can be applied to a range of novel situations. There is evidence that a mixed approach called 'concreteness fading' works best. New ideas are initially introduced in a concrete way and then gradually moved towards the abstract. In this way the teacher scaffolds the learning.

An example of this (Fyfe, McNeil, and Borjas, 2015) was an experiment in teaching the maths equivalence concept (i.e. that 5 + 3 = 3 + 5). Pupils were either taught entirely with concrete materials (objects and balancing scales), entirely using abstract symbols (5 + 3 = 3 + ?), or in a concreteness fading approach which moved from concrete objects, to pictures of objects, to abstract symbols (numeric representations). It was found that the latter was most effective in helping children solve similar but novel problems, thus demonstrating transfer. It is thought that this approach is effective because it avoids cognitive overload.

Scaffolding is difficult to measure (van de Pol et al 2010) and so researching it often requires detailed, situated descriptions. We suggest that scaffolding is easier to describe in theory than to do well in practice. From their careful analysis of 30 trials in which children aged 3-5 were supported by a teacher to build a particular structure with wooden blocks, Wood et al (1976) characterised scaffolding as involving recruitment (engagement in the task), reduction in degrees of freedom (simplifying the task or the tutor taking on the difficult aspects), direction maintenance (including motivation and support in risking doing something new), marking critical features (and noticing discrepancies between those and what the child does) frustration control and demonstration (modelling solutions). They also explained what this task means for the teacher: 'Where the human tutor excels or errs, of course, is in being able to generate hypotheses about the learner's hypotheses and often to converge on the learner's interpretation. It is in this sense that the tutor's theory of the learner is so crucial to the transactional nature of tutoring.' (Wood et al 1976:10). There are considerable day to day challenges for teacher judgements 'on the fly', and scaffolding is of course related to formative assessment.

Scaffolding refers to '…the usual type of tutoring situation in which one member "knows the answer" and the other does not,..' (Wood et al 1976:1). If the aim of education is not only to support understanding of existing ideas, but also to develop pupils as citizens who feel empowered to think creatively and to develop change ideas, there is a tension here. We have long moved away from the view of children as 'empty vessels' who need to be filled with information from more knowledgeable adults (Rodriguez, 2012). Arguably, this tension is resolved in Alexander's conception of dialogic education (Alexander, 2010) in which we need both scaffolded dialogues AND open-ended exploration of ideas.

The discussion of scaffolding also takes us back to the difficulties of 'transfer' (CCF 3.8) and the situatedness of learning (Lave and Wenger 1991). As Hobbiss (2018) explains; 'The type of scaffolding that is used may become inextricably linked to the solution that is produced, to the point where the 'partial representation' that we have of the solution is not accessed when the problem is framed differently.'

Questions for Practice

How should guidance and scaffolding be removed?

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CCF 4.5

Explicitly teaching pupils metacognitive strategies linked to subject knowledge, including how to plan, monitor and evaluate, supports independence and academic success.

Interpreting the Statement

This 'Learn that' statement emphasises metacognition in relation to subject knowledge, and seems to focus on metacognition as self -assessment. This may be in part due the increased focus on learning of content rather than a concern with the process of learning that is associated with 'progressivism' (eg. Ashman, 2018). Metacognition can be more broadly understood as a part of self-regulated learning (SRL) and connected with the emotional and motivational dimensions of learning; students take responsibility for their own learning and are active in the learning process. Self-regulation is seen as being comprised of three interacting parts: cognition, metacognition and motivation (Muijs and Bokhove, 2020).

Cognition refers to the information-processing strategies being used such as attention, rehearsal and elaboration. metacognition refers to strategies to control and regulate cognition. Metacognition involves using knowledge about oneself as a learner and knowledge of learning strategies to plan, monitor and evaluate one's own learning. Motivation includes; beliefs about having the tools, knowledge and skills to do the task (self-efficacy) and mindset, interest in the task and emotional reactions in relation to self and the task. As monitoring and regulating cognition is very effortful, the role of motivation is important. Learners need to be able to delay gratification - to recognise that putting in effort that might be uncomfortable now will have benefits later.

