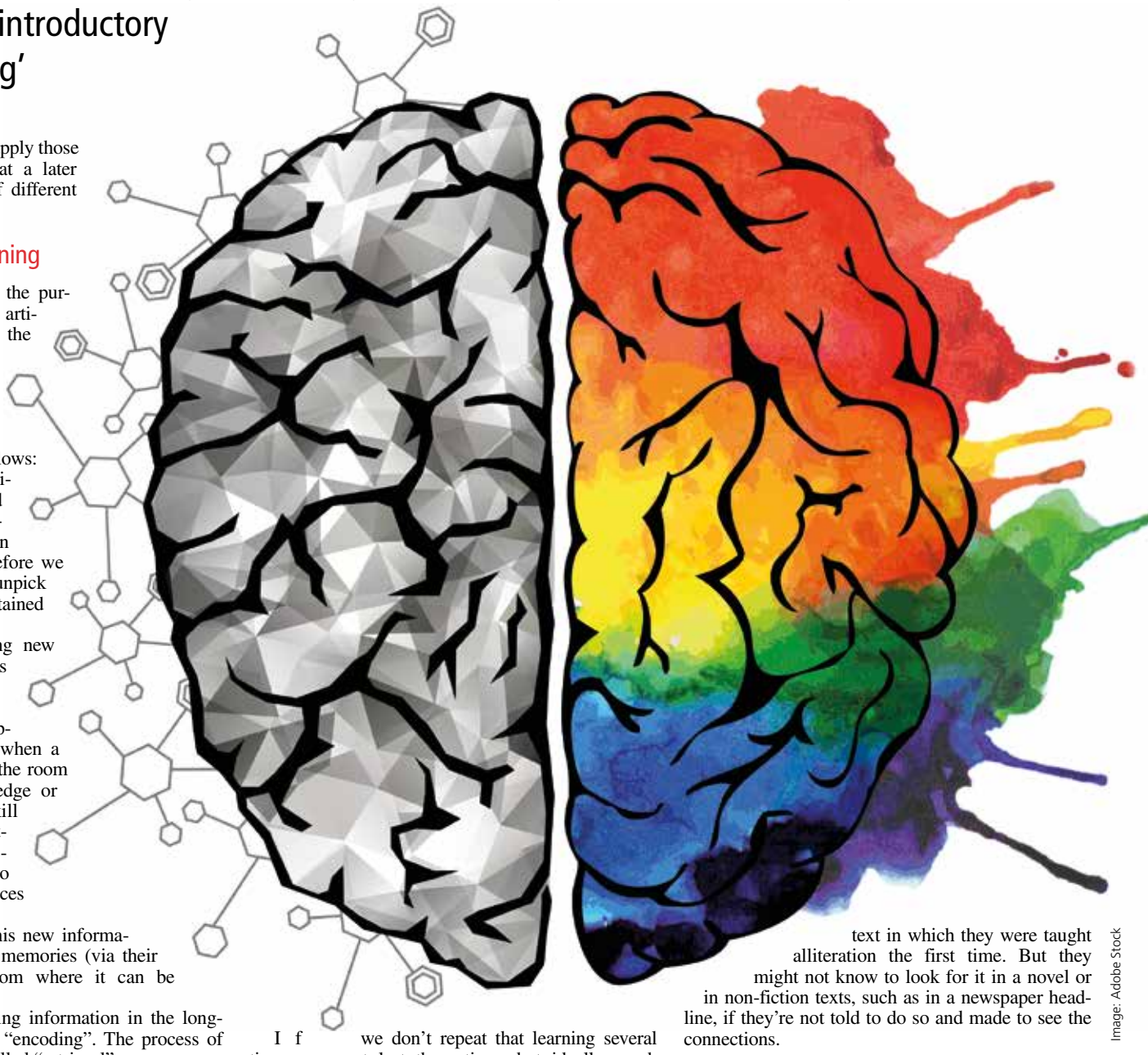
The process of learning

Teaching is the input and learning is the output. But what goes on in-between? In this new 10-part series, **Matt Bromley** will be dissecting the process of teaching and asking what learning looks like – offering practical advice for school staff. In this first introductory piece, he defines what he means by 'learning'



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What is learning? It's a simple question, isn't it? And surely, as teachers, our understanding of what we do – the act of teaching – is contingent on having first developed a fundamental understanding of what we are paid to produce – learning.

After all, we wouldn't attempt to assemble a flat-packed cabinet without first looking at a picture of the finished product and without then following step-by-step instructions that take us from flat-pack to fully assembled furniture.

In short, if pedagogy is a process whereby teaching is the input and learning is the output, then we need to know what the output should look like in order to decide what raw components to use and in what sequence to put them together.

Learning can be a range of different things depending on its purpose and context, and can encompass different processes, procedures and indeed outcomes.

For example, learning my telephone number (which, admittedly, I struggled to do for longer than I care to admit) is not the same as learning to ride a bike which, in turn, is not the same as learning how to analyse a poem or interpret a set of raw data and present the findings in a graph.

It is true that practice – no matter whether we're practising our golf swing or our times tables – has the same biological effect on the brain (namely, that it creates more layers of myelin around our nerve fibres – what we call "muscle memory" but which is, in fact, nothing to do with our muscles). But this doesn't mean that we follow the same learning process whether we're learning to swing a golf club or memorise our seven times table. And it doesn't mean that what we learn is stored and used in the same way, nor that it can be, or needs to be, demonstrated in the same way.

Learning is multi-faceted

When I taught my daughter to ride a bike, for example, I could see that she'd learnt it immediately by observing her riding without my help and without the support of stabilisers. She cycled down the hill, turned around, and cycled back up it. She got off and back on again, and pedalled some more. She was able to demonstrate her learning and I was able to observe it. I don't think anyone would suggest she was merely regurgitating, rote-like, something I'd just modelled for her and that therefore riding her bike was merely a "performance" as opposed to genuine, deep "learning".

Yes, her skill may erode over time if she doesn't keep practising it (despite the fact we're told "it's just like riding a bike, you never forget"), but that doesn't mean she didn't learn it initially.

However, not all types of learning are observable and not all learning is acquired immediately. For example, if I taught a pupil how to identify bias in a non-fiction text – let's say the *Daily Mail* – and they immediately identified an example of bias in the pages of the *Daily Mail* in the same lesson, I couldn't be certain they'd learnt the various interconnected skills of – to name but a few – skimming, scanning, distinguishing between facts and opinions, and identifying emotive language, and were able to apply those skills to the pages of the *Daily Mail* as well as to *The Guardian* and online in Wikipedia and on Facebook, and would then know to do so in history and economics, not just with me in English.

To be certain she had learnt all these skills and that those skills could be transferred, I would need to observe and assess her doing so at a later time and in a range of different contexts.

The pupil's immediate demonstration could, in this case, be a mere "performance", the instant regurgitation of what I'd instructed and modelled – mimicry rather than mastery.

There's nothing necessarily wrong with mimicry if it helps a pupil pass a test and get a qualification, but, assuming we want to do more than "teach to the test" and assuming we regard education as something meaningful and life-long, a way of becoming an engaged and active citizen, and an inquisitive, cultured adult, then surely we must aim to move beyond mimicry and towards mastery.

It follows, therefore, that our pupils must move beyond performance to genuine learning. And, if this is the case, then we must teach in such a way as to ensure that our pupils not only acquire new knowledge and skills but can apply those knowledge and skills at a later time and in a range of different contexts.

A definition of learning

With this in mind, for the purpose of this series of articles, and as applied to the process of "learning" more complex curriculum content within an academic setting, my definition of "learning" will be as follows: Learning is the acquisition of knowledge and skills and their application at a later time and in a range of contexts. Before we go any further, let's unpick the various threads contained in that definition...

The act of acquiring new knowledge and skills is the start of the learning journey. It is what happens (or begins to happen) in the classroom when a teacher – the expert in the room – imparts their knowledge or demonstrates their skill (perhaps through the artful use of direct instruction and modelling) to their pupils – the novices in the room.

Next, pupils store this new information in their long-term memories (via their working memories) from where it can be recalled and used later.

The process of storing information in the long-term memory is called "encoding". The process of getting it out again is called "retrieval".

A pupil could demonstrate their immediate understanding of what they'd been taught by repeating what the teacher had said or by demonstrating the skill they'd just seen applied. But this immediate display is not "learning". Rather, it is "performance". It is a simple regurgitation of what they'd just seen or heard and takes place in the working memory, without any need for information to be encoded in the long-term memory.

We can all repeat, rote-like, something someone else has just said or mimic a skill they've just demonstrated. But unless we can retain that knowledge or skill over time, we haven't really learnt it. And if we can't apply that knowledge or skill in a range of different situations, then – similarly – we haven't really learnt it, or at least not in any meaningful sense.

Let me give you an example...

We can, perhaps through direct instruction, teach pupils what "alliteration" means. Next, pupils can repeat the definition and pick out an example of alliteration from four sentences in a multiple-choice quiz:

1 A golden orb illuminated the sky.
2 The sun spun strips of silk across the sky.
3 The sun looked like a giant blood orange.
4 The sky was turned red by the low winter sun.

If most pupils identify B as an example of alliteration and can explain that it is so because the initial consonant "s" is repeated (a type of alliteration known as "sibilance"), then great, we think, they must have successfully learnt alliteration so we can now move on to the next thing. But...

> **"Learning, therefore, is being able to apply knowledge or skills long after we were first taught them and in a number of different situations – perhaps in an assessment as well as repeatedly over a period of time, or even a lifetime"**

If we don't repeat that learning several times – at last three times but ideally much more often – then their memory of what alliteration is will inevitably fade. It will probably remain in their long-term memories somewhere (we forget very little) but like a box of childhood toys stowed in the attic the knowledge will grow dusty and get pushed to the back, hidden among all the other items we heave through the hatch over time.

If we told pupils the definition again, chances are they would think "oh yes, of course – I remember now", but unprompted, they would be unable to volunteer a definition or identify an example.

The more we repeat the information – the more often we ask pupils to tell us what alliteration is and identify an example of it within a text – the stronger the retrieval strength of that information will become, making its recall easier and more efficient.

But the act of recalling the information from their long-term memory and bringing it into their working memory will also increase the storage strength of that information. It will be returned to the attic dusted down and in an easier-to-reach location.

However, if we simply repeat the information over and again verbatim, we will only really improve their surface knowledge of that information. They will more easily remember what alliteration is and be able to pick out an example. But they are unlikely to get any better at, say, writing alliterative sentences of their own, or at identifying why a writer has used alliteration, for what purpose and effect.

There's a danger they may not be able to identify alliteration in other contexts, too. For example, they may be attuned to its use in poetry if that's the context in which they were taught alliteration the first time. But they might not know to look for it in a novel or in non-fiction texts, such as in a newspaper headline, if they're not told to do so and made to see the connections.

Different contexts

In order to improve and deepen pupils' understanding of alliteration (rather than stick with surface knowledge), we need to teach it in different contexts. We need to model examples of its use in a range of different text types. We need to teach pupils how to use alliteration in their own writing and explain how, why and when to do so.

And when we repeat learning we should do so in different ways. For example, we could ask a hinge question which requires pupils to identify an example of alliteration from four sentences, then we could get pupils to write about that sentence, explaining what makes it alliterative, why the writer chose to use that device and what effect it creates – why, for example, the writer uses sibilance.

Then we could ask pupils to write a piece of fiction that uses alliteration, followed by a piece of non-fiction. Then we could get them to teach each other and/or test each other, perhaps by creating their own multiple-choice quizzes.

The more times we repeat the information and the more we do so in different ways, requiring pupils to demonstrate their learning through various means, the stronger it will be stored, the more easily it will be retrieved, and the better pupils will be at transferring their learning to different contexts.

