INSTITUTE FOR TEACHING

Learning

What is it, and how might we catalyse it?

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Version 1.1, 21st June 2018

Contents

Introduction

Learning is important. It is the mechanism that enables us to adapt to our environment, to survive and succeed in the world. All life learns in one form or another – what marks us out as humans is our capacity to learn from our predecessors (Harari, 2014), to capture and communicate information critical for our survival and success as a species.

Over time, the amount of information we must pass on to the next generation has grown. Some of this is quick and easy to learn instinctively, but much is not (Geary, 2007). As a result, we have created processes and organisations dedicated to this endeavour.

This is *one* of the reasons that schools and teachers exist. We work to broaden minds, enrich communities and advance civilisation (Spielman, 2017). The more we know about learning and how it works, the more likely we will be able to make it happen (Willingham, 2017b). Without an understanding of the how learning works, we remain limited to imitating what others have done before us.

This paper attempts to provide a coherent, high-level overview of what learning is and how we might catalyse it – organised around nine *insights* with a taste of the *implications* of these insights for our classrooms[1]. It has been produced to share our thinking, guide our programmes, and stimulate discussion around the nature of learning and teaching.

Whilst learning and teaching are hugely important, they are also vastly complex. We recognise that we have lots to learn, and welcome your support and suggestions to help make this 'Version 1' *even better*.

Thank you to everyone who has generously provided feedback to date[2]. All errors that remain are mine. If you have questions, comments or suggestions, please *do* get in touch – we'd love to hear from you.

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[1] Practising teachers are arguably those in the best position to fully flesh out the implications of these insights. This is a big part of what we do on our *Masters in Expert Teaching programme*.

[2] Including Marie Hamer, Harry Fletcher-Wood, Katy Patten, Jacynth Bennett, Emma Mccrea, Nick Rose and Kyle Bailey.

Insight 1 Learning is a persistent change in knowledge

Learning is an unwieldy term, because it attempts to describe both a *process* and a *product* (Alexander *et al.*, 2009). We refer to learning as something we *do*, as well as something we *end up with*. We can immediately sharpen the precision of any discussion about learning by teasing apart these two aspects, referring to the process of learning as *thinking*[3] and the product of learning as *knowledge*. It can also be useful to think about *information*, in the broadest sense – emerging from both our environment and our experience – as the *raw material* of learning.

Knowledge is information that exists in our mind, in our long-term memory. We often refer to this as beliefs, understandings, identities, skills, mindsets, facts and more. It represents what we know, who we are, and guides how we act.

Our knowledge is constructed as *mental models* of the world. Mental models refer to *what we know and how that knowledge is organised to guide our perception, decision and action*. All models are incomplete, but some are more *useful* than others. The better our mental models predict the world around us, the more effectively we can steer our lives (Berliner, 2004), and the more likely our decision and action will lead to survival and success, both for ourselves and for our communities (Geary, 2007).

The aim of learning is to generate a persistent change in knowledge (Kirschner *et al.*, 2006). Thinking is the process that leads to such a change, a process governed by our working memory. We attend to information in our environment (or in our minds) and in attempting to make sense of it, we alter the very fabric of our memory (Cowan, 2010).

What we can attend to and make sense of is limited by what we know. The more we know, the better we can think, and the better we think, the more we can know. This chicken-egg relationship is known as the Matthew Effect[4], and is the fuel that powers the engine of education (Rigney, 2010).

Implication 1.1

Increase the life chances of your pupils by helping them build useful mental models. Create persistent changes in pupil knowledge by harnessing, directing and catalysing pupil thinking. The rest of the paper will explore how we might achieve this.

[3] Where I use the word learning in the remainder of this paper, it refers to the *process* definition.
[4] An effect of accumulated advantage, eg the rich get richer and the poor get poorer.

Insight 2 Some things are easier to learn than others

What we know influences our chances in life. However, some things are easier to learn than others. Certain kinds of information have been highly stable for long periods of time (let's call this *instinctive information*), and over a great many generations we have evolved efficient mental mechanisms for processing it (Geary, 2007). This is why we find it easy or 'instinctive' to learn to speak, recognise faces and build relationships. In fact, we are so good at learning instinctive information that we can often get by without being formally taught it.

Other information has been generated relatively recently by our ancestors. This *cultural information* is equally vital to our success, but we have not yet had time to evolve efficient mental mechanisms for processing it (Harari, 2014). Instead, we have developed sophisticated social and technological approaches for *using our instinctive information processing capabilities to learn this cultural information* (Geary, 2007).

This is one of the reasons that schools and teachers exist, and why our curricula prioritise domains like reading, mathematics and history – knowledge that is critical for our individual and collective survival but is hard to acquire without support. The greater the gap between cultural information and instinctive information, the greater the need for explicit teaching[5].

It is important to remember that our capacity to learn from cultural information is limited by our instinctive information processing abilities. The better we can speak, build relationships and read body language, the more readily we are able to learn history and mathematics (Geary, 2007). Finding the right balance between these competing yet complementary concerns is a critical endeavour for schools and teachers.

Implication 2.1

Prioritise learning of the most valuable cultural information in your classroom. Recognise that developing instinctive information capabilities can contribute to this goal, but that this may require less explicit teaching.

[5] As a result, this paper deals predominantly with the challenges of helping pupils learn valuable cultural knowledge.

Insight 3 What we attend to is what we learn

We learn what we think about, and what we think about is determined by what we attend to (Schweppe & Rummer, 2013). *Attention* is the primary gatekeeper of learning and so the ultimate commodity of our classrooms. A large part of our job as teachers is to harness and direct attention.

Implication 3.1

Actively monitor and manage attention to focus on the right things[6] at the right times, to help pupils build useful mental models.

Our attention can be directed externally, towards information in the environment or internally, towards our own thinking and knowledge. There are many things that compete for our attention externally, particularly in the information-rich environment of our classrooms (Fisher *et al.*, 2014). This information exists in multiple guises:

- text or images in a book
- the speech or gestures of a peer
- the texture or structure of our physical environment
- our own thoughts and feelings about lunch

Filtering through this information incurs a cost on our limited mental resources and performance (Willingham, 2017a).

Implication 3.2

Where possible, eliminate redundant information and distractions in the environment. These include social distractions (eg peers or other adults), environmental distractions (eg display boards or clocks), activity distractions (eg irrelevant images or tasks), or internal distractions (eg performance anxiety, mind wandering).

Pupil attention can be directed externally in various ways. We can: tell our pupils what to look for; point, gesture or even gaze at something; use tone to emphasise the most salient aspects of an explanation (Mccrea, 2017). Our environment can be leveraged to direct thinking towards particular information – we can dim the lights, or use a spotlight or pointer.

Implication 3.3

Actively direct pupil attention, using the most appropriate tools at your disposal (eg voice, hands, body, lights) with regard for the attentional sensitivity of your pupils.

[6] Whatever it is we intend our pupils to learn.

We can also direct pupil attention internally, towards particular parts of *their* thinking or knowledge. This is an important strategy for multiple reasons, and is most easily achieved by *posing questions*. Questioning enables us to:

- accurately build on what pupils already know (see *Insight 7*)
- activate relevant prior knowledge in preparation for elaborating it (see *Insight 5*)
- help pupils to make sense of what is being explored
- consolidate existing understanding (see *Insight 9*)
- support pupils to monitor and regulate their own thinking (see *Insight 4*)

It is little surprise that questioning is such an integral part of teaching.

Implication 3.4

Use targeted questioning to direct pupil attention internally. Tailor the kinds of questions you ask to meet the purposes you wish to serve.

Insight 4 We can only attend to a few things at once

We are only able to attend to a few pieces of information at any one time. If we are merely attempting to hold a string of simple digits in our mind, then we could attend to about seven. However, for anything more complex our capacity drops sharply. Thinking works best when we attend to no more than two or three interacting pieces of information at once[7] (Sweller *et al.*, 2011). Multitasking is a myth – in reality, we are *task-switching*, and this regular redirection of attention comes at a cost (Hattie & Yates, 2013).