Experienced teachers will recognise that much of their role is providing a classroom culture that scaffolds and models SRL: by establishing a noise level conducive to work; by setting expectations through strategies such as showing 'what a good one looks like' or setting out what should be achieved in a time period; by structuring peer and self-assessment; modelling reflecting on learning in a plenary; reminders to focus that help children learn how to concentrate (pay attention) and helping pupils to learn from mistakes. Learners may absorb some of these patterns of work unconsciously, but teachers can support metacognition by actively explaining how these are strategies to support learning - by making them explicit. We also need to remember that we are very bad at judging ourselves - we are biased to see our own work and actions in an overly positive light (Burnett, 2016). This is where having clear expectations and constructive feedback matter to support evaluation.

Guidance on supporting metacognition in the 'Learn how to' section which locates metacognition with scaffolding as follows: 'Plan effective lessons, by: • Observing how expert colleagues break tasks down into constituent components when first setting up independent practice (e.g. using tasks that scaffold pupils through meta-cognitive and procedural processes) and deconstructing this approach'. Also relevant is: 'narrating thought processes aloud when modelling to make explicit how experts think'.

External Links

MOOC Metacognition (8 minute video)

Going Further

The EEF report (Muijs and Bokhove, 2020:25-6) presents three key types of strategies included in self-regulated learning:

- Cognitive strategies, which are to do with the activities a student will undertake while learning, such as rehearsal, reviewing, retrieval practise and spaced learning;
- Metacognitive strategies, to do with the monitoring and regulation of learning, such as planning, deciding which strategies to use, monitoring how successfully a learning activity is going, and adapting strategies based on that assessment; and
- Social-emotional strategies, to do with regulating motivation and relations with others, such as delay of gratification, developing self-efficacy and help-seeking

It is worth noting that measuring metacognition is problematic and no one method exists (Muijs and Bokhove, 2020:19-21). Some argue that domain specific knowledge is essential if learners are to use metacognition to select appropriate tools and strategies for a task and therefore metacognition shouldn't be seen as a separate higher order skill. Not all studies agree; the review by the Education Endowment Foundation suggests that improving SRL and metacognition can lead to improved attainment (Muijs and Bokhove, 2020:25).

The EEF review summarises that explicit teaching of strategies and teacher modelling, such as 'thinking aloud' while problem solving, are essential. However, the report also goes on to argue that in order to develop metacognitive reflection, it is also necessary to develop practise through dialogue and more open-ended, though guided, inquiry work in which pupils are given more autonomy (p33). Neuroatatomically, metacognition is linked with the anterior frontal cortex - drawing together sensory input and preexisting knowledge. This is an example of how the brain is highly interconnected.

If being a SRL depends on drawing on prior knowledge we need to recognise the diversity of that knowledge and its origins in social experience. Although in recognising diversity, we need to avoid stereotyping particular social groups; 'the best evidence suggests that development of metacognition and SRL is related to social background, but that the relationship is no more than modest...' (Muijs and Bokhove, 2020:17).

This focus on the individual learner can draw attention away from social factors affecting learning. For example, delaying gratification depends, in part, on trust rooted in previous positive experiences (Watts et al, 2018). For example, in the child's experience, does waiting patiently lead to a fair share of food or to being hungry? In a school context, does a child's previous experiences of working hard lead to teacher disappointment or recognition? Although supporting SRL is all about giving learners power and control, if associated with unrealistic accounts of society it might accord with Lauren Berlant's notion of 'cruel optimism' that holds pupils responsible for their own success, but also their failures too (Chadderton, 2020). This is part of a wider critique of neoliberal values that locate success and failure entirely within individuals rather than recognising how social structures constrain and support people differently. Teachers might consider how in their professional work they can support both individual development and social justice.

Questions for Practice

How might teachers support individuals (ITE trainees or pupils) in developing metacognition?

How far can we hold individual learners responsible for their own learning?

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CCF 4.8

Practice is an integral part of effective teaching; ensuring pupils have repeated opportunities to practise, with appropriate guidance and support, increases success.

Interpreting the Statement

The value of practice and in particular of regular, spaced practice are introduced in CCF 2.7 and CCF 2.8 respectively. The related CCF 'Learn how to' statement says that: trainee teachers should practice, receive feedback and improve at: 'providing sufficient opportunity for pupils to consolidate and practice applying new knowledge and skills'.