Learning, therefore, is being able to apply knowledge or skills long after we were first taught them and in a number of different situations– perhaps in an assessment as well as repeatedly over a period of time, or even a lifetime. SecEd

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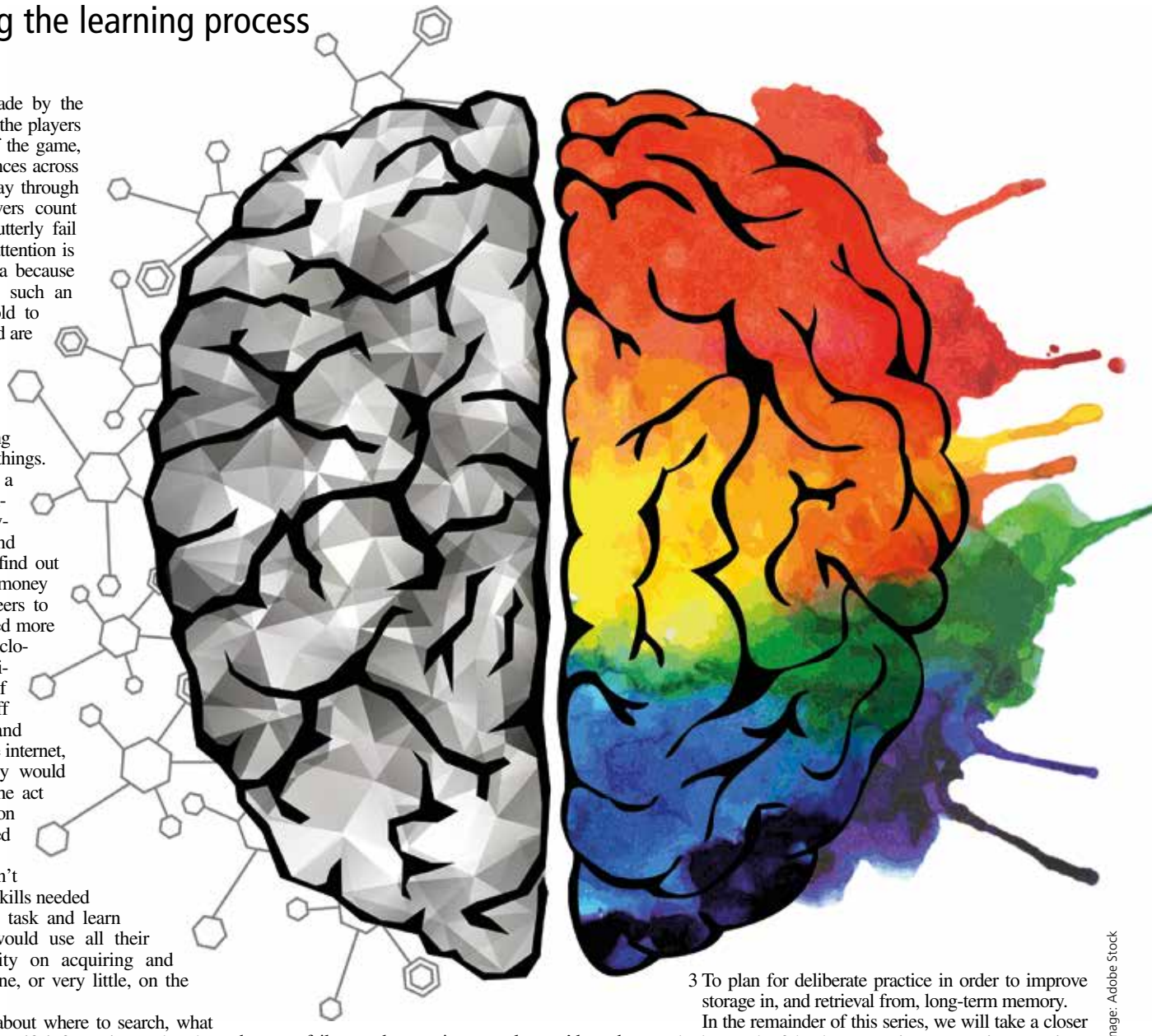
Further information

This is the first in a series of 10 articles focusing on how learning works. The second part of the series, which will publish on Thursday, September 14, will focus on the learning process.

Improving the learning process

In the second part of his series on how students learn and the practical implications for teachers and teaching, **Matt Bromley** continues to explain the process of learning, discusses the secrets to accessing pupils' long-term memories and offers three steps to improving the learning process



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In the first part of this series on "how to learn", I attempted to answer the question, What is learning?

Althouwgh it's a simple question, it is not easy to answer because learning is multi-faceted. Some forms of learning, like learning to ride a bike, are immediate and observable but other types of learning are neither of these things. A pupil's immediate demonstration of knowledge or skill could be mere performance, mimicry rather than mastery.

There's nothing necessarily wrong with mimicry if it helps a pupil pass a test and get a qualification but, assuming we want to do more than teach to the test and assuming we regard education as something meaningful and life-long, a way of becoming an engaged and active citizen, and an inquisitive, cultured adult, then surely we must aim to move beyond mimicry and towards mastery.

We must, therefore, teach in such a way as to ensure our pupils not only acquire new knowledge and skills but can apply them at a later time and in a range of different contexts.

The process of learning

The process of learning, meanwhile, is the interaction between one's sensory memory (sometimes referred to as our "environment") and one's long-term memory.

Our sensory memory is made up of: what we see (this is called our iconic memory), what we hear (this is called our echoic memory), and what we touch (our haptic memory).

Our long-term memory is where new information is stored and from which it can later be recalled when needed, but we cannot directly access the information stored in our long-term memory.

"This matters because if pupils don't think, they don't learn. We must gain pupils' attentions and make them think hard in order for information to be processed in their working memories and then be encoded in their long-term memories"

As such, the interaction that takes place between our sensory memory and our long-term memory occurs in our working memory, which is the only place where we can think and do.

It might be helpful to think of our sensory memory as a haulage truck, our long-term memory as a warehouse, and our working memory as the holding bay where new deliveries are received, processed and labelled ready for stowing. The payload cannot be passed directly into the warehouse, it must first pass through the holding bay to be sorted.

In order to stimulate pupils' sensory memories and thus engage the attention of their working memories and make them think, we need to create classroom conditions conducive to learning, conditions that stimulate pupils' iconic, echoic and haptic memories. In other words, we need to engage pupils' senses in order to gain their attention.

It might sound like common sense – indeed it is – to say that, in order for our pupils to learn, we must first gain their attention, but it's all too easy for learning to fail simply because we haven't stimulated our pupils' senses and therefore gained their attention, or because we have focused their attention on the wrong things.

Let me give you an example...

I'm sure you've seen the dancing gorilla awareness test before. In short, observers are asked to watch a video of some people playing basketball and are told to count the number of passes made by the players in white, ignoring the players in black. In the middle of the game, a man in a gorilla suit dances across the scene, weaving his way through the players. Most observers count the passes correctly but utterly fail to spot the gorilla. Their attention is not grabbed by the gorilla because they don't expect to see such an incongruous thing, are told to ignore figures in black, and are only focused on the ball as it passes from one player in white to another.

It's just as easy for pupils to focus on the wrong things and ignore the right things. For example, if I wanted a class to research the origins of two online encyclopaedias, Wikipedia and Microsoft's Encarta, and find out why Wikipedia – with no money and a reliance on volunteers to act as contributors – proved more successful than the encyclopaedia backed by big business, boasting an army of well-paid, qualified staff including Bill Gates, and asked them to do so on the internet, there's a danger that they would focus their attention on the act of researching rather than on the topic they'd been asked to research.

In other words, if I didn't explicitly teach them the skills needed in order to carry out the task and learn about Wikipedia, they would use all their working memory capacity on acquiring and using these skills and none, or very little, on the actual content.

They'd have to think about where to search, what search terms to use, how to sift information and make decisions about what was relevant and what was not, and what was reliable and what was not. However, if I'd explicitly taught them how to conduct independent research – such as the use of three independent sources, skimming and scanning for key facts, names and dates, how to use quotations, how to detect bias, etc – then modelled the process and got them to practise the skills until they become automatic, they could then have focused their attentions on the information they'd found about Wikipedia. In short, their attention could have been focused on the right things.

This matters because if pupils don't think, they don't learn. We must gain pupils' attentions and make them think hard in order for information to be processed in their working memories and then be encoded in their long-term memories. And if we get them thinking hard about how to research, then they will process and encode this and learn nothing – or too little – about what they actually researched.

In short, stimulating pupils' sensory memories and focusing their attention on the right things is essential if our pupils are to engage their working memories.

Talking of which...

In order to help pupils utilise their limited working memories (depending on which research paper you read, it's thought that we can only handle between five and nine concepts in working memory at any one time – see, for example, Miller 1956), we need to ensure they are made to think hard; are challenged with work that is difficult but achievable.

If the work is too easy, pupils will be able to complete it through habit without thinking – this is called "automaticity". For example, if I asked you to calculate 2 x 5, you would do so automatically, through habit, without having to think about it because you mastered your times tables many years ago.

If the work's too hard, pupils will be unable to complete it because they will overpower their limited working memories with too much information (what's called "cognitive overload") and the learning process will fail. For example, if I asked you to calculate 367 x 2,892 in your head in a minute, you wouldn't be able to do so. Either you'd not attempt it because you'd quickly assess the task to be beyond your reach and therefore a pointless waste of energy, or you'd attempt it but be unable to hold so much information in your working memory and so would fail. Either way, you would be demotivated by your failure and, more importantly, you'd not have learnt or practised anything so the task would have been pointless.

In other words, we need to pitch class-work in the "struggle zone", or what Robert Bjork calls the "sweet spot" at the edge of pupils' current knowledge and abilities, albeit just within their reach.

But, in making pupils think hard, we also need to help them think efficiently. Thinking, as we have seen, will fail if pupils overload their working memories. As such, we need to help pupils cheat the limited space in their working memories (to mitigate cognitive overload) by learning new things in the context of what they already know (allowing them to "chunk" information, thereby reducing the space required) and by teaching requisite knowledge and/or skills before they need to be applied because, as Dan Willingham puts it, "memory is the residue of thought".

Once pupils have been made to think hard but efficiently and have processed information in their working memories, we need to ensure they encode that information in their long-term memories and can easily retrieve the information at a later time.

In order to help pupils store information in their limitless long-term memories (long-term memory is so big, it will take more than a lifetime to fill it), we need to plan opportunities for deliberate practice. In particular, we need to use two teaching strategies called spacing and interleaving.

Only by repeating learning and by doing so in a range of contexts, will we increase the storage strength of the information in long-term memory. The better the storage strength, the more readily available will be our knowledge and skills.

Repeating learning – the very act of recalling prior knowledge and skills from long-term memory – also improves retrieval strength. The better the retrieval strength of information, the more easily, quickly and efficiently are knowledge and skills recalled from long-term memory and brought into the working memory where they can be used.

In summary

And so, to my mind, there are three steps to improving the learning process:

1 To create a positive learning environment in order to stimulate sensory memory.
2 To make pupils think hard but efficiently in order to gain the attention of – but cheat – working memory.
3 To plan for deliberate practice in order to improve storage in, and retrieval from, long-term memory.

In the remainder of this series, we will take a closer look at each of the three steps in turn, starting next time, with creating a positive learning environment in order to stimulate sensory memory. SecEd

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Further information

This is the second in Matt's series of 10 articles focusing on how learning works. The third part of the series, which will publish on Thursday, September 21, will focus on creating a positive learning environment. To read the previous articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl

Comfortable with discomfort

Our series on the learning process continues. **Matt Bromley** is looking at the three secrets to boosting students' long-term memory and recall. This week, he considers the first of these – creating a positive learning environment

Last time, I argued that the process of learning is the interaction between our sensory memory and our long-term memory.

Our sensory memory, I said, is made up of: what we see (this is called our iconic memory), what we hear (this is called our echoic memory), and what we touch (our haptic memory).

Our long-term memory, meanwhile, is where new information is stored and from which it can be recalled later when needed. But we cannot directly access the information stored in our long-term memory – instead, this interaction between our sensory memory and our long-term memory occurs in the working memory.

In order to ensure our pupils learn, therefore, we need to stimulate their sensory memory, gain the attention of – and help them cheat – their working memory, and improve the strength with which information is stored in, and the ease and efficiency with which it can later be retrieved from, their long-term memory. In order to do this, we need to follow three steps:

- First, we need to create a positive learning environment.
- Second, we need to make pupils think hard but efficiently.
- Third, we need to plan for deliberate practice.

This week I'm going to share some tips for creating a positive learning environment and next week I'm going to look at ways of stimulating pupils' senses. First, though, let's define our terms.

A positive learning environment

When I talk about a positive learning environment I refer to one in which pupils' senses are stimulated so that they pay attention to the right things and are made to think hard but efficiently about curriculum content.

I refer, too, to an environment in which pupils are challenged by hard work but know that they are safe to take risks and make mistakes.

What I do not mean by the term "positive learning environment" is one in which fun and laughter are paramount. There's nothing wrong with pupils enjoying themselves while they learn and we certainly wouldn't want school to be a dull and boring place. However, fun is never the goal.

Rather, as I have already said, we want pupils to think and work hard. If, along the way, they can have fun and enjoy learning, then all the better, but fun is not a prerequisite for pupils to be able to learn and enjoyment is not an essential ingredient in the recipe for a positive learning environment.

In short, when we start the process of lesson-planning, we should start with the question "what do we want pupils to think about?" not "what do we want pupils to do?" – in other words, activities should be secondary to instruction.

Having said this, we do want our learning environment to be one in which pupils are enthusiastic about learning, for enthusiasm breeds intrinsic motivation.

So what, if not fun, are the hallmarks of a positive learning environment? To my mind, a positive learning environment – for starters – is one in which all pupils:

- Feel welcomed.
- Feel valued.
- Are enthusiastic about learning.
- Are engaged in their learning.
- Are eager to experiment.
- Feel rewarded for their hard work.

Comfortable with discomfort

I could, of course, go on, and I'm sure you could add to my list with some important characteristics of your own. But behind all these characteristics – and any more we care to add – is a simple, albeit oxymoronic, aim: to ensure pupils are comfortable with discomfort.

In other words, we want our pupils to know that the work they will be asked to do in our classrooms will be tough, that they will be challenged with hard work and made to think.

We want our pupils to know that there will be no hiding place in our classrooms; they must ask and answer questions and attempt everything.

However, in so doing, we want pupils to feel safe and protected, we want them to eagerly accept challenge, and to willingly attempt hard work because they know we have strung a safety net beneath them: they might falter but we will catch them if they fall.

We also want them to know that taking risks and making mistakes is not just accepted in our classrooms but is positively and proactively welcomed as an essential part of the learning process. After all, if pupils don't make mistakes, they can't receive feedback, if they don't receive feedback, they won't know how to improve, and if they don't know how to improve, they are unlikely to do so.

There are many ways of achieving a positive learning environment in which pupils are comfortable with discomfort: some are plain old common sense, some are more counter-intuitive.

Let's deal with each of the hallmarks I listed above in turn and explore tangible ways of achieving them.

Some key tenets

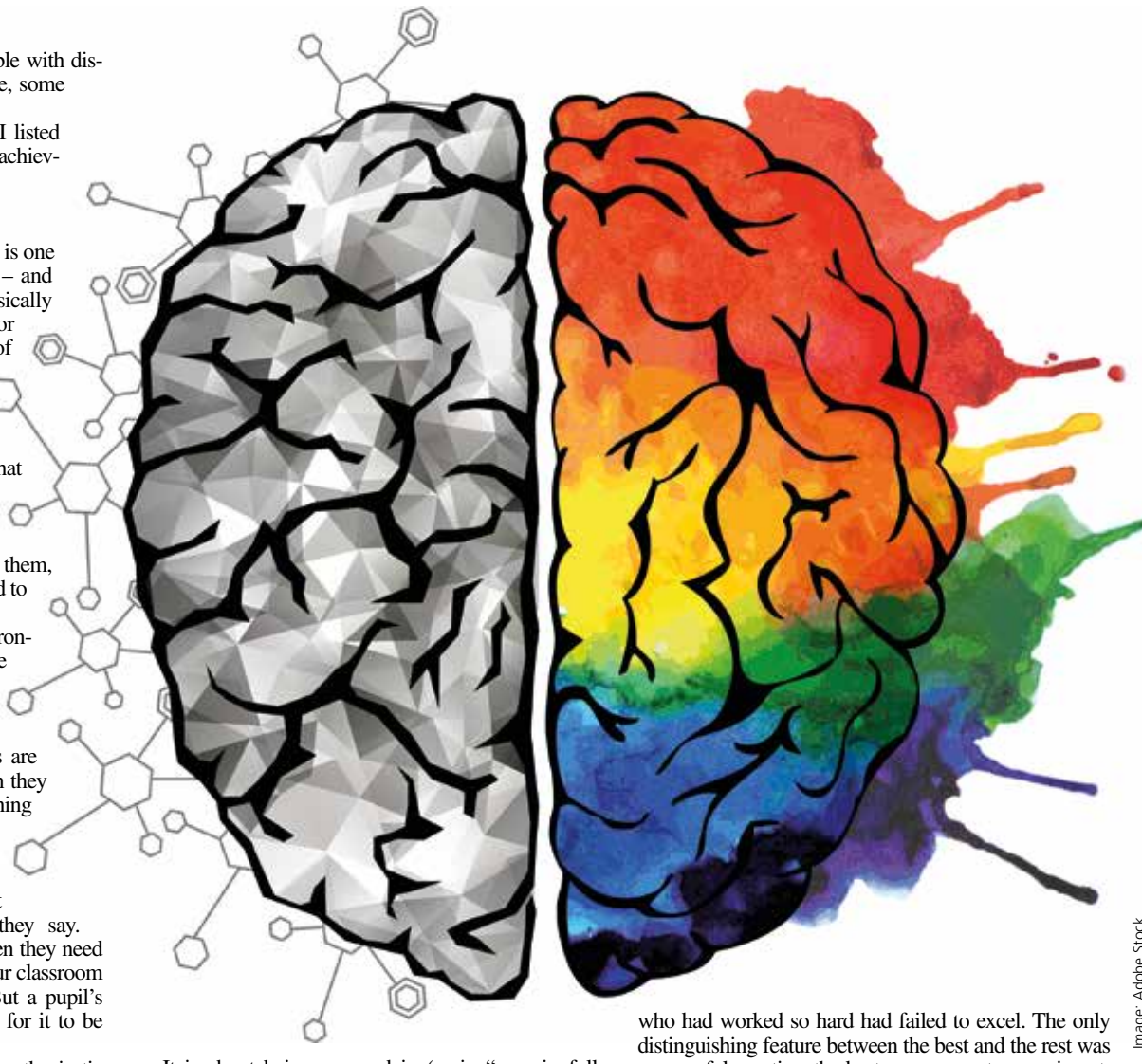
First, I said a positive learning environment is one in which pupils feel welcomed. The best – and simplest – way of achieving this is to physically welcome pupils into our classrooms. For example, we could establish a habit of greeting pupils at the classroom door at the start of every lesson, and then do so with a smile and by greeting at least some pupils by name.

For some pupils in some contexts, that might be the first time someone – an adult, at least – has acknowledged their existence. If we can't show our pupils that we are pleased to see them and eager to teach them, then can we really expect them to be pleased to be in our lesson?

Second, I said a positive learning environment is one in which pupils feel valued. We can achieve this by making sure we are on time and have a lesson planned and ready to go. We can also do this by creating a culture whereby everybody's contributions are welcomed and given the time and attention they deserve. This might involve explicitly teaching and repeatedly reinforcing, not to mention modelling debating skills such as active listening.

Valuing each pupil's contribution is not the same as agreeing with everything they say. Indeed, if a pupil gives a wrong answer then they need to know it is wrong and why it is wrong. Our classroom should be a place of intellectual rigour. But a pupil's response doesn't have to be right in order for it to be useful.

Third, I said that we want pupils to be enthusiastic about learning. This is, in part, achieved by developing pupils' sense of intrinsic motivation but this isn't always possible and is rarely easy. So another tangible, teacher-led strategy for enthusing pupils is to model that enthusiasm by constantly articulating – through our words and actions – our joy at teaching our pupils and at teaching our subject. In this regard, sometimes a little over-acting goes a long way. It's better to be considered the kooky, eccentric teacher who's truly, madly, deeply in love with science, say, than the boring, staid one who never cracks a smile and only perseveres for the pension.



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"This matters because if pupils don't think, they don't learn. We must gain pupils' attentions and make them think hard in order for information to be processed in their working memories and then be encoded in their long-term memories"

Fourth, we want our pupils to be engaged in their learning. But what is "engagement" and why does it matter? Let me return to the point with which I started this article: fun is never our goal; we don't need pupils to enjoy our lessons in order to learn. We need them to pay attention to the right things. If they happen to enjoy what they do, then that's an added bonus. But "fun activities" are not our guiding star; rather, thinking hard but efficiently about curriculum content is.

So when I talk about pupils being engaged in their learning I don't mean – or do not solely mean – that they are enjoying what they're doing. Instead, I mean they are actively paying attention to the right things and are thinking hard.

It is about being engaged in (as in "meaningfully occupied by or connected to") as distinct from enjoying (as in "taking pleasure from") their learning because it is not desirable to employ a strategy in which pupils are engaged by something that appears interesting but leads to little substantive learning or, at any rate, slows down the process of learning because this will prove ultimately demotivating.

Our goal as teachers should therefore be to ensure that our pupils learn in an effective, efficient, and enjoyable way (in that order). Yes, we want pupils to be motivated and enjoy lessons but motivation and enjoyment are not proxies for learning. After all, without learning, what's the point of pupils being motivated and enjoying lessons?

Fifth, I said a positive learning environment is one in which pupils are eager to experiment. I have already said that taking risks and making mistakes is an essential part of the learning process; it is not just to be accepted but to be positively and proactively welcomed in our classrooms. But why? Why is taking risks and making mistakes so desirable?

The importance of practice

In 1991, Anders Ericsson, a psychologist at Florida State University, conducted an investigation into the causes of outstanding performance. His subjects were violinists from the Music Academy of West Berlin.

He divided his subjects into three groups: the first group were the outstanding violinists who were expected to become soloists; the second group were very good (though not as accomplished as the first group) and were expected to join the world's top orchestras; the third group were good but the least able and were expected to become music teachers.

The "setting" of the three groups was based on assessment conducted by the academy's professors and on the level of success the students had enjoyed in open competitions.

The biographical details of all the students were very similar with no systematic differences: they each began playing the violin when they were aged eight; they each decided to become musicians when they were 14; they each had the same number of music teachers and had studied the same number of musical instruments beyond the violin. In fact, there was only one difference but it was quite a striking one: the number of hours they had devoted to practice.

By the age of 20, the students in the first group had practised an average of 10,000 hours which is 2,000 hours more than the second group and 6,000 hours more than the third group. Ericsson found that there were no exceptions to this pattern: nobody in the first group who had reached the top of their game had done so without copious amounts of practice; and nobody who had worked so hard had failed to excel. The only distinguishing feature between the best and the rest was purposeful practice: the best were eager to experiment; the best took risks and made mistakes.

Being eager to experiment should therefore be about instilling in pupils the importance of practice, of redrafting and redrafting work until it is the best it can be. In short, in our classrooms, if it isn't excellent, it isn't finished.

And finally

The final feature of our positive learning environment, I said, is that pupils feel rewarded for their hard work. Rewarding hard work and effort not only creates a level playing field on which every pupil has equal chance of scoring a goal (because everyone can try hard, after all), it also makes explicit the progress each pupil is making from their individual starting points. Not every pupil can achieve a grade 9 but every pupil can improve and beat their previous score.

We know, too, from the work of Professor Carol Dweck and experiments carried out by Harry Harlow and Edward Deci that extrinsic rewards and rewards for ability or talent are counter-productive, whereas intrinsic rewards and rewards for effort lead to improvements.

Conclusion

Those are just six features of a positive learning environment. We could add more. But, as I said at the beginning, they all point to a classroom in which pupils are comfortable with discomfort – in other words, pupils in our classrooms are encouraged to hard work and accept challenges but know they can do so within a safe, supportive environment.

As well as being comfortable with discomfort, in order to stimulate pupils' sensory memories and gain the attention of their working memories, we need to appeal to their iconic, echoic and haptic memories: sight, sound and touch. In the next article in this series we will explore ways of doing just this. SecEd

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Further information

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Memory: Sense and sensibility

Our series on how students learn continues with advice on creating a positive learning environment in your classroom in order to appeal to pupils' iconic, echoic and haptic memories – and thus make learning stick. **Matt Bromley** explains

In this series of articles I'm exploring the process of learning which, I have argued, is the interaction between our sensory memory and our long-term memory.

Our sensory memory, I said, is made up of: what we see (this is called our iconic memory), what we hear (this is called our echoic memory), and what we touch (our haptic memory).

Our long-term memory, meanwhile, is where new information is stored and from which it can be recalled later when needed, but we cannot directly access the information stored in our long-term memory – instead, this interaction between our sensory memory and our long-term memory occurs in the working memory.

In order to ensure our pupils learn, therefore, we need to stimulate their sensory memory, gain the attention of – and help them cheat – their working memory, and improve the strength with which information is stored in, and the ease and efficiency with which it can later be retrieved from, their long-term memory. In order to do this, we need to follow these three steps:

- First, we need to create a positive learning environment.
- Second, we need to make pupils think hard but efficiently.
- Third, we need to plan for deliberate practice.

Last week I said that a positive learning environment is one in which all pupils:

- Feel welcomed.
- Feel valued.
- Are enthusiastic about learning.
- Are engaged in their learning.
- Are eager to experiment.
- Feel rewarded for their hard work.

Behind all these characteristics is a simple, albeit oxymoronic, aim: to ensure pupils are comfortable with discomfort (the focus of last week's article). In other words, we want our pupils to know that the work they will be asked to do in our classrooms will be tough, that they will be challenged with hard work and made to think. We want our pupils to know that there will be no hiding place in our classrooms; they must ask and answer questions and attempt everything.

However, in so doing, we want them to feel safe and protected, we want them to eagerly accept the challenge, and to willingly attempt hard work because they know we've strung a safety net beneath them: they might falter but we will catch them if they fall.

But creating a positive learning environment is more than this: it is also about stimulating pupils' senses in order to gain the attention of their working memories. To do this, we need to appeal to their iconic, echoic and haptic memories: sight, sound and touch.

Sight, sound and touch

First of all, a caveat: appealing to pupils' senses does not mean identifying a pupil's preferred or dominant sense and teaching in a way that appeals to that sense alone. It means utilising all pupils' senses in order to make use of their visual and verbal processing powers and thereby expanding the capacity of their working memories.

Pupils are more likely to want to learn – and to actually learn – if their senses are piqued by the unfamiliar. All pupils crave variety; they need lessons to surprise them, to excite them, to ignite new sparks and pose new questions. They need lessons to unsettle them, too; to discomfort and challenge them.

In short, we all grow tired of repetition, of the predictable and prosaic, of the monotonous and mundane, and we all need a frequent frisson of freshness in our lives and, although I'm not suggesting that every lesson we teach should provide novelty value. I do believe that, in order to stimulate pupils' senses and therefore make information "stick" in long-term memory, we need to make that information concrete by grounding it in sensory reality.

When we are exposed to new information, we process it and then attempt to connect it to existing information (in other words, we try to assimilate new knowledge with prior knowledge). The richer – sensorily and emotionally – the new information is, and the deeper the existing information is ingrained, the stronger we encode the new information in our long-term memories.

Ensuring our lessons provide variety and novelty, therefore, helps to appeal to pupils' senses and engage their emotions – if nothing else, simply by piquing their interest in something out of the ordinary, we are making them think – and therefore the information we teach them is more likely to be retained over the long-term.

In practice, there are four ways to make information stick: Making it tangible, making it clear, making it satisfying, and making it concrete.

Make information real

One way to make information real is to use metaphor. Metaphor is good at making information stick because it brings ideas to life, it draws connections between new knowledge and existing knowledge. For example, if you are trying to describe how electricity flows through a material, you'll need to explain the structure of atoms.

You might use a metaphor which describes atoms as "nature's building blocks" to help pupils understand an atom's function. You will then need to explain how each atom is comprised of protons, which are positively charged, neutrons, which have no charge, and electrons, which are negatively charged.

Then you would need to explain that, together, the protons and neutrons form the "nucleus" of the atom, and that the electrons travel around this nucleus. You might then use a metaphor which compares this "orbit" to the way the earth travels around the sun.

In each case, you are relating new information which pupils are unlikely to be able to process and therefore retain, with existing information (or prior knowledge) in order to help them imagine it, process it and retain it.

Make information clear

Another way to make information stick is to make it clear – in other words, we should make sure each of the lessons we teach in a learning sequence clearly articulates its "lead" (the big idea, concept, question or hypothesis you need pupils to think about).

Lesson plans should be focused on what pupils will think about rather than what they will do. And, although we are not naturally good thinkers, we do enjoy problem-solving – so we should frame our key messages (or "lead") around a problem to be solved or an enquiry to be investigated and answered.

> **Lesson plans should be focused on what pupils will think about rather than what they will do**

First, we need to decide on the vital "take-away" messages – rather than what will merely add hue and texture – then concentrate on writing questions rather than creating fun activities. We need to try to write a "big question" which forms the basis for the lesson. Alternatively, we could pose a hypothesis to be proven or disproven.

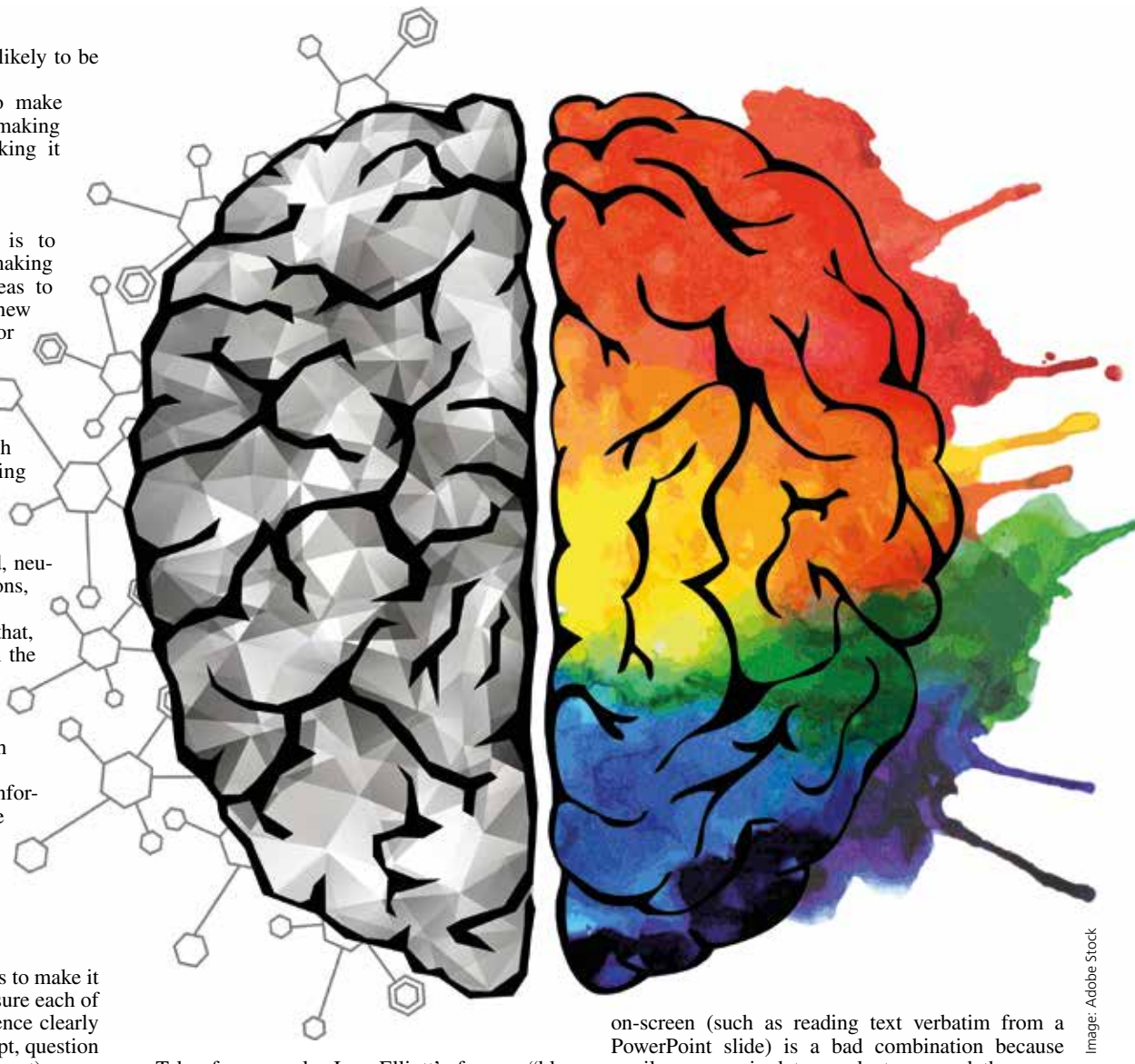
Make information satisfying

We can also make information stick by piquing pupils' curiosity. Teachers tend to focus on imparting facts, but unless pupils know why those facts are important they are unlikely to retain them. Therefore, we should make sure that before teaching our pupils the facts, we take time to pique their curiosity and make them realise why they need those facts.

The secret to convincing pupils that they need the information we intend to teach them, according to Professor George Loewenstein at least, is to start by highlighting the knowledge they are missing. Another technique is to start a lesson by asking pupils to make a prediction.

Make information concrete

Another way to make information stick is to make it tangible. Pupils find it hard to care about or understand abstract concepts. Instead, we should try to make ideas concrete by using sensory hooks – the more sensory hooks we use, the better the ideas will stick.



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Take, for example, Jane Elliott's famous "blue-eyed/brown-eyed" experiment with third grade pupils the day after Martin Luther King had been assassinated in 1968. The purpose of the exercise was to teach her pupils the effects of belonging to a minority. Elliott had tried holding a class discussion about racism but said she "could see that (the pupils) weren't internalising a thing". Instead, "they were doing what white people do ... when white people sit down to discuss racism ... (they experience) shared ignorance".

So, instead, she divided the class on the basis on their eye colour and treated some pupils less favourably than others. Once she had concluded the experiment, she asked the children to reflect by writing down what they had learned and it became clear that her pupils had come to deeply understand racism because Elliot had made it feel real, she had grounded an abstract concept in sensory reality and thus engaged her pupils' emotions.

What Elliott's experience teaches us is that we should obey the maxim "show don't tell" wherever possible. Telling pupils something means we do all the work for them; showing them means they have to work for themselves.

Not only does appealing to pupils' various senses make information stick, it also helps to utilise the limited space in their working memories. This approach is often called "dual coding".

Dual coding

Dual coding is the combination of words and images. We have two specific yet connected cognitive subsystems: one specialises in representing and processing non-verbal objects or events; the other specialises in language. In other words, we process verbal and visual information separately and so can double the capacity of our working memory if we utilise both verbal and visual processing at the same time.

What's more, dual coding allows us to boost the information traces in our long-term memory (as two connected traces are stronger than one single trace) and it enables us to recall – or recognise – the information in two different ways.

By combining an image with a complementary word (written or preferably spoken), we're utilising both a verbal/semantic process (deciphering spoken/written words) and an iconic process (deciphering images).

However, as with all teaching strategies, dual coding only works when it's done well. Reading a text aloud in parallel with the same written text on-screen (such as reading text verbatim from a PowerPoint slide) is a bad combination because pupils are required to conduct one and the same verbal/semantic decoding process in two different ways – rather than splitting and therefore doubling working memory capacity, it requires pupils to process twice the information using one process, thus halving working memory capacity. As a result, working memory becomes overloaded in what's known as "the redundancy effect".

The best way to make use of dual coding is to, for example, explain a visual (a diagram, graph, mind-map, etc) verbally, not through text on the visual. If there is writing on the visual, it's best not to explain it. Furthermore, we should present visuals and text at the same time so that pupils don't have to remember one part while processing the other.

Next week we will move on to the second or our three steps: ensuring pupils think hard but efficiently in order to utilise – and cheat – their working memories. SecEd

• *Matt Bromley is an education journalist and author with more than 18 years' experience in teaching and leadership. He is the author of best-selling books for teachers including* Making Key Stage 3 Count *and* Teach. *His latest book,* The New Teacher Survival Kit, *is available in paperback and various ebook formats. Visit www.bromleyeducation.co.uk or follow @mj_bromley.*

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Further information

This is the fourth in Matt's series of 10 articles focusing on how learning works. The fifth part of the series, which will publish on Thursday, October 5, will focus on the second of the three steps to boosting long-term memory – thinking efficiently. To read the previous articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl

Hard times

In the fifth instalment of his series on how students learn, **Matt Bromley** moves onto the second of his three secrets to boosting pupils' long-term memory and recall abilities – ensuring they think hard but efficiently in order to 'cheat' their working memories

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If I asked you to calculate 57 x 4,389 in your heads, no cheating, and in the space of a minute, I'm pretty confident most of you would fail. And in the process of failing, you'd likely do one of two things:

You'd decide the task was unachievable – especially with the time constraints attached – and therefore not attempt it.

Or you'd try to complete the task but fail because to succeed would involve processing too much information all at once. Your working memory wouldn't be able to cope with the demands you'd placed upon it, in just 60 seconds, and you'd reach the point of cognitive overload.

Whichever of these two paths you took, you wouldn't calculate the answer and wouldn't, therefore, encode anything into long-term memory.

Put simply, you wouldn't learn anything new or practise something you already knew. This complex thing called "learning" would not occur.

Now, if I were to ask you to calculate 2 x 10, once again in your heads and in the space of a minute, I'm confident all of you would succeed this time. And you wouldn't need a full minute to do so either. In fact, you'd proffer your answer instantaneously.

But, and here's the rub, you wouldn't have calculated anything – you'd have given your answer automatically.

In other words, you wouldn't have engaged the attention of your working memory, at least not in any meaningful sense, because you've practised your times tables to the point of automaticity whereby you can reel them off through habit, without thinking about them, just as you tie your shoe laces or button your shirt.

Most of the time, you drive your car without thinking about it, too; you've done it so many times that the task no longer needs to engage your active attention, which helps explain why you sometimes arrive at your destination with absolutely no memory of the journey.

And because you answered 2 x 10 without thinking about it, you didn't learn anything new or practise something that you already knew, as was the case with the first sum.

In other words, this task – though ostensibly a success – was also pointless because learning did not occur.

The struggle zone

If we want our pupils to learn anything – by which I mean, encode information in their long-term memories – then we need to engage their active attention and get them thinking hard. We need to give them work to do that's challenging but achievable because if the work's too easy pupils will complete it through habit, if the work's too hard pupils will be unable to complete it. In both cases, learning will fail.

So we need to pitch work in pupils' "struggle zones" – what they can do with time, effort and support. This is sometimes referred to as the "zone of proximal development", a term invented by the Russian psychologist Lev Vygotsky and defined by him in 1978 as "the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers".

Working on problems that are too easy or too difficult is not enjoyable because there is no sense of progress, and thus we become frustrated. Working on problems that are pitched in our struggle zone, however, is rewarding.

This is why giving pupils work to do that is too easy for them and which they can therefore accomplish without thinking – in the misguided belief that it will give them a sense of success and thus motivate them – doesn't work. Instead, we are motivated by thinking hard and overcoming difficulty; we are motivated by overcoming challenges.

There's evidence from the field of neurochemistry to support this notion, too. When we solve a problem, we are rewarded with a small dose of dopamine which is a naturally occurring chemical that's important to the brain's pleasure system. Indeed, alongside serotonin, dopamine is one of only two things that – chemically speaking – give us pleasure.

Thinking hard

So how can we ensure that our pupils are made to think hard? Sometimes, we need to place artificial barriers in the way of their initial encoding of information so that the information is stored more effectively and can more easily be retrieved later. These artificial barriers or road-blocks in our thinking are what Professor Robert Bjork called "desirable difficulties".

Bjork, a cognitive psychologist at UCLA, coined the phrases "storage strength" (SS) and "retrieval strength" (RS) in order to help improve our understanding of how we learn (which is to say, how we commit things to long-term memory).

SS is the measure of how effectively we have encoded something. Studying something in greater detail increases the chance of us storing it in our long-term memory. The better it is learned, the higher the SS. If it has a high SS, it is more likely to be stored in our long-term memory (rather than remain in our working memory to be quickly forgotten) and more likely to be ready to be "retrieved" later.

Retrieval strength, meanwhile, is the measure of how easily we can access a memory of something we've learned. In other words, RS is our ability to recall information at a later date. RS decreases over time – which is why we forget things as we get older – and the lower the SS, the faster the RS will decrease.

Put simply, if we want to learn something well enough so that it will be accessible to us in the future (rather than quickly forgotten or hidden away in an impossible-to-reach location), then we need to learn it in greater depth, and we need to "over-learn" it.

Bjork identified a number of conditions which over time increase SS and RS and which therefore lead to information being retained for longer. These conditions, Bjork cautioned, "slow down the apparent learning, but under most circumstances help long-term retention, and help transfer of knowledge, from what you learnt to new situations".

Bjork called these conditions "desirable difficulties" because they are ways of teaching which are intentionally challenging to pupils because difficulty and hard work are what assists their long-term learning.

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Put simply, then, Bjork argued that teachers should spend longer teaching fewer things but in greater detail. In other words, our pupils should cover less curriculum content but what they do cover should be in much greater depth.

An example

I'll give you an example of desirable difficulties but, before I do so, quickly answer this question: How many animals of each kind did Moses take onto the Ark?

The more quick-witted, eagle-eyed among you will have spotted the deliberate mistake and answered "none". But I bet some of you said "two". I've asked this question at several conferences and INSET events and a healthy proportion of the audience always insist the answer's "two".

If you said "two" then you fell into the trap of skimming the question too quickly and offering the obvious answer. The fact is, the question asks you how many animals Moses took onto the Ark when, in fact, Moses didn't build an ark, it was Noah.

That question was a perfect example of work that is too simple, too easy, too obvious. Because it has all the hallmarks of a straightforward question, some of you put two and two together and made five. You skimmed over the words and filled in the gaps then offered an answer out of habit. That answer happened to be wrong but you were convinced of its accuracy. You simply didn't think hard enough.

There are several ways to help pupils avoid falling into this trap – each of which is an example of a desirable difficulty, a barrier that slows down the initial encoding of information so that it is stored better and more easily retrieved from long-term memory.

First, we can use more complex language constructions. For example, instead of asking a question worded as a simple sentence ("How many animals of each kind did Moses take onto the Ark?'), we could ask it using a complex sentence ("In the biblical story, to save them from the flood, how many animals of each kind did Moses take onto the Ark?").

Second, we could put a deliberate block in the way – something incongruous that stops pupils in their tracks ("How many animals of each kind did Donald Trump take onto the Ark?").

Third, and this is rather counter-intuitive, we could use a hard-to-decipher font for written information on the board or in handouts. To prove the effectiveness of this strategy, consider Professor Shane Frederick's Cognitive Reflection Test involving 40 Princeton students (search online for more about this).

Half of the students saw a puzzle in a small font in washed-out grey print. The puzzle was legible, but the font induced cognitive strain. The other half saw the puzzle in a normal font. The results told a clear story: 90 per cent of the students who saw the puzzle in a normal font made at least one mistake in the test, but the proportion dropped to just 35 per cent when the font was barely legible. In short, performance was better with the hard-to-decipher font.

Cognitive strain, whatever its source, mobilised what Professor Daniel Kahneman – in *Thinking Fast and Slow* – calls System 2 (System 2 thinks slow – it works rationally and methodically; it can assess and analyse choices in a sophisticated and analytical way) which meant the participant was more likely to reject the intuitive answer suggested by System 1 (System 1 thinks fast – it's instinctive and intuitive. It can react more quickly than conscious thought. But it is also prone to error).

The difficult font slowed down thinking and helped participants in the test to avoid mistakes.

Professor John Hattie echoed Bjork's belief that teachers should slow down learning and set challenging work. He said that the best way for pupils to learn is not always pleasurable for them: "Learning is not always easy; it requires over-learning at certain points, spiralling up and down the knowledge continuum, building a working relationship with others in grappling with challenging tasks." (Hattie, 2012)

Hattie went on to say that the most "accomplished teachers set tasks that (have) a greater degree of challenge".

Don't dumb down

Therefore, we "dumb down" at our peril. Setting work that's too easy and placing artificial limits on what we expect our pupils to achieve is not the best way to help them learn. Instead, we should model high expectations for all our pupils, no matter their starting points and their most recent performance. We should teach to the top, not the middle, and ensure our classrooms provide challenge for all.

Of course, some pupils fear challenge. We need to eliminate – or at least mitigate – pupils' feelings of fear and hesitation by creating a classroom environment which encourages the making of mistakes as a sign of learning, and which explicitly says (through our choice of language, our modelling and thinking aloud, and the routines we engage in) that there is nothing to fear by trying your best and pushing yourself to do hard work.

After all, challenge is innate

In their lives outside the school gates, pupils are always seeking hard things to do such as computer games. They are the YouTube generation who spend hours watching video tutorials, looking at graphic organisers on Pinterest or reading articles on Buzzfeed so they can learn by increments and improve their performance in, say, Minecraft, baking, football, make-up and nail art, hair design, and so on.

They love challenge when it is private because, in the safety of their bedrooms, there isn't the fear of humiliation or peer pressure.

In order to promote challenge in the classroom, therefore, we need to reduce the threat level, we need to ensure no-one feels humiliated if they fall short of a challenge. Rather, they need to know they will learn from the experience and perform better next time. They will learn by increments.

In conclusion, in order to ensure pupils engage the attention of their working memories effectively and therefore encode information into long-term memory, they need to think hard and accept challenging work.

However, because space in working memory is very limited, we need to help pupils to use that space efficiently. As such, next week we will look at ways of cheating working memory. SecEd

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Further information

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Cheats prosper

Our series on how students learn continues. **Matt Bromley** is looking at the second of his three secrets to boosting long-term memory – how we can help pupils to access their long-term memories quickly by 'cheating' their working memories

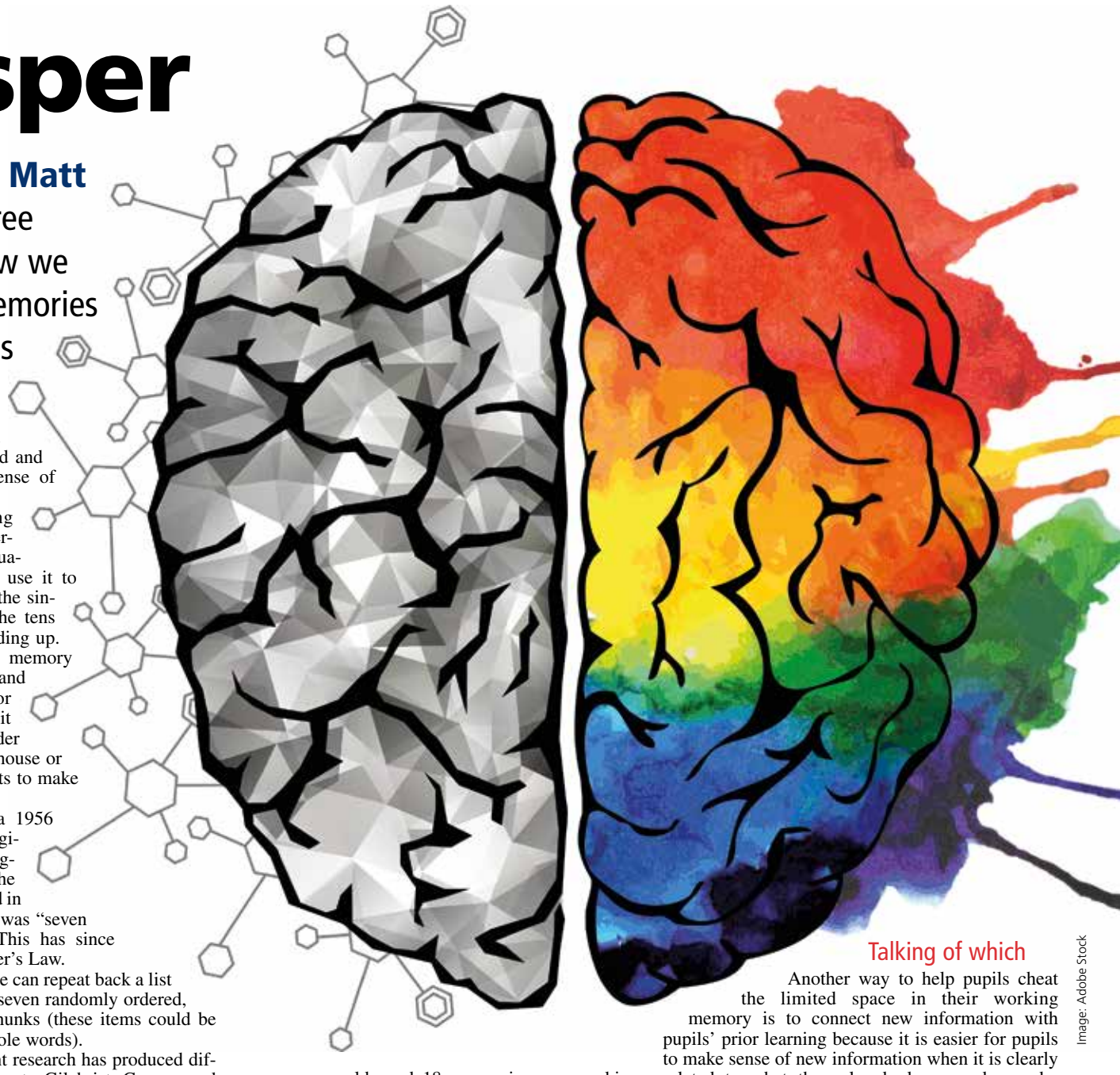

Image: Adobe Stock

Last time I argued that, if we want our pupils to learn anything (by which I mean, encode information in their long-term memories), then we need to engage their active attention and get them thinking hard. We need to give them work to do that's challenging but achievable, because if the work's too easy pupils will complete it through habit, but if the work's too hard pupils will be unable to complete it. In both cases, learning will fail.

But to help pupils think hard, we need to teach them how to cheat the limited space in their working memory in order to avoid cognitive overload. In other words, we need them to think hard but efficiently.

Whereas long-term memory is practically limitless – we can keep filling it for a lifetime and never run out of space – working memory is very limited. What we get when we are born is what we're stuck with for the rest of our lives. We can't increase it, no matter how much so-called "brain-training" we do. And a lack of space in working memory is a functional bottleneck – when we hit the point of cognitive overload, we stop thinking and learning fails. However, there are ways to cheat this limitation...

Let's consider the example of tying our shoe laces. At first, tying our laces requires our full attention and thus absorbs all of our working memory, but with practice we can tie our shoes automatically while our working memory is otherwise engaged, for example by having a conversation. The same rules apply to learning in a classroom environment.

Take for example learning to read. Once we have mastered reading in the sense that we know the sound each letter makes and how letters combine to make words, we still keep practising our reading not just to get faster at reading but in order to get so good at recognising the letters and words and the sounds they make that word recognition becomes automatic. We see words and understand them and

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how they sound without having to think about it and this automaticity frees up precious space in our working memories which we once had to use in order to retrieve sounds and meanings from our long-term memories but which we can now devote to thinking about the meanings of sentences and texts.

Eventually, we get so good at reading that we have enough working memory to be able to recognise allusions and make other connections between the text we are reading and all the background knowledge we already possess.

What's true of reading is true of all the skills our pupils use in all the subjects we teach.

In short, there are ways to making some processing activities automatic so that they bypass – or at least limit the space needed in – working memory, and thus free up space for more complex tasks. We'll explore some of these in a moment, but first let's define working memory then examine just how limited it is.

Working memory and cognitive overload

Our working memory, also called short-term memory, is used to perform mental tasks. For example, we use working memory to retain the meaning from the beginning of a sentence so that we can combine it with the end and thus understand the sense of the whole sentence.

We use working memory to help us perform mathematical equations, for example we use it to carry digits over from the single digits column to the tens and hundreds when adding up. We also use working memory to help us plan ahead and organise our actions. For example, we will use it to help us decide the order in which we clean the house or combine raw ingredients to make a meal.

George Miller, in a 1956 paper, said that "the magical number" of meaningful items or chunks the average person can hold in their working memory was "seven plus or minus two". This has since become known as Miller's Law.

Miller argued that we can repeat back a list of no more than about seven randomly ordered, meaningful items or chunks (these items could be letters, numbers, or whole words).

However, subsequent research has produced different results. According to Gilchrist, Cowan, and Naveh-Benjamin (2008), young adults can only recall between about three and four longer verbal "chunks", such as idioms or short sentences.

Others have simply concluded that the limits of working memory depend on the type of task being performed, the person performing the task, and other environmental factors.

Cognitive load is the amount of mental effort it takes to do a task. There are three types of cognitive load needed for every task:

1 Intrinsic load: This is the amount of mental activity involved in actually performing the task. For instance, in working out a maths problem we must follow a number of mathematical procedures. This effort is intrinsic to the task itself.
2 Germane load: This is the amount of mental effort involved in trying to understand the task or material. For instance, if I read an unfamiliar text, much of my effort would be focused on trying to make sense out of it.
3 Extraneous load or the immediate environment: This is extraneous to learning the subject or doing the task at hand, and is about dealing with the instructional context in which a task is being taught or performed. Disorganised instruction, for example, contributes extraneous load to a task.

Every kind of learning involves a combination of these three sources of mental effort. How we balance the three is the trick to cheating working memory.

Our capacity – and indeed our pupils' capacity – to process information is, as we have already seen, limited. People can manipulate only a few pieces of information at any one time. Pupils are often asked to take in large amounts of new information that exceed their processing capacity, resulting in cognitive overload which, in turn, causes learning to fail. However, we can improve our pupils' capacity for learning by managing and reducing the cognitive load required in our lessons. So, here are some strategies for reducing cognitive load.

Chunk it

As I say above, we can hold between five and nine meaningful items in working memory at any one time. We can help improve the usefulness of these items by combining several separate ideas into one item. This is called "chunking". For example, if I asked you to memorise the following list of letters...

X D H
P E S
C G E
F D V
T I C
B B X

…you would need 18 spaces in your working memory to do so and so would be unable to complete the task. But if I were to ask you to memorise this list instead...

X
B B C
I T V
D F E
G C S E
P H D
X

...I bet you'd fare better than on the first list because you'd be able to chunk various letters into single items. And yet both lists contain the same number of letters (18) and, what's more, both lists are identical albeit for the fact the letters are given in reverse order the second time around.

So why, given that the information you're required to remember is identical, is the second list easier to memorise? Well, it's because you were able to use your prior knowledge to combine separate items into single units, thus reducing the space required in working memory.

Because, for example, you know what the BBC is (a media organisation), you were able to chunk the three letters B, B and C into one item thus reducing the space required in working memory from three to one. The same applies to GCSE which you know is a type of qualification and so you could reduce the space required to memorise this line from four to one, using only a quarter of the space. Rather than 18 items, you could manage with six if you consider the Xs at the beginning and end as one item.

You could also improve your memorisation of the first list by chunking information in other ways. For example, you could invent your own mnemonic to help you cheat the limited space available in working memory, perhaps using the first letter in each line to create an acronym, or you could use the "loci" method made famous by the Sherlock Holmes novels by placing the letters – perhaps represented by household objects – into memorable locations within your mind palace. You could also put the letters to song to help you through rhyme and rhythm.

In the classroom, this means we need to think of ways of reducing the amount of information pupils are expected to remember at any one time. We can teach in chunks and pause between ideas or topics. We could also present information in ready-made mnemonics such as AFOREST (which is a mnemonic used in English to help pupils remember what to include in a piece of persuasive writing).

We could also make explicit the transitions from one topic to another, and make explicit references to how ideas and topics are related to one another. And we could make sure we teach in a logical sequence so that pupils can place new learning within the context of what they already know.

Talking of which

Another way to help pupils cheat the limited space in their working memory is to connect new information with pupils' prior learning because it is easier for pupils to make sense of new information when it is clearly related to what they already know and can do. Large amounts of unfamiliar material automatically increases cognitive load.

By connecting new learning with old, we help reduce the germane load, allowing more space for intrinsic load. This means drawing links, perhaps through the use of metaphor and analogy, and relating new ideas to pupils' own life experiences, and hobbies and interests.

The use of worked examples can also be helpful in reducing germane load because they provide support that simplifies complex tasks. Worked examples and writing frames scaffold complex tasks in much the same way as stabilisers help children learn to ride a bicycle – they provide support so the novice can learn to pedal, steer and brake without also having to concentrate on maintaining their balance.

Once these aspects of cycling become familiar, there is more space in working memory to concentrate on balance and the training wheels can come off. Using a worked example or writing frame involves making the entire solution available so the pupil can explore different aspects of the problem without holding all its various parts in working memory.

And finally, we could remove all irrelevant information – thus reducing the extraneous load – so that pupils need focus only on the information that matters.

Well-organised information is better understood and remembered. Irrelevant material poses problems for pupils because they don't always know that it is irrelevant or tangential and so devote unnecessary mental effort to trying to connect it to the topic at hand.

We should therefore try to reduce extraneous material or move it into a designated part of the lesson where pupils understand that it is not critical information. SecEd

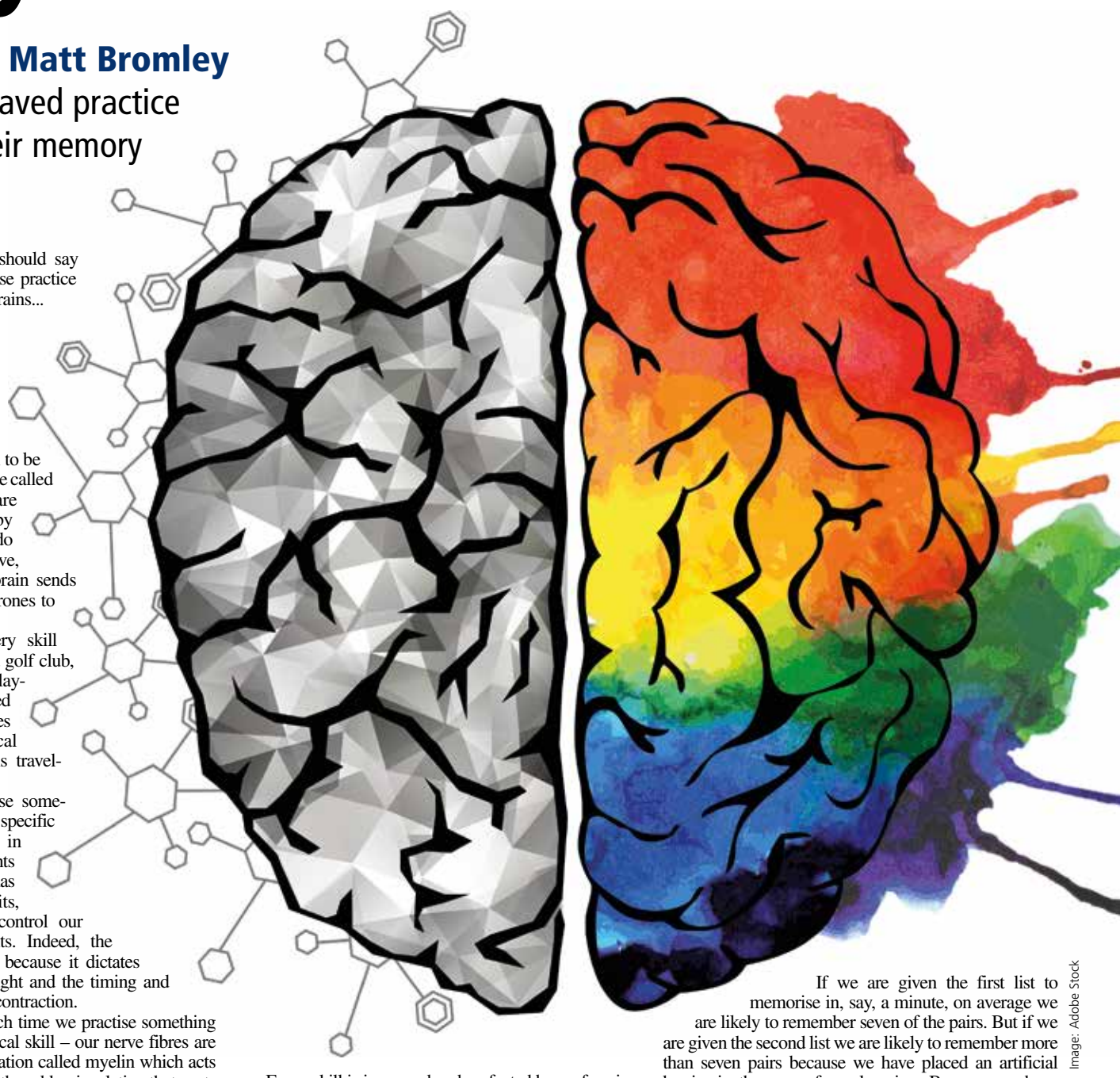
• *Matt Bromley is an education journalist and author with more than 18 years' experience in teaching and leadership. He is the author of best-selling books for teachers including* Making Key Stage 3 Count *and* Teach. *His latest book,* The New Teacher Survival Kit*, is available in paperback and various ebook formats. Visit www.bromleyeducation.co.uk or follow @mj_bromley.*

Further information

This is the sixth in Matt's series of 10 articles focusing on how learning works. The seventh part of the series, which will publish after the half-term on Thursday, November 2, will move on to the third of Matt's secrets to boosting students' recall abilities – deliberate practice. To read the previous articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl

Deliberately difficult

Our series on how students learn continues. **Matt Bromley** moves on to distributed practice and interleaved practice techniques that can help pupils to boost their memory and recall abilities



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The process of learning is the interaction between our sensory memory and our long-term memory.

Our sensory memory, as I have previously explained, is made up of: what we see (this is called our iconic memory), what we hear (this is called our echoic memory), and what we touch (our haptic memory).

Our long-term memory, meanwhile, is where new information is stored and from which it can be recalled later when needed, but we cannot directly access the information stored in our long-term memory – instead, this interaction between our sensory memory and our long-term memory occurs in the working memory.

In order to ensure our pupils learn, therefore, we need to stimulate their sensory memory, gain the attention of – and help them cheat – their working memory, and improve the strength with which information is stored in, and the ease and efficiency with which it can later be retrieved from, their long-term memory. In order to do this, we need to follow three steps...

First, we need to create a positive learning environment. Second, we need to make pupils think hard but efficiently. And third, we need to plan for deliberate practice.

So far in this series we have explored the first two steps and so are at the point where new information has been encoded into long-term memory. But that's not the end of the learning journey.

Now we need to help pupils reduce the likelihood of forgetting this information, and increase its storage strength in long-term memory so that they can access it at a later stage. We also need to improve the retrieval strength of this information from long-term memory so that pupils can recall it with ease and efficiency when needed. In short, we need to help pupils practise what we've taught them – we need to repeat, repeat, repeat...

> **Deliberate practice is about struggling in certain targeted ways – placing artificial barriers in the way of our success in order to make it harder to learn something. We slow our learning down and force ourselves to make mistakes**

The art of repetition

The art of effective repetition is that each time a pupil revisits prior learning it must be as hard as it was the first time they learnt it. After all, when information comes easily to mind and feels fluent, it's just as easy to forget it again. In short, challenging learning is long-term learning.

Retrieval practice – and we'll examine a few different types in a moment – makes learning effortful and challenging. It is important to acknowledge and make pupils aware of this apparent paradox because they'll often think they are doing badly if they can't remember something.

But the mental effort required to retrieve information is the key to improving the storage and subsequent retrieval strength of that information.

When we feel like progress is slow, we do our best learning. In short, the more difficult the retrieval practice is, the better it is for long-term learning.

Struggling to learn – through the act of "practising" what you know and recalling information – is much more effective than simply re-reading, taking notes, or listening to lectures.

In a moment we'll explore some examples of retrieval practice, but first a note on the power of practice more generally, or perhaps I should say the "superpower", because practice physically changes our brains...

The wiring of our brains

Our brain is like the back of an electrician's van: a tangle of coloured wires – about 100 billion to be imprecise. These wires are called neurones and they are connected to each other by synapses. Whenever we do something – think, move, read this article – our brain sends a signal down these neurones to our muscles.

In other words, every skill we possess – swinging a golf club, writing great fiction, playing the piano – is created by chains of nerve fibres carrying small electrical impulses like the signals travelling through a circuit.

Each time we practise something, a different highly specific circuit is illuminated in our heads like fairy lights strung round a Christmas tree. It is these circuits, not our muscles, that control our thoughts and movements. Indeed, the circuit is the movement because it dictates the content of each thought and the timing and strength of each muscle contraction.

More importantly, each time we practise something – be it a mental or physical skill – our nerve fibres are coated in a layer of insulation called myelin which acts in much the same way as the rubber insulation that coats a copper wire: it makes the electrical impulses stronger and faster by preventing the signals from leaking.

Each time we practise a skill, a new layer of myelin is added to the neurone like the lagging on a boiler. The thicker the myelin gets, the better it insulates our nerve fibres and, therefore, the faster our movements and thoughts become.

But that's not all. As well as getting faster, our thoughts and movements also become more accurate as we add more and more layers of myelin, because myelin regulates the velocity with which those electrical impulses travel through our nerve fibres, speeding up or slowing down the signals so that they hit our synapses at exactly the right moment. And timing is all important because neurones are binary: either they fire or they don't. Whether or not they fire is dependent on whether the incoming impulse is big enough to exceed their so-called "threshold of activation".

Imagine, for example, a skill circuit where two neurones have to combine – doubling their impulses – to make a third high-threshold neurone fire, for example to serve an ace in a game of tennis. In order to combine their forces effectively, the two incoming impulses must arrive at almost exactly the same time (and by "almost", I mean within about four milliseconds of each other). If the first two signals arrive more than four milliseconds apart, the third neurone won't fire and the tennis ball will be called out.

Left to their own devices, because our brain has so many connections, our genes are unable to code our neurones to time things as accurately as this. That's why we coat our nerve fibres with myelin to help us achieve such precision.

If you are feeling somewhat dubious that myelin can hold to key to developing every imaginable human skill – from playing sports to playing Schubert – then remember this: everything on Earth is made from the same stuff – atoms. We may not closely resemble a fish or a tree, but we are all made from the same material and share the same cellular mechanism to convert food into energy.

Myelin is also universal: everyone can grow it, most swiftly during childhood but also throughout life. And it is indiscriminate, its growth enables the development of all manner of skills, both mental and physical.

In short, although skills vary in every which way – learning to play tennis is as different from learning to sing as learning to sing is from learning to write poetry – they all, without exception, rely on us growing more layers of myelin around our neurones which, in turn, relies on us practising over and over and over again.

Every skill is improved and perfected by performing it repeatedly because this helps us improve by honing our neural circuitry. And yet not all forms of practice are equal. We create myelin most effectively when we engage in a form of retrieval practice called deliberate practice...

Deliberate practice

Deliberate practice is about struggling in certain targeted ways – placing artificial barriers in the way of our success in order to make it harder to learn something. In other words, we slow our learning down and force ourselves to make mistakes.

In the fifth article in this series (see link in further information), I introduced what Robert Bjork calls "desirable difficulties" – the idea that, by slowing down and making mistakes, we ensure that we are operating at the edges of our ability, avoiding silly mistakes by over-riding System 1 with System 2 – i.e. thinking slow.

So the best form of practice – and therefore the best way to create more myelin – is to set yourself a target just beyond your current ability but within your reach.

If the task is hard yet just within our grasp, then we will learn. And because we struggle but overcome the challenge, our brains are rewarded with a dose of the naturally occurring chemical dopamine which makes us feel good and encourages us to keep on learning. As an example, consider these two lists of word pairs:

List 1:
ocean/breeze
leaf/tree
sweet/sour
movie/actress
petrol/engine
school/uniform
turkey/stuffing
fruit/vegetable
computer/chip
chair/couch

List 2:
sun/clo_ds
river/b_at
music/l_rics
bread/b_tter
pen_il/paper
fish/chi_s
l_nch/dinner
be_r/wine
television/rad_o
duvet/p_llow

If we are given the first list to memorise in, say, a minute, on average we are likely to remember seven of the pairs. But if we are given the second list we are likely to remember more than seven pairs because we have placed an artificial barrier in the way of our learning. Because we have to fill in the missing letters, although this may take but a microsecond, we have to stop and stumble until we work it out.

That microsecond makes all the difference – in that moment, we don't practise any harder but we do practise deeper. We slow down and locate what Robert Bjork calls "the sweet spot" – the optimal gap between what we know and what we're trying to do. When we find that sweet spot, Bjork says, "learning takes off".

Returning to myelin

Let's return to myelin, our magic insulation. Deliberate practice or desirable difficulties – whatever you wish to call it – is the notion that targeted, mistake-focused practice is the most effective means of developing skills. And it is so effective because the best way to build a fast and accurate neural circuit is – to quote Daniel Coyle – "to fire it, attend to mistakes, then fire it again, over and over". Why? Because "struggle is not an option, it's a biological requirement".

In summary, practice does not make perfect, it makes myelin, and myelin makes perfect. And myelin is not built to respond to fond wishes or vague ideas; it is built to respond to actions – the electrical impulses travelling down nerve fibres. As such, it responds to urgent repetition.

This is why, once we have taught something for the first time and pupils have encoded it in long-term memory, we must return to it again and again and, each time, ensure that retrieval practice is hard work. Only by repeating learning in deliberate, targeted ways, will pupils improve the storage and retrieval strength of that information – and thus learn it in any meaningful sense.

SecEd

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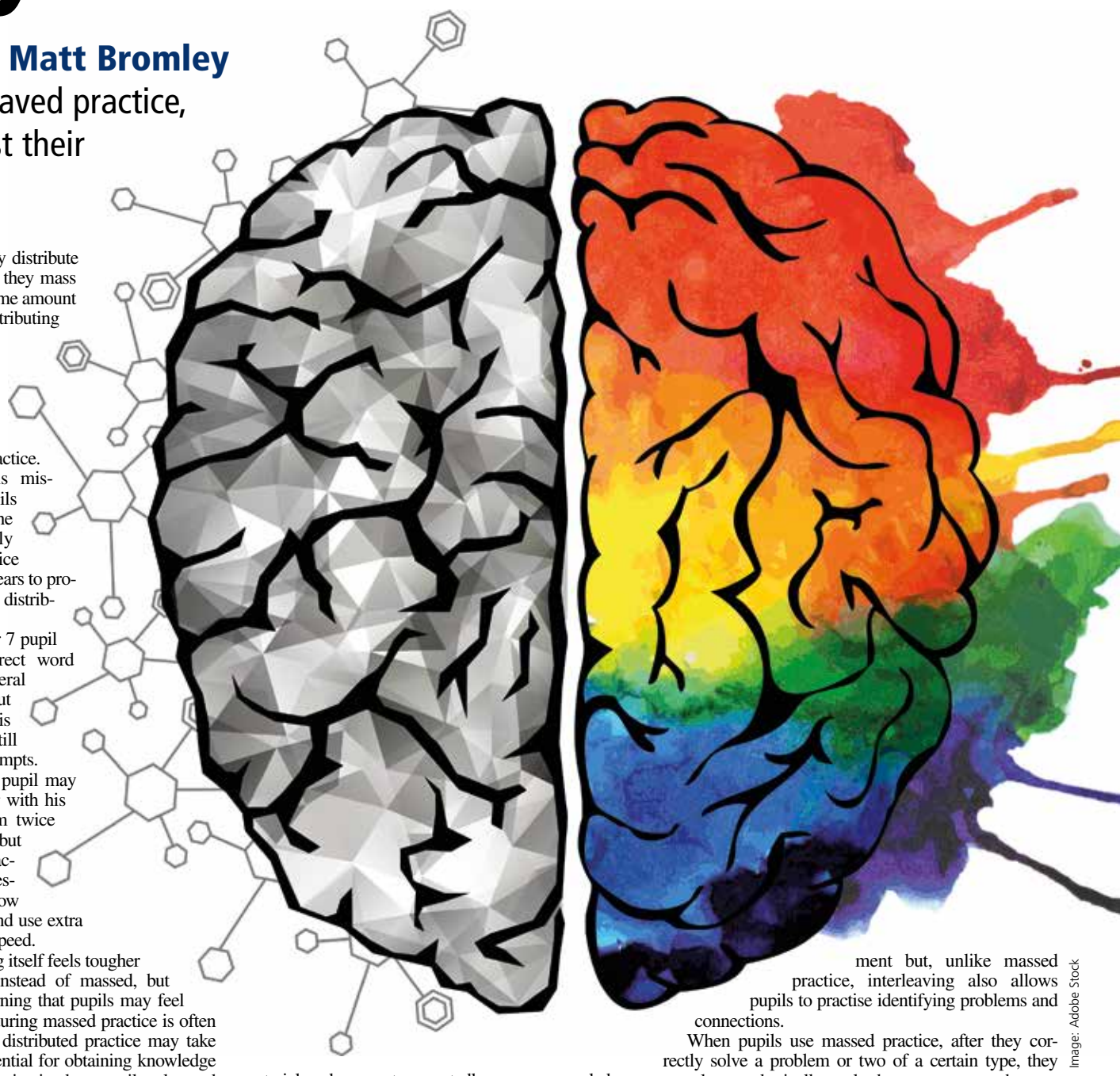
Further information

This is the seventh in Matt's series of 10 articles focusing on how learning works. The eighth part of the series, which will publish on Thursday, November 9, will continue the focus on practice techniques. To read the previous articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl

Deliberately difficult

Our series on how students learn continues. **Matt Bromley** moves on to distributed practice and interleaved practice, two techniques that can help pupils to boost their memory and recall abilities



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The process of learning is the interaction between our sensory memory and our long-term memory and takes place in the working memory. In order to ensure our pupils learn, therefore, we need to stimulate their sensory memory, gain the attention of – and help them cheat – their working memory, and improve the strength with which information is stored in, and the ease and efficiency with which it can later be retrieved from, their long-term memory. In order to do this, we need to follow these three steps...

First, we need to create a positive learning environment. Second, we need to make pupils think hard but efficiently. And third, we need to plan for deliberate practice.

Last week we said that, once new information had been encoded into long-term memory, we had to help pupils reduce the likelihood of forgetting it, and increase its storage strength so that pupils can access the information at a later stage. We also need to improve the retrieval strength of the information held in long-term memory so that pupils can recall it with ease and efficiency as and when needed.

In short, we need to help pupils practice what we've taught them and the secret to doing this well is ensuring that each time a pupil revisits prior learning the task must be as hard as it was the first time they learnt it. This is called deliberate practice.

As well as deliberate practice, however, we can help improve the storage and retrieval strength of the information in pupils' long-term memories by getting them to engage in spaced – or distributed – practice.

Spaced practice

Spaced practice is a straightforward and easy-to-use technique. Consider the following examples.

A year 7 pupil studies for a spelling test. Using a worksheet to guide her practice, she might take one of two approaches. She could practise spelling the words by writing each one several times directly below the word printed on the sheet. After practising one word repeatedly, she would move on to the next one and practise writing that word several times below it. This kind of practice is called massed practice, or cramming, because the pupil practises each word multiple times together, before moving to the next one.

> **Distributed practice may take more effort, but it is essential for obtaining knowledge in a manner that will be maintained – or easily relearned – over longer, educationally relevant periods of time**

An alternative strategy for the pupil would be to practise writing each word only once, and after transcribing the final word, going back and writing each one again, and so forth, until the practice is complete. This kind of practice is called spaced or distributed practice, because practice with any one word is distributed across time (and the time between practising any one word is filled with another activity – in this case, writing other words).

In this example, the pupil either masses or distributes her practice during a single session.

Now, imagine a year 8 pupil trying to learn some basic concepts for an upcoming test. He might read over his notes diligently, in a single session the night before the exam, until he thinks he is ready for the test – a study tactic called cramming, which practically all pupils use.

Or, as an alternative, he might study his notes and texts during a shorter session several evenings before the exam and then study them again the evening before. In this case, the pupil distributes his studying across two or more sessions.

Pupils will retain knowledge and skills for a longer period of time when they distribute their practice than when they mass it, even if they use the same amount of time massing and distributing their practice.

Give mass a miss

Unfortunately, however, many pupils believe that massed practice is better than distributed practice.

One reason for this misconception is that pupils become familiar with the target material quickly during a massed practice session, but learning appears to proceed more slowly with distributed practice.

For instance, the year 7 pupil quickly writes the correct word after practising it several times in succession, but when the same practice is distributed, she may still struggle after several attempts.

Likewise, the year 8 pupil may quickly become familiar with his notes after reading them twice during a single session, but when distributing his practice across two study sessions, he may realise how much he has forgotten and use extra time getting back up to speed.

In both cases, learning itself feels tougher when it is distributed instead of massed, but the competency and learning that pupils may feel (and teachers may see) during massed practice is often ephemeral. By contrast, distributed practice may take more effort, but it is essential for obtaining knowledge in a manner that will be maintained – or easily relearned – over longer, educationally relevant periods of time.

Most pupils, whether they realise it or not, use distributed practice to master many different activities, but not when they are studying...

For instance, when preparing for a music recital, most pupil violinists will practise a piece nightly until they have mastered it; they will not just do all the practice the night before the recital, because everyone knows that this kind of practice will likely not be successful.

Similarly, when playing computer games, pupils see their abilities and skills improve dramatically over time, in large part because they keep coming back to play the game in a distributed fashion.

In these and many other cases, pupils realise that more practice or play during a current session will not help much, and they may even see their performance weaken near the end of a session, so, of course, they take a break and return to the activity later. However, for whatever reason, pupils don't typically use distributed practice as they work toward mastering course content.

Encouraging distributed practice

To distribute practice over time, pupils should set aside blocks of time throughout each week to study the content for each class. Each study block will be briefer than an all-night cramming session, and it should involve studying (and using practice tests) for material that was recently introduced in class and for material they studied in previous sessions.

To use distributed practice successfully, teachers should focus on helping pupils map out how many study sessions they will need before an exam, when those sessions should take place (such as which evenings of the week), and what they should practice during each session. For any given class, two short study blocks per-week may be enough to begin studying new material and to restudy previously covered material.

Ideally, pupils will use practice tests to study the previously covered material. If they do, they will quickly retrieve the previously learned material after just a handful of sessions, which will leave more time for studying new material.

Of course, pupils may need help setting up their study schedules, and they may need some encouragement to use the strategy. But by using distributed practice (especially if it is combined with practice testing), many pupils will begin to master material they never thought they could learn.

We can also use distributed practice in the classroom. The idea here is to return to the most important material and concepts repeatedly across several days. For instance, if weekly quizzes are already being administered, we could easily include content that repeats across quizzes so pupils will relearn some concepts in a distributed manner.

Repeating key points across lessons not only highlights the importance of the content but also gives pupils distributed practice. Administering a cumulative exam that forces pupils to review the most important information is another way to encourage them to study content in a distributed fashion.

Having explored spaced practice, let's now consider the importance of interleaved practice.

Interleaved practice

Interleaved practice involves not only distributing practice across a study session but also mixing up the order of materials across different topics.

Distributed practice is better than massed practice, but the former typically refers to distributing the practice of the same problem across time. Thus, for spelling, a pupil would benefit from writing each word on a worksheet once, and then cycling through the words until each has been spelled correctly several times.

Interleaved practice is similar to distributed practice in that it involves spacing one's practice across time, but it specifically refers to practising different types of problems across time.

Consider how a standard science or maths textbook encourages massed practice: in a text, pupils may learn about adding and subtracting real numbers, and then spend a block of practice adding real numbers, followed by a block of practice subtracting. The next chapter would introduce multiplying and dividing real numbers, and then practice would focus first on multiplying real numbers, and then on dividing them, and so forth.

Thus, pupils are massing their practice of similar problems. They practise several instances of one type of problem (e.g. addition) before practising the next type (e.g. subtraction). In this example, interleaving would involve solving one problem from each type (adding, subtracting, multiplying, and dividing) before solving a new problem from each type.

One aspect of massed practice that pupils may find appealing is that their performance will quickly improve as they work with a particular problem. Unfortunately, such fluent performance can be misleading; pupils believe that they have learned a problem well when in fact their learning is fleeting.

So, why does interleaving work so well? In contrast to massed practice, interleaving problems requires distributing practice, which by itself benefits pupil achievement but, unlike massed practice, interleaving also allows pupils to practise identifying problems and connections.

When pupils use massed practice, after they correctly solve a problem or two of a certain type, they can almost robotically apply the same steps to the next problem. That is, they do not have to figure out what kind of problem they are solving; they just have to apply the same rules to the next problem.

For interleaving, when a new problem is presented, pupils need to first figure out which kind of problem it is and what steps they need to take to solve it. This is often a difficult aspect of solving problems.

Teachers often demonstrate how to do a few problems (whether writing compound sentences or adding fractions), and then ask pupils to complete a set of similar problems on their own. Pupils learn more, however, when they are given incremental guidance on problem-solving.

In a type of interleaving, problems with written-out solutions should alternate repeatedly with problems that the pupils will solve. Solved problems help pupils focus on the underlying principles that apply to each situation, instead of promoting mechanical solutions to problems. Here's how it works...

First, we interleave worked example solutions with problem-solving exercises. For example, we could get pupils to alternate between reading already worked solutions and trying to solve problems on their own.

Next, as pupils develop greater expertise, we reduce the number of worked examples we provide and increase the number of problems that pupils solve independently. Finally, we use explanations to accompany solved problems in order to help pupils comprehend any underlying principles, taking them beyond the mechanics of problem-solving.

So practice makes permanent and spaced and interleaved practice works best of all. But what else can we do to help increase the storage and retrieval strength of the information we've taught them? One answer is to test pupils, and we will explore this next week. SecEd

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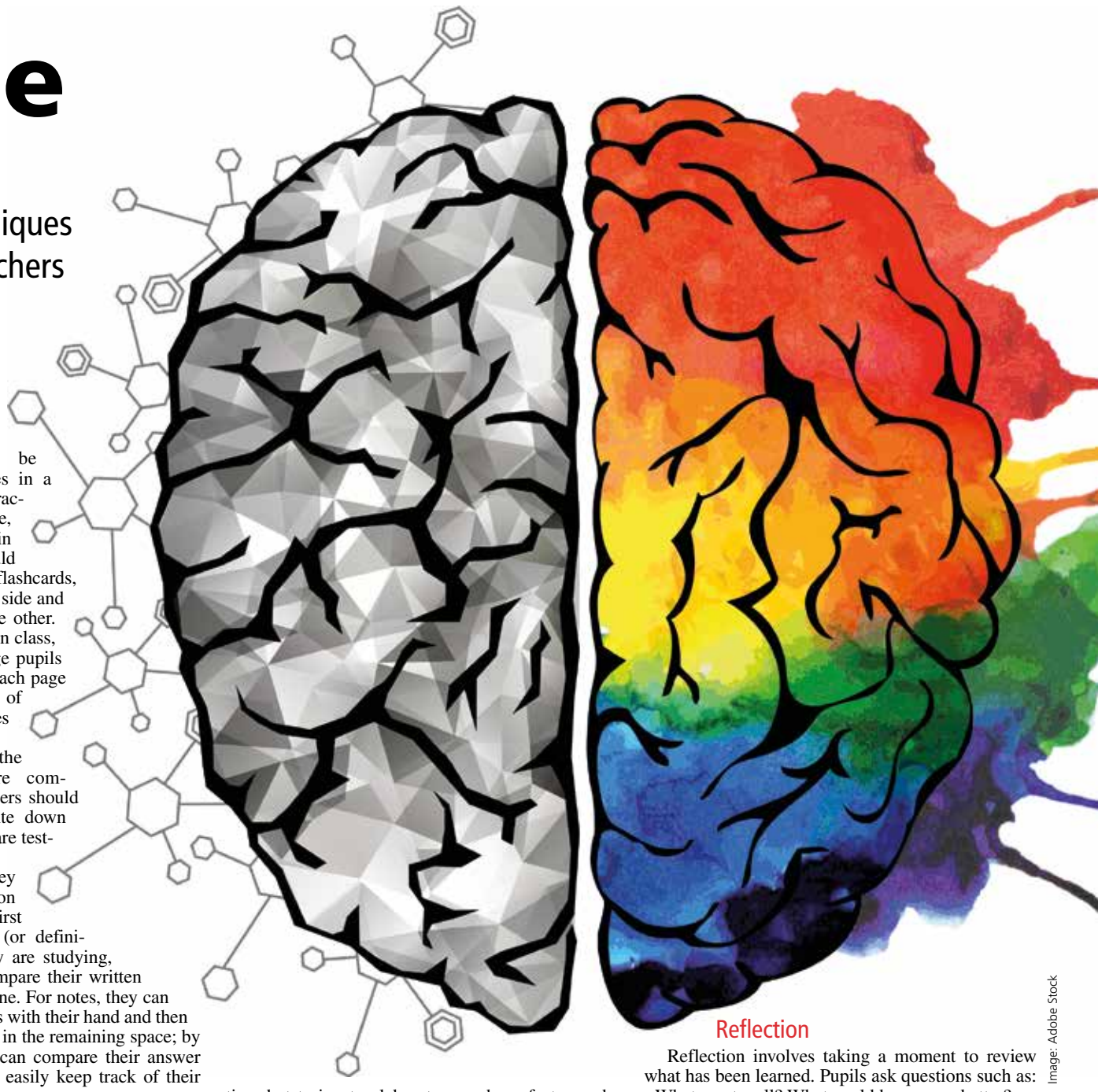
Further information

This is the eighth in Matt's series of 10 articles focusing on how learning works. The penultimate part of the series, which will publish on Thursday, November 16, will look at in-class testing to help improve memory abilities. To read the previous articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl

It's quiz time

Our series on how students learn continues. **Matt Bromley** looks at how quizzing techniques can be used by students at home and by teachers in class to help improve memory and recall



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As we have discovering in this series, we can do three things to help our pupils learn: we can create a positive learning environment. we can make pupils think hard but efficiently, and we can plan for deliberate practice.

In the last few articles, I have argued that, once new information has been encoded into pupils' long-term memories, we have to help reduce the likelihood of them forgetting it and increase its storage strength so that pupils can access that information at a later stage. We also have to help pupils improve the retrieval strength of that information so that pupils can recall it with ease and efficiency as and when needed.

We do this by ensuring pupils repeatedly practice what we've taught them and by making sure that each time they revisit prior learning the task is as hard as it was the first time they learnt it. This, I explained, is called deliberate practice, and two forms of deliberate practice – spacing and interleaving – work best of all (see the eighth article in this series: *The process of learning: Deliberately difficult*, