Ambition Institute

# LEARNING:
## WHAT IS IT, AND HOW MIGHT WE CATALYSE IT?

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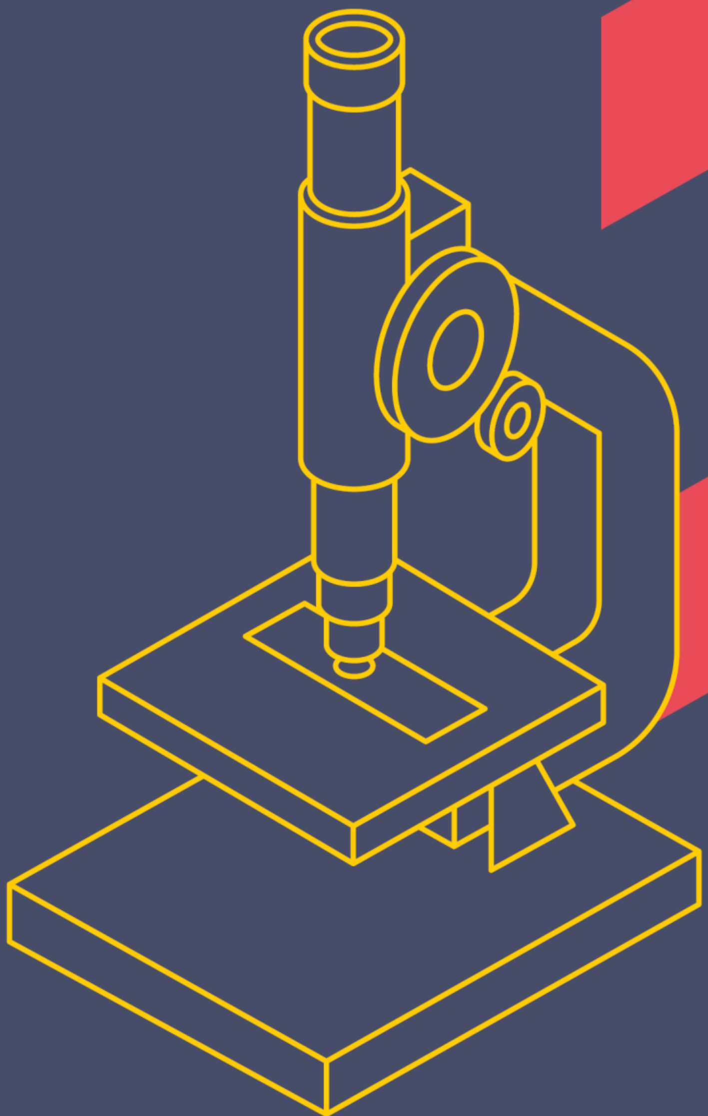

KEEP GETTING BETTER

# 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 cumulatively from our predecessors (Harari, 2014), to pass on knowledge vital 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, but much is not (Howard-Jones, 2018). As a result, we have created processes and institutions dedicated to this endeavour.

This is *one* of the main reasons that schools and teachers exist. 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, 2018). Without a firm grasp of the underlying mechanics of cognition, our practice will remain bounded by intuition, imitation and trial and error.

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 what the *implications* are for our classrooms[1]. It has been produced to share our thinking, guide our programmes, and stimulate discussion around the nature of *learning*.[2]

While learning is hugely important, it is also vastly complex. We recognise that we have lots to learn and welcome your support and suggestions to help make this 'Version 2' *even better*. Thank you to everyone who has generously provided feedback to date[3]. 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] As a result, this paper draws predominantly from the basic sciences, rather than attempting to capture everything we know about teaching.
[3] Including Marie Hamer, Harry Fletcher-Wood, Katy Patten, Jacynth Bennett, Emma Mccrea, Nick Rose and Kyle Bailey.

# INSIGHT ONE

## 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 in schools by teasing these two aspects apart, referring to the process of learning as thinking[4] 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[5] 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 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 (Howard-Jones, 2018).

The aim of teaching is to generate a persistent change in the knowledge in our long-term memory (Kirschner et al., 2006). Thinking is the process that catalyses such a change, a process involving 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[6], and is the engine at the heart 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 and directing pupil thinking. The rest of the paper will explore how we might achieve this.*

[4] Where I use the word learning in the remainder of this paper, it refers to the *process* definition.
[5] It can also exist in books, stories, products etc.
[6] An effect of accumulated advantage, for example: the rich get richer and the poor get poorer.

# INSIGHT TWO

## 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. Our brain evolved over deep history to enable us to develop certain knowledge through natural interactions with others and the environment (Howard-Jones, 2018). Things like language, terrain mapping and social information.

However, our modern world has changed a lot in the last 20,000 years, and radically in the last 200. The knowledge required to survive and succeed has changed too, but our biology has not kept up. These days, it is important to develop knowledge such as reading, mathematics and science, but we find these things difficult to learn without formal instruction. Today's children are expected to learn things that took humankind centennials of accumulated endeavour to achieve (Howard-Jones, 2018).

This is one of the reasons that schools and teachers exist, and why our curricula prioritise academic domains – knowledge that is critical for society but is hard to acquire without support.

It is important to note that our capacity to develop academic knowledge is catalysed by the knowledge we evolved to learn naturally. The better we can speak, build relationships and read body language, the more readily we are able to learn history and mathematics (Geary, 2007).

> **Implication 2.1**
>
> *Prioritise teaching knowledge that is both valuable and hard to learn unaided. Employ highly guided (rather than unguided, 'discovery') teaching approaches to help develop secure knowledge in these domains.*

# INSIGHT THREE

## What we attend 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 whatever it is we intend our pupils to learn 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, for example in:

- 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, 2017).

> **Implication 3.2**
>
> *Where possible, eliminate redundant information and distractions in the environment. These include social distractions (for example, peers or other adults), environmental distractions (for example, display boards or clocks), activity distractions (for example, irrelevant images or tasks), or internal distractions (for example, 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 also 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 (for example, voice, hands, body, lights) with regard for the attentional sensitivity of your pupils.*

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 Seven)
- Activate relevant prior knowledge in preparation for elaborating it (see Insight Five)
- Help pupils to make sense of what is being explored
- Consolidate existing understanding (see Insight Nine)
- Support pupils to monitor and regulate their own thinking (see Insight Four)

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 FOUR

## We can only attend 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 comfortably juggle around 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 (for example, analysing a passage whilst listening to it, or trying to follow instructions whilst remembering them). Avoid multitasking.*

Information can be represented in various modes (for example, 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 effective at exposing the connections between elements (Clark *et al.*, 2006)

We are able to process visual and spoken information simultaneously (for example, someone narrating a video) but processing the same information via both modes can disrupt attention (for example, 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, 2004). 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.*

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 cognitive capacity of our pupils, we can seek to scaffold some of their thinking.

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

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 Five).

**Implication 4.3**

*During 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' (for example, 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 other 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 Six*).

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 Six).

**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 FIVE

## What we attend is what we 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 attend to things we have a frame of reference for. This is what makes something meaningful to 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, each with distinct meanings. These meanings are 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 meaningful connections they possess (see Insight Eight). 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 Nine). 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).

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, while at the same time being a product of our achievements (Marsh & Craven, 2006).

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

### 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 reliable ways to learn. Communicate your belief in their potential and hold high expectations. Provide early and frequent success (particularly for novices).*

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 (EEF, 2018).*

# INSIGHT SIX

## 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 we attend to. Our attention directs our thinking towards information that promises to help us survive and succeed in the world (Howard-Jones, 2018). 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 (Jiang et al, 2018).

We value things that bring us pleasure, increase our sense of competence, and provide promise of a better future. However, immediate rewards will often overpower longer-term ambitions.

The more we know about something the more likely we are to value it, because knowledge increases our sense of competence, familiarity with the material, curiosity around the topic, and ease with which we can build new relevant knowledge (O'Keefe & Harackiewicz, 2017). Mastery is a powerful motivator.

> **Implication 6.1**
>
> *Help your pupils understand and feel the value of what they are learning. The most reliable route to this is by helping them develop their knowledge and sense of mastery.*

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 (for example, 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 (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. Orientate your relationship with your pupils around their goals, and build 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.

Our own feelings and the emotions communicated by others can influence 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 evolved to help us prioritise information critical for our survival and success, but they are not well adapted to what we learn at school (Howard-Jones, 2008). As a result, schools often resort to rewards and sanctions as levers to catalyse learning. However, these approaches can sometimes be detrimental in the long-term. Rewards can signal that the material is not a valuable thing in itself, and when rewards are removed motivation can drop lower than initial levels (Willingham, 2010).

> **Implication 6.3**
>
> *Demonstrate passion for learning what you are teaching. Recognise that what pupils feel can determine what they attend to. Use rewards and sanctions as little as possible and remove them at the earliest opportunity. Build long-term motivation through mastery.*

# INSIGHT SEVEN

## We learn by gradually elaborating on what we know

In Insight Four, we discussed how we can only think about a few things at once. As a result, we can't just insert a new idea in its 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 develops 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 while 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 Two, we can develop some kinds of knowledge easier than others (Howard-Jones, 2018). Left to our own devices we are likely to develop crude and idiosyncratic mental models of academic knowledge. A more rigorous and efficient way of developing this 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 (for example, 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**
>
> *To develop academic knowledge, provide explicit models and worked examples 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 (for example, 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 EIGHT

## Understanding arises through connection

Classroom 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 Nine).

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 (non-examples) 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 mental models.

> **Implication 8.1**
>
> *Focus on helping pupils see and make meaningful connections between what they know and what they are experiencing. Provide non-examples as well as examples. 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 explore 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 concepts 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 and self-explanation for sense-making.*

As our knowledge becomes deeper and more comprehensive, our capacity for critical thinking, problem solving and creativity within that domain emerges (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 model is strong enough 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 necessarily 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 generate new knowledge with how pupils learn existing 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 NINE

## 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 to 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 practising across *increasingly distributed intervals* is superior to practising in 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 approaches provide insufficient incentive for pupils to perform, and excessively high stakes can induce anxiety, which uses up valuable mental resources.

> **Implication 9.1**
>
> *View the core work of teaching as consolidating connections, as well as forging them. Consolidate learning by scheduling regular, 'increasingly spaced out' opportunities for retrieval (for example, 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 practice 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.

Retrieval works best 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).

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[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'.

### Implication 9.2

*Interleave content within practice activities (for example, 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 should be reserved for only the most useful knowledge (for example, phonics and times-tables)[17].

Spaced retrieval and interleaving of practice 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, 2017) and slower progress to begin with (Rohrer & Pashler, 2010).

This is because they are able to lean on fewer 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 (for example, 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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