There is growing interest in the idea that regular practice can help move things into the long term memory more effectively. This idea has in part arisen as a result of insights from neuroscience into how we move things from our working memory to our long term memory, and involves something called long term potentiation. It seems that, if a stimulus is repeated several times at spaced intervals, this leads to intercellular signals, which activate genes, which in turn produce proteins that strengthen the sensitized synapses and trigger long term potentiation and coding. In other words, this spaced repetition has a physical and observable impact on the brain, strengthening the synaptic activity - the signals between specific neurons or neural networks - and leads to the creation of long term memories.

External Links

MOOC Retrieval practice (11 minute video)
MOOC Spacing and interleaving (9 minute video)
EEF blog on classroom translation of retrieval practice (short blog)

Going Further

One study, which used insights from neuroscience and behavioural research, designed an approach based on what is known about long term potentiation and long term memory encoding (Kelley and Whatson, 2013). They found that even very short periods of practice can have a big impact. This large spaced learning study, involving over 400 13 - 15 year olds, found that spaced learning appeared to be very effective. Overall, using results from a series of three different experiments, the results indicated that one hour of spaced learning was as effective as, or more effective than, four months of traditionally delivered lessons, covering the same material.

The spaced learning sessions were designed so that three very rapid, intense sessions (from 12 - 20 minutes long) were used, in which the same material was repeated each time; these three sessions were divided by two 10 minute distractor sessions. The distractor sessions had to involve something physical (such as juggling, clay modelling). The results were significant, and the authors suggest that there are educational implications here that indicate a potential mismatch between the neuroscience evidence on how fast we learn, and current educational time scales (also suggested by Tetzlaff, 2012). Whilst this is just one, albeit relatively large, study, which relates to one particular age group subject area and type of testing, it does suggest that further research into the way we deliver detailed educational content is warranted.

Questions for Practice

What evidence is there to underpin decisions about how often practice should take place and with what gaps of time between practices?

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CCF 4.9

Paired and group activities can increase pupil success, but to work together effectively pupils need guidance, support and practice.

Interpreting the Statement

Kirschner et al., (2018) argue that one of the justifications for collaborative learning, where two or more pupils work towards a common goal, is that most of the information we learn is from other people; through imitation, listening to what they say or reading their ideas. If we are unable to obtain the information from others, we test problem solving strategies through trial and error. Collaborative learning can facilitate learning by increasing our ability to collectively process new information due to a 'collective working memory effect'. This can be thought of as a shared working space that combines and connects the knowledge held in the working memory of each individual group member, reducing the cognitive load for each individual. In this way, collaboration can be a scaffold for complex problems or tasks.

However, if members of a group have not worked together before, or are not familiar with how to interact successfully in a particular context, the demands on their cognitive load will increase and their learning will be negatively affected. The collaborative process can be supported by helping group members to share knowledge and information effectively, for example through providing worked examples of the product or supporting the process by assigning group roles. Guidance and support are particularly important for large groups and those with less experience of working collaboratively. The use of 'ground rules' for group work to support 'exploratory talk' has been a successful way forward with this (Littleton & Mercer, 2013).

These points are addressed in the CCF 'Learn how to' statement that trainees should stimulate pupil thinking and check for understanding, by: 'Discussing and analysing with expert colleagues to consider the factors that will support effective collaborative or paired work (e.g. familiarity with routines, whether pupils have the necessary prior knowledge and how pupils are grouped)'. And also 'Receiving clear, consistent and effective mentoring in how to provide scaffolds for pupil talk to increase the focus and rigour of dialogue'.

External Links

Columbia MOOC Reciprocal Teaching - students teaching students (2 minute video)
Why putting children together in groups doesn't always work (blog post 4 minute read)

Going Further

It seems that humans, almost uniquely amongst the animal world, learn by looking at what other humans are doing, and that they also find the experience of shared attention rewarding, and this can be seen at the neural level. In addition to 'mirror neurons', there also seem to be other factors at play. One fMRI study (Schilbach et al, 2009) found that shared attention had an impact in two distinct ways. When the subject was following another person's gaze, this was correlated with raised activation in areas of the brain associated with learning, or perception and cognition (part of the prefrontal cortex). However, when the subject's gaze was being followed by another person, this increased activation in a different area associated with pleasure (the ventral striatum) indicating that this was a rewarding experience. It appears that our brains have evolved to make shared attention pleasurable and useful.

Neil Mercer and colleagues' work on 'interthinking' and the collective construction of knowledge draws on Vygotskian theory and classroom research to propose that through talk we create shared understanding in which teachers and learners are 'tuned in' to each other and that it is in this 'intermental development zone' that educational activity takes place (e.g. Mercer, 2002). It will be interesting to see how neuroscience research explores the issues of joint meaning making as research techniques develop and move beyond the emphasis on individuals in an MRI scanner.

Questions for Practice

How do ideas about 'the social brain' help us understand what might be happening during group work?

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CCF 5.1

Pupils are likely to learn at different rates and to require different levels and types of support from teachers to succeed.

Interpreting the Statement

Every brain is different. An important feature of human brains, is that they seem to be evolutionarily adapted to continually adapt; we grow our brain in response to the environment - both physical and social - into which we are born (Fine, 2017) (see also CFF 2.1 on neuroplasticity). Brain development in children is an epigenetic process. There are a sequence of events that occur to trigger brain development (Dehorter and Del Pino, 2020) triggering processes to sacrifice neurons and connections or to increase production of myelin (the substance that makes white matter, developing neuronal nets proximally and distally). The consequence of this environmental influence for learning is that you can never be sure when looking at a child who shares an exact birth date with another child in your class that the two are equivalent. One child might have hit milestones more efficiently whereas the other might have received poor nutrition (Schwarzenberg and Georgieff, 2018; Mattei and Pietrobelli, 2019; Ekstrand et al., 2020) or experienced an adverse early life experience (e.g., Kolb, 2009; Kimple and Kansagra, 2018; Little and Maunder, 2020). Any child's emotional and cognitive development is on a trajectory, and in a class of 20 children, it would not be unexpected if they were each on a different trajectory.

In this picture, concepts such as dyscalculia are based on identifying particular, similar, behavioural manifestations such as difficulties with understanding and manipulating numbers. While a label may have some use in helping to identify common issues and provide appropriate support, it may also oversimplify and lead to unhelpful matching of off the peg solutions to 'problems'. There should be no single way of helping children overcome a developmental trajectory problem; this is not a logical expectation. Every child might require something different to another - brains are individually and experientially grown, after all. One size fits all cannot work without understanding more about the mechanisms that trigger brain changes. Many neuroconstructivist theorists propose that adolescence begins around 10-11 and ends somewhere between age 20-24 (Sawyer et al., 2018). The brain has periods of quite drastic change during this time span and some of those changes were triggered before birth or in perinatal events.

Neurodiversity is a useful term but we typically only use it to refer to people at either end of the childhood spectrum. This isn't necessarily helpful because each child will have cognitive, emotional or even structural brain changes. There is the forgotten middle, who will also have their own neurodiversity, albeit perhaps not as extreme as those at the extremes, but still changes that make life including education more challenging. Sometimes diversity is expressed in terms of diagnoses such as ADHD, autistic spectrum, dyslexia, dyscalculia. Other times they are expressed in internalising disorders such as anxiety or depression or externalising disorders such as self-harm or conduct disorder, (Oerlemans et al., 2020). Each of these processes may have been triggered as a result of different developmental trajectories and each child affected is by nature, neurodiverse. Every child is different and, of course, each deserves a good education.

Many of the ‘Learn how to’ statements in the CCF5 would be relevant to this overarching position including: ‘Making effective use of teaching assistants and other adults in the classroom; Making use of well-designed resources (e.g. textbooks); Planning to connect new content with pupils’ existing knowledge or providing additional pre-teaching if pupils lack critical knowledge: Building in additional practice or removing unnecessary expositions: Reframing questions to provide greater scaffolding or greater stretch’, and most importantly: ‘Applying high expectations to all groups, and ensuring all pupils have access to a rich curriculum’.

Tutor resources for PGCE: SEND Every brain is different seminar

External Links

Amanda Kirby talks about Neurodiversity (45 minute webinar)

Going Further

The brain is a physical entity, so that as well as indirect links between neuroscience, psychology and education, there are also more direct links between neuroscience and the capacity to learn, because of the metabolic constraints of this biological organ of the body (Thomas et al, 2019). Each pupil will come to the learning environment with different levels of energy supply, nutrition,stress hormones and the impact of pollution.all of which can influence brain function. Therefore, as well as genetic, motivational, social and economic factors, alongside the impact of educational and wider experiences so far, other factors such as aerobic fitness, diet and air quality will have an impact. Because of this wide range of factors, pupils will not all learn with the same ease or at the same rate, and part of the skill of the teacher will be to find out where each pupil is starting from and what support they need to succeed. Beyond this, each pupil exists within and forms part of a wide network of factors, many of which will be outside of the school, from national education policy to local economic circumstances, all of which will have an impact when interacting with the experiences of each unique individual (Bronfrebrenner, 1992).

One possible way in which educational neuroscience could make a positive social impact is by better understanding of different learning disabilities. If safe and effective programmes could be developed or well-timed interventions provided to individuals, then the impact on those individuals but also on society could be considerable. Martinez-Montez, Chobert and Besson (2016) have edited a collection of articles that illustrate the potential of this approach with examples such as strategies for remediation of dyslexia.

Questions for Practice

How might neuroscience help teachers to understand individual differences between learners?

How might neuroscience help develop timely interventions for learning disabilities?

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CCF 5.6

There is a common misconception that pupils have distinct and identifiable learning styles. This is not supported by evidence and attempting to tailor lessons to learning styles is unlikely to be beneficial.

Interpreting the Statement

The learning styles approach is one of the better known examples of a neuromyth, and led a number of scientists to challenge it in an open letter to the Guardian in 2017. Despite this, it is an idea that clings on and is still widely discussed in teaching. The argument against learning styles is not that it is bad to use a range of styles to teach new ideas, but rather that the evidence does not support the need for teachers to match teaching styles to individual pupil's preferred learning styles. There is no robust evidence showing that (even if we did this accurately) it leads to improved learning outcomes (Aslaksen and Loras, 2018; Nancekivell, Shah, & Gelman, 2020). It appears that this is partly because we are not especially good at identifying specific learning styles, partly because definitions are vague, and partly because these things are not set in stone - we all tend to prefer a range of different ways of learning and teaching approaches at different times and for different subjects.

The CCF states that trainees should discuss and analyse 'how they decide whether intervening within lessons with individuals and small groups would be more efficient and effective than planning different lessons for different groups of pupils. This might be achieved by observing how expert colleagues adapt lessons, whilst maintaining high expectations for all'.

Bath Spa University PGCE Activity for Students - a critical look at learning styles
Bath Spa University PGCE Activity for Students - a critical look at 'left brain/right brain'
Bath Spa University teaching and learning resources for teaching about neuroscience and challenging neuromyths

External links

Guardian article 2017 Teachers must ditch myth of learning styles
Dan Willingham Learning styles do not exist (7 minute video)
Willingham - Clarification are Learning Styles do not exist (but differentiation is good) (2 min video)
Paul Howard Jones Introduction to the Learning Brain (6 minute video)

Going Further

The learning styles myth has been very influential in education, with a thriving industry producing a number of commercial products for schools (Pashler et al., 2008). It has been widely accepted and believed, and this has been exacerbated by 'confirmation bias', where we seek out information that confirms our beliefs and ignore any contradictory information (Willingham, 2010). This neuromyth may have arisen from the idea that since different modalities are processed in different areas of the brain, individuals will process certain modalities more efficiently than others (Howard-Jones, 2010). This perception might be supported by studies suggesting that teaching in varied modalities can aid learning.

For example, it was found that performing actions or gestures when learning new vocabulary can aid learning when compared to reading or listening (Zimmer et al., 2001). It is also true that learners are individuals, with particular strengths and interests, and that teachers should take these differences into account (Willingham, 2010).