Implication 4.1

Identify and prioritise the 2-3 things you want your pupils to be thinking about at any one time. Eliminate unnecessary tasks and don't make them hold too many things in their heads at once (eg analysing a passage whilst listening to it, or trying to follow instructions whilst remembering them). Avoid multitasking.

Information can be represented in various modes (eg speech, text, diagrams or images). These different modes influence how we are able to *think about* the information they carry. For example

- we don't have to hold *text* in our heads
- *speech* can also carry non-verbal information
- *diagrams* are good at exposing the connections between elements (Clark *et al.*, 2006)

We are able to process visual and auditory information simultaneously (eg someone narrating a video), but processing the same information via both modes can disrupt attention (eg reading aloud from a slide show).

The way information is *organised* also influences how we are able to think about it. Pieces of information that are situated close together are easier to attend to at any one time (Clark *et al.*, 2006), and ideas wrapped up in narrative are more readily grasped (Willingham, ND). The optimal mode and amount of information to present depends on the prior knowledge of the pupils we are working with.

Implication 4.2

Be intentional about the mode (and combinations of modes) you draw on to represent and communicate information. Keep related elements close, and use visual hierarchy to expose underlying information structures. Tailor your exposition to the expertise of your pupils.

[7] This is the basis of *Cognitive Load Theory* (Sweller *et al.,* 2011).

There are times when we *need* to present multiple pieces of information at once to move pupil understanding forward. In cases where this might overload the mental capacity of our pupils, we can seek to scaffold some of their thinking.

For example, giving certain pupils a *times-tables grid* or *writing frame*, or encouraging them to *write down their workings*[8] can free up mental resources to focus on the most salient aspects of a multi-component problem. However, these kinds of scaffolds are best seen as temporary fixes (Brown *et al.*, 2014). Building such capacities *within* the long-term memories of our pupils puts them in a much stronger position for the future – we think *with* knowledge, not just *about* it. The ultimate way to free up further thinking capacity is to have more extensive and better organised mental models (see *Insight 5*).

Implication 4.3

In complex tasks, offer pupils (who need them) scaffolds so they can focus their thinking on the things they are trying to learn. Provide and encourage the use of 'thinking surfaces' (eg mini-whiteboards, sections in exercise books, or even classroom desks[9]). Build knowledge in parts and bring them together over time to gradually eliminate the need for scaffolding.

We are able to control our *own* attentional processes to a certain degree. This requires us to attend to our thinking and so consumes valuable mental resources that could be used for learning. Self-regulation can improve our capacity to learn independently, but comes at an initial cost (Ambrose *et al.*, 2010).

This cost reduces with age and experience, as we develop the cognitive architecture and habits required for efficient self-regulation. The usefulness of our self-regulation depends on how accurately we are able to assess our own understanding, something which is not easy to do well (see *Insight 6*).

The internal dialogue we use when monitoring our thinking is also an important factor, particularly if it generates too much of an emotional response (Krakovsky, 2007). Getting over excited or anxious about the consequences of our performance can limit it (see *Insight 6*).

Implication 4.4

Build pupil self-regulation slowly, over time. Don't expect pupils to be able to be effective self-regulators without practice – instead, take responsibility for managing their range of possible actions. Share learning goals with pupils and get 'buy in'. Encourage your pupils to think 'how can I do this', rather than 'can I do this'?

[8] Of course, in cases where pupils are unable to write fluently, this strategy will generate an unhelpful load.
[9] Where they are wipe-clean of course!

Insight 5 What we know determines what we can learn

Our capacity to attend to something is influenced by our knowledge of it, and how recently we've been thinking about it. We find it much easier to perceive or *see* things we have a frame of reference for. This is what makes something *meaningful* for us. It's hard to spot the 'Plough' in the night sky if we don't know about constellations. And if we've recently bought a red coat and look into a crowd, we are likely to notice more red coats than usual (Brown *et al.*, 2014).

Implication 5.1

Teach pupils new ideas by using what they already know. Activate or 'warm up' relevant prior knowledge before building on it.

Although we can only attend to a limited number of elements of our own knowledge at once, there is no limit to how *complex* these elements can be (Willingham, 2010). To read this sentence we don't have to process each letter individually – we have internalised various combinations of letters as words, which each have separate meanings. Each of these meanings is connected to a host of further concepts which together allow us to rapidly make sense of what each sentence is trying to convey.

The more information each of these knowledge networks[10] contain, the more we are able think about. The amount of information they contain is determined by the number of useful *connections* they possess (see *Insight 8*). The ease with which we can access and think with these elements is determined by how *consolidated* these connections are in our mind (see *Insight 9*). Connection and consolidation are the two fundamental levers of learning.

Implication 5.2

Invest in helping pupils to build increasingly complex knowledge structures. Don't rely on pupils being able to just 'Google' it as they need to have this information in their minds to be able to 'think with it'.

What we know also influences what we *think* we can do and so what we end up learning. If we *think* we can do something, then we are more likely to invest the mental resources required to do it. Our *expectancy* of success is partly influenced by our past success rate in similar situations, but also by the reasons we attribute to those previous successes or failures (Ambrose *et al.*, 2011).

[10] More commonly known as 'schema' in the literature.

Attributing success to *effort* and *smart strategies* – and failure to *bad luck* – increases our expectation of success for similar tasks in the future (and vice-versa). Knowing how learning works, and understanding our 'personal biases' can help us attribute the causes of our achievements more accurately.

Over time, these ideas can influence our perception of *who we are as learners*. Our academic identities *influence* our achievements, whilst at the same time being a *product* of our achievements (Marsh & Craven, 2006).

Implication 5.3

Where possible, help pupils understand how learning works and why you are teaching them the way you are. Support pupils to reflect on and accurately attribute the cause of their achievements. Emphasise the power of study, practice and feedback as dependable ways to learn. Communicate your belief in their potential and hold high expectations. Provide early and frequent success (particularly for novices). Help pupils position themselves as scholars, and build a sense of community around purposeful scholarship within your class.

We find it hard to judge our own and others' learning. We tend to overestimate how much we or others know, and underestimate how long it will take for us or others to learn something (Brown *et al.*, 2014). This is similar for both pupils and teachers, but the less prior knowledge you have, the more pronounced the effect is (Kruger & Dunning, 1999).

Implication 5.4

Regularly sense-check your assumptions about what your pupils know. Delay and seek evidence to support your judgements. Assume your pupils know less than you think, and that it will take them longer to learn than you predict. Provide opportunities for pupil self-assessment, and offer feedback to help them build a more accurate understanding of what they know and don't know. Celebrate increases in self-assessment accuracy over time.

Insight 6 We attend to things we value

Having limited thinking capacity in an environment of abundant information means that we need some kind of mechanism for prioritising what to attend to. Our attention directs our thinking towards information that promises to help us survive and succeed in the world (Geary, 2007). These are the things we perceive to be of greatest *value*.

The more value we place on something, the more attention we will allocate to it. The more mental resources we allocate, the more gritty, determined and resilient we are likely to be in pursuing it.

The more we *know* about something the more likely we are to value it, because knowledge increases the chances that it will find utility in our lives (Hattie & Yates, 2013). This is why younger children tend to exhibit curiosity for instinctive information over cultural information (Geary, 2007).

Implication 6.1

Find out what matters to your pupils, and help them understand the value (for them) of the information you are exposing. Recognise that they do what they do for important reasons (many of which they may not be aware of, but can often be explained from an evolutionary perspective), and take ultimate responsibility for directing them to the most useful information. Don't expect grit or resilience for things pupils don't value or know much about.

Our knowledge of the *value* of information is constrained by our limited personal experience[11], and so we are not always best placed (particularly as novices) to decide where to direct our attention. As a result, we are sensitive to cues from others about the relative value of information – particularly from people we identify with, trust and respect (Hogg & Reid, 2006).

These people vary depending on our stage in life and the goals we're pursuing, but they often include parents, peers and other high prestige individuals (eg idols). The more we feel we belong to a particular group, and share what they value and want to achieve, the more likely we will learn *within* and *from* it (and vice-versa) (Deans for Impact, 2015).

Implication 6.2

Build trust and respect with your pupils. Establish areas of common identity and interest. Show them that you care about what they know, what they value, and what they are learning. Orient your relationship with your pupils around their goals, and use social cues to promote the value of important academic information. Build community by creating a sense of belonging and shared purpose within your classroom.

[11] And biased towards those things that enabled our species to survive and succeed over time.

Emotions can flavour our perception of value, and so guide our attention (Dolan, 2002). How *others* react to something is an indicator of how much they value it. How we *feel* about something is an internal barometer for how important it might be for us. Our emotional state before, during and after an experience can influence what we learn from it (Kiely, 2017).

These mechanisms have evolved to help us prioritise information critical for our survival and success (Geary, 2007). However, they are unlikely to be attuned to cultural information, and emotional signals are partly relative. If someone continually signals excitement, there is a danger that over time, we will interpret that response as neutral.

Implication 6.3

Demonstrate passion for learning what you are teaching, particularly the highest leverage aspects. Recognise that what pupils feel can determine what they attend to. Emotions may be powerful levers for learning, but due to our relatively underdeveloped understanding of how they work in the classroom they should be wielded with caution.

Insight 7 We learn by gradually elaborating what we know

In *Insight 4*, we discussed how we can only think about a few things at once. As a result, we can't just insert an new idea in it's entirety into a corner of our mind that has space – or exchange an old mental model for a new one. Knowledge develops gradually, by *elaborating* what already exists in our minds, one piece at a time. In trying to make sense of new information all we've got to draw upon is our existing knowledge. As a result, we are biased toward information that fits most closely with our existing views[12] (Brown *et al.*, 2014).

Implication 7.1

Teach in ways that build on existing mental models gradually and incrementally. Deconstruct and sequence curricula so knowledge builds in a coherent and cumulative fashion. Assess regularly to enable these approaches. Recognise that pupils will favour evidence and explanations that align with their existing beliefs.

Sometimes the things we are trying to learn build logically and incrementally on our existing mental models. Other times, they require a *leap* in understanding[13]. In these cases, we benefit from 'conceptual bridges' to help us make those leaps. This is where analogies, examples and other concrete representations can be powerful teaching aids (Fyfe *et al.*, 2014). However, it is important to recognise that these tools are incomplete by definition, and so as soon as they have served their purpose, we should gradually withdraw them whilst helping pupils to appreciate their limitations.

Implication 7.2

Draw on what pupils already know to help them elaborate their mental models. Juxtapose, recombine and reason with existing knowledge for fresh insights. Use analogies, examples and concrete representations to teach difficult concepts. Explore the limits of these scaffolds and fade them out as early as possible.

As explored in *Insight 2*, we can develop instinctive knowledge fairly independently, whereas cultural knowledge is harder to acquire without support (Geary, 2007). Left to our own devices we are likely to develop crude and idiosyncratic mental models of cultural information. A more rigorous and efficient way of developing cultural knowledge is to be given access to the most robust mental models refined by expert others.

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[12] This is the basis of 'confirmation bias'.

[13] Sometimes the new ideas we encounter can contradict our existing knowledge (eg as we address misconceptions). However, this new knowledge needs to be strong enough to 'drown out' the old for it to prevail over time (Bjork & Bjork, 1992).

However, expert mental models are extensive and complex and so cannot be accessed wholesale without mental overload. We can reconcile this by providing our pupils with the *most sophisticated model that they can appreciate*, given their prior knowledge, as a kind of a loose skeleton framework which we can then begin to flesh out and refine over time (Mccrea, 2017). Partial conceptions are often a necessary stepping stone towards building more powerful mental models.

Implication 7.3

In learning new cultural information, provide models and worked examples explicitly to pupils, rather than trying to help them discover things for themselves[14]. Give them access to increasingly complex models over time. Offer an overarching big picture before integrating constituent components.

[14] There is some evidence to suggest that particular forms of heavily guided inquiry prior to providing explicit models can enhance learning (eg Loibl *et al.,* 2016). However, these approaches often require high degrees of control and teacher skill, without which they risk pupils developing idiosyncratic knowledge and unhelpful misconceptions (Willingham, 2010).

Insight 8 Understanding arises through connection

Learning can happen in one of two ways: by *forging connections* and by *consolidating those connections*. We'll look at *forging connections* in this chapter and *consolidating connections* in the next (*Insight 9*).

Connections are forged in our memory when we attempt to make sense of the information we encounter. Negative connections are at least as important as positive ones – it is just as important to know what a triangle *isn't* as what it *is*. A variety of positive and negative connections allow us to establish a boundary around an idea or process, and so be more precise in how we think about and use it (Engelmann & Carnine, 1991).

Where information is limited, and connections are not obvious, we seek to fill in the blanks using our own prior knowledge. This is a recipe for misconceptions and idiosyncratic metal models.

Implication 8.1

Focus on helping pupils see and make meaningful connections between what they know and what they are experiencing. Highlight negative links as well as positive. Don't leave out any parts or steps, even though they may seem obvious. Provide opportunities for pupils to ask questions and attempt to make sense of what they are encountering. Ensure pupils have adequate thinking time to seek and establish connections.

The more meaningful connections we forge, the more comprehensive and refined our understanding becomes. The greater our variation of experience, the more abstract and transferrable our knowledge becomes, and the more flexibly we can apply it across a range of situations (Lo, 2012). Sense-making can be supported by our peers, especially those coming from a similar starting point (or just ahead of us in the process).

Implication 8.2

Ensure pupils are exposed to the fullness of an idea or process, building up gradually from a narrow to more comprehensive understanding. Vary guises and situations systematically, changing one aspect at a time to draw attention to and refine understanding in a controlled and gradual manner. Leverage structured peer discussion for sense-making.

As our knowledge becomes deeper and more comprehensive, our capacity for critical thinking, problem solving and creativity within that domain unfolds (Willingham, 2007). At a certain level of expertise, problem solving starts to become a more effective mechanism for learning than being provided with a robust model – because our internal mental representation is sufficient to guide us (Kalyuga *et al.,* 2012).

This is how new knowledge is generated in a field, but we must be careful about conflating what experts *do* with how novices *learn* (Kirschner, 2009). You don't learn to be a mathematician by thinking like a mathematician, and solving problems is not necessarily the best way to become an effective problem solver.

Implication 8.3

Help your pupils to become better critical thinkers, problem solvers and more creative by focussing on building their domain knowledge. Be careful not to conflate how experts develop new knowledge with how pupils learn new knowledge.

Even *if* a class were presented with an almost flawlessly constructed sequence of mental models, the idiosyncratic nature of our prior knowledge means that each pupil would interpret the information in a slightly different way and so forge different connections.

To ensure that pupils are building the most robust and precise mental models, we must systematically and repeatedly expose pupil understanding – and provide corrective, timely feedback. Effective feedback:

- aims to close the gap between what pupils know and the exposed model
- focuses on granular changes that are linked to broader strategies
- targets understanding or behaviour rather than character
- is provided alongside opportunities for further progress (Wiliam, 2015)

Feedback can act as a crutch for learning, and providing too much, too soon, or not withdrawing it over time can inhibit progress in the long run (Fletcher-Wood, 2017).

Implication 8.4

Routinely expose pupil understanding in efficient and reliable ways. Employ feedback with a view to maximising progress in the long term. Align the mode of your feedback (individual, whole-class, self, peer) with the needs of your pupils or class.

Insight 9 Fluency arises through consolidation

For knowledge to be useful it must be sufficiently stable and persistent. However, our mind is an organic network, and connections begin to fade soon after they are formed – as new learning interferes with old[15] (Lustig *et al.*, 2001). Unless we are intentional about mitigating this, we risk our pupils forgetting much of what they learn in our lessons. As well as *forging connections*, we've also got invest in *consolidating those connections*.

Our mental models become stronger in response to being used. We consolidate our knowledge by practising or *retrieving* it – pulling information out of our minds is just as important as putting it in. The more effortful this process is, the greater the strengthening effect, provided the retrieval attempt is actually successful[16] (Bjork & Bjork, 2006).

One way to generate this effort (and so impact) is to space out the intervals between retrieval. *When* we learn appears to be just as important as *what*. The optimal time to retrieve something is just before you forget it, and so we end up with a consolidation pattern of *increasingly distributed intervals*, rather than organising practise as one single block (Bjork & Bjork, 2006).

Consolidation works best when it focuses on what pupils already know, rather than attempting to simultaneously build new connections (Davis *et al.*, 2017), and when the stakes for pupils are relatively low. Zero stakes can lack the incentive for pupils to perform – excessively high stakes can induce anxiety which uses up valuable mental resources.

Implication 9.1

View the core work of teaching as consolidating connections, not just forging them. Consolidate learning by scheduling regular opportunities for retrieval (eg using low stakes quizzes) – during which, do 'nothing new, just review'.

Increasingly spaced intervals are effective at inducing retrieval between lessons. But we can also achieve this *within* a lesson by *interleaving* different topics within a practise activity. Interleaving works by putting knowledge 'out of our mind', and so creates the opportunity to productively retrieve it again (Rohrer & Pashler, 2010). It also pushes pupils to identify the areas of knowledge needed to answer the interleaved question, a critical skill to practise in any domain.

[15] This is an extremely beneficial mechanism - imagine if you remembered everything you ever thought about.
[16] The Bjork's have coined this phenomenon 'desirable difficulties'.

Retrieval works better when fewer clues or 'cues' to the answer are provided. This is why asking questions and setting tests can lead to stronger consolidation than re-teaching or re-studying – although combining the two can be powerful, as long as the test component comes first (Pyc & Rawson, 2011).

Implication 9.2

Interleave content within practise activities (eg make every third question in a set about a different topic). Offer as few cues as possible to induce retrieval (or remove them over time), and follow up with re-teaching or re-studying as required.

The amount of retrieval we need to do depends on the level of fluency we wish to attain. If we just want knowledge to *persist* for several years, then a carefully timed sequence of five-ish retrieval sessions might be sufficient.

If we want that knowledge to become rapidly and easily usable, in a way that minimises the burden on mental capacity, then we need to facilitate regular practice over a sustained period of months or even years (Ambrose *et al.,* 2010). This is a substantial investment and so must be reserved for only the most useful knowledge (eg phonics and times-tables)[17].

Spaced retrieval and interleaving are tools that optimise pupil learning in the long run. However, they don't always *feel* productive in the short term. When we space (and to a certain extent, when we vary) practice, our pupils are likely to make more errors (Willingham, 2017a) and slower progress to begin with (Rohrer & Pashler, 2010).

This is because they are able to lean on fewer of the invisible scaffolds offered by the context of the lesson – by the structure of previous questions, and of recently activated knowledge. This is one of the reasons we need to be cautious when inferring what our pupils *know* by what they are able to *do* at the end of a lesson (Soderstrom & Bjork, 2015). Learning is a long-term endeavour.

Implication 9.3

Schedule retrieval according to the level of fluency you wish to attain. Identify and invest in the highest leverage knowledge (eg times-tables in maths, reading and writing in English). Manage pupil (and your own!) expectations around the perceived productivity of these approaches, and be brave in trusting evidence-informed approaches. Assess progress over the long term for a true indication of learning.

[17] The more fluent knowledge becomes, the harder it is to change and access consciously, and so there is always a balance to be struck between accuracy and stability (Wiliam & Leahy, 2014).

Complementary Readers

For an even more concise summary of the science of learning:

- Deans for Impact (2015) *The Science of Learning*. Available for free online.

And for a superb introductory book on the subject:

- Willingham, D. (2010) *Why Don't Students Like School? A Cognitive Scientist Answers Questions About How the Mind Works and What It Means for the Classroom.* Available at all good book stores.

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