However, despite the extensive literature on learning styles, few studies have used a methodology able to test the validity of learning styles applied to education, and, of those that did, several found results that contradicted this approach (Pashler et al., 2008). Although students may have preferences, there is little evidence that teaching to one 'preferred' style is beneficial, and this may even be detrimental to learning (Coffield et al., 2004; Kratzig and Arbuthnott, 2006) since we do not learn through one sense alone, and this contradicts what is known about the interconnectivity of the brain (Geake, 2008). It is argued that educators should present information in the way that is most appropriate for the content and context, taking prior knowledge, strengths and interests of pupils into account (Willingham, 2010).

Other common neuromyths include that environments rich in stimulus improve the brains of preschool children, that there are critical periods in childhood after which certain things can no longer be learned, and that the right or left cerebral hemisphere is dominant (OECD, 2002). Additional neuromyths that have been used in studies of educators include that humans only use 10% of their brains and that drinking less than 6-8 glasses of water per day can cause the brain to shrink (Howard-Jones et al., 2009). These myths often originate in scientific findings but have been misinterpreted or over-simplified, and may have a detrimental impact on teaching practice (Dekker et al., 2012), although recent evidence suggests that belief in neuromyths does not make a good or bad student teacher (Krammer et al 2020). It is argued that limited educational resources should instead be used to adopt educational practices which have a strong research base (Pashler et al., 2008).

Challenging neuromyths can be a useful way into introducing elements of neuroscience into initial teacher education by both taking a critical consumer approach that looks at how to evaluate brain-based claims (McMahon et al, 2019). In addition to providing trainee teachers with ideas about the brain that help explain why teaching works (or doesn't), arming trainee teachers with a basic understanding of the brain dispels some existing neuromyths and might protect them from developing myths in the future (Howard-Jones et al., 2020).

Questions for Practice

How can we support multimodal approaches learning without reinforcing the learning styles myth?

How trainees might be best prepared to avoid them holding 'neuromyths' or developing new ones?

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CCF 7.3

The ability to self-regulate one's emotions affects pupils' ability to learn, success in school and future lives.

Interpreting the Statement

The ability to self-regulate can involve impulse control, or can involve the ability to deal with stress. Firstly, impulse control, or the ability to delay gratification and wait for a greater longer term reward by resisting a short term reward (as in the famous pre-school marshmallow test; Mischel, Ebbesen and Zeiss, 1972) is often regarded as predictive of longer term success in a number of areas, from dieting to education. The CCF states that trainee teachers should 'support pupils to master challenging content', and see success in school in relation to 'their long-term goals'.

Learning can be hard, and there are often more rewarding options on offer: those who can resist these and stick to the learning are likely to be more successful. It seems that the ability to control what is being attended to is key here - in the marshmallow test, those who could move their attention away from the immediate reward and distracted themselves (for instance the children who sang, or looked away from the marshmallow) were more successful in resisting. The ability to do this is not limitless, and is prone to fatigue, with some evidence that this is linked to blood glucose levels (lower glucose means less ability to self-regulate).

The marshmallow test has been revisited since the original 1970s experiments, and it is clear that there are many factors at work here which need to be taken into account, such as the child's life experiences and expectations (de Neubourg et al., 2018). For instance, for a child whose life experiences so far suggest that the marshmallow may in fact be taken away before the end of the experiment, the sensible option would be to grab it right away. One recent study in China (Ma, Zeng, Xu, Compton, Heyman, 2020) has suggested that there is also a social element at work here, finding that children behave differently depending on who they think will find out what they did. It appears that some children in China are more likely to resist temptation if they think their peers will find out what they did, and even more so if they think their teacher will be told.

External Links

Marshmallow test and executive function (7 minute video)
Revisiting the marshmallow test 2020 (BPS digest, short article)
Self-regulated learning and metacognition Columbia MOOC (5 minute video)

Going Further

Students who can self-regulate may be better at managing their emotional responses to challenging situations. There is growing evidence of links at neural level between emotion and learning, confirming what many teachers will have experienced in the classroom. The functioning of the amygdala (linked to emotion) is affected by stress levels, because these trigger hormonal responses which have an impact on the amygdala, and this in turn has an impact on how memories are formed (because the functioning of the amygdala has an impact on the hippocampus). Those learners who can control and regulate their stress levels, for example during a test, are likely to find it easier to learn, remember and use information.

Some recent research has found that students with maths anxiety under-performed in tests, not through lack of skills or understanding, but because of reduced working memory capacity induced by stress.

Some people seem to exert good self-control with little effort - think of people you know who are healthy eaters. Psychological research suggests that self-control may reflect the formation of productive habits and that this in turn reduces the need for effortful self-control (Galla and Duckworth 2015; Fiorella, 2020). Focussing on disrupting bad habits and creating an environment that supports building good habits may be more productive rather than focussing on building motivation, or will-power (Fiorella, 2020) Teachers could consider how they can support the development of productive habits related to learning both within and beyond school.

Questions for Practice

How should teachers respond to children who have difficulty with self-regulation?

How might daily classroom life promote the building of good habits?

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CCF 7.6

Pupils are motivated by intrinsic factors (related to their identity and values) and extrinsic factors (related to reward).

Interpreting the Statement

Some teachers are uncomfortable with offering external rewards, partly because not only can they be cumbersome to administer fairly and effectively, partly because the evidence for their effectiveness is mixed, and partly because of a sense that intrinsic rewards are more important. It is stated in the CCF that trainee teachers should learn 'how to support pupils to journey from needing extrinsic motivation to being motivated to work intrinsically'. It can be hard to untangle whether it is the reward itself, or the increased attention it engenders, that is the cause of success, and there is some evidence that offering a reward can be counter-productive, for instance being paid for something people do as a hobby, such as playing an instrument, can put them off doing it (Kohn, 1999).

Our response to reward appears to be quite complex. Being rewarded for doing something that is perceived as easy can sometimes be off-putting and it appears that achievements which involved significant effort can be seen as more rewarding than the same result with little effort (Inzlicht,Shenhav and Olivola, 2018).

However, there is some evidence at a neural level for positive links between reward and successful learning, as there are links between reward, attention and memory. Trainee teachers should establish 'a supportive and inclusive environment with a predictable system of reward and sanction in the classroom' to develop an environment that is both safe and positive. Because there is more sensory information available than we can consciously attend, we have to decide (consciously or unconsciously) what to pay attention to, and without attention we cannot learn.

External Links

Paul Howard-Jones, 2020 Engagement (12 minutes, video)

Going Further

Our brains have evolved to pay attention to what is rewarding - however, it is the nature and definition of reward that can make this area so complex. Cognitive psychologists consider 'reward' to include social as well as material factors, so shared attention can be a strong motivator, or reward.

Motivation can be seen as the approach to (rather than withdraw from) stimuli. In the midbrain, there is an area called the nucleus accumbens (within the ventral striatum) which shows increased dopaminergic activity when humans experience pleasure and is a motivating factor in the approach response. It is possible that if this pleasure response can be triggered by the use of rewards in learning, leading to higher levels of engagement and motivation, then learning will be more successful. There is some evidence for this in gaming studies (Howard-Jones and Jay, 2016).

However, Kim (2013) explains that pleasure and enjoyment in the moment (liking) are not enough to account for intrinsic motivation that might support the learner to go through discomfort in order to reach a wanted goal. This distinction between 'wanting' and 'liking' is helpful and challenges notions of 'intrinsic reward'. Interestingly, there is no neuroscientific evidence that intrinsic and extrinsic rewards are different in a biological sense. The distinction between liking and wanting means that how we predict what might be rewarding is important and so is our judgment of whether the reward will be enough to be worth delaying gratification. Reward in the classroom could include: positive feedback, praise, an interesting activity, diversity or novelty, utility, relevance, social support, with rewards being varied and sometimes unexpected (Kim, 2013). Kim also recommends that teachers help children to see the hierarchy between close goals and more distant ones and suggest that providing choices could support learners in understanding the value of activities and evaluating their own decision making.

Questions for Practice

How might we help motivate learners to engage in activities for learning?

What kinds of rewards and understanding of reward might help learners to sustain their engagement (even when they don't immediately enjoy an activity)?

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Pupils' investment in learning is also driven by their prior experiences and perceptions of success and failure.

Interpreting the Statement

We know that the areas of the brain involved with emotion (the amygdala) and memory formation (the hippocampus) are located close to each other, and evidence indicates that they have a reciprocal relationship - strong emotion can either help or hinder us from forming memories, just as memories can have a positive or negative impact on our emotions. There is, therefore, a growing understanding that emotions and learning in an academic context are closely linked. For pupils who have experienced failure at school, this can have a negative impact on their ability to learn in the future, as negative emotions such as stress reduce the effectiveness of working memory, hampering new efforts to learn.

Equally, there is evidence that experiencing success can make future learning easier, as pupils associate learning new things with reward and success. However, these things are not set in stone, and there is growing evidence of the malleability of the brain. Experiences, emotions and social contexts shape neural connections and perceptions of success and failure, so it is incumbent on us as teachers to help move our learners from a sense of failure to a sense of success.

According to the CCF, trainee teachers should achieve this by 'discussing and analysing with expert colleagues effective strategies for liaising with parents, carers and colleagues to better understand pupils' individual circumstances and how they can be supported to meet high academic and behavioural expectations'. In the classroom, this includes 'establishing a supportive and inclusive environment' and supporting pupils to both master challenging content and to see how their long-term goals are related to their success in school.

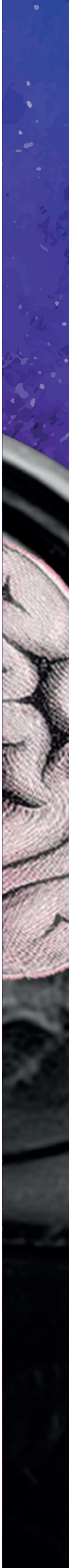
External Links

[David Daniels and Daniel Willingham Growth mindset: Is it really THAT easy?](#)
(25 min podcast)

Going Further

There are some studies that show that previous failure in maths can trigger maths anxiety, which then triggers a heightened response in parts of the brain associated with threat and pain (the bilateral dorsal posterior insula) when faced with an upcoming maths task (Goetz et al, 2013). Nicolson, in his work on dyslexia, calls this a toxic cycle, in which children who experience repeated failure at school end up with a sense of learned helplessness which can then extend beyond the initial subject and to the experience of school itself. He argues that until this negative reaction can be replaced with a more positive sensation, even the most effective teaching will be ineffective.

Carol Dweck has argued that helping children to develop a growth mindset, in which they understand that effort and learning can physically change the way their brain is working, can help close the achievement gap. Dweck (2012) says that effort alone is not enough, it needs to be an effective effort that leads to learning - and she also suggests that it is possible to appear to espouse a growth mindset whilst actually having a fixed mindset (Dweck, 2015).



There is mixed evidence for the impact of growth mindset, and the interplay with intrinsic motivation, but it has been suggested that this is a promising area for further research, with a need for a better understanding of the neural correlates of both (Ng, 2018).

Bath Spa University PGCE Student Activity - a critical look at Mindset

Questions for Practice

How might teacher language used in the classroom and with parents support honest and constructive dialogues about children's progress?

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Engaging in high-quality professional development can help teachers improve.

Interpreting the Statement

In this section we offer 3 provocations for thought from authors who have explored scientific accounts of learning and worked with teachers to develop their practice.

University of Bristol PGCE - Using Science of Learning Concepts in mentoring dialogues
The Science of Learning in Initial Teacher Education (SoLFiTE) project based at the University of Bristol and led by Paul Howard-Jones has explored how to support trainee teachers in using concepts from the Science of Learning. It includes videos that illustrate using their EBC (Engage/Build/Consolidate) framework to support mentoring dialogues that go beyond superficial performative features to focus on pupil learning.

Dylan Wiliam: Teacher Reflective Practice (4 min video)
In this clip Dylan Wiliam talks about how to create a culture of continuous improvement.

Mike Hobbiss: Habit Formation and Teacher Development (58 min video)
This talk explores how teachers' learning curve tend to plateau after the first few years and how this may be due to the automation of frequent actions as habits. He suggests that the persistence of unconscious habits may explain why much knowledge-focussed CPD is not successful in changing teacher behaviour, whereas coaching appears to be more successful. The discussion with the audience is interesting too as it considers other factors such as the school environment and teacher motivation and leads into ITE as well as CPD.

Hobbiss, M., Sims, S. and Allen, R. (2020) Habit formation limits growth in teacher effectiveness: A review of converging evidence from neuroscience and social science. Rev Educ. doi:10.1002/rev3.3226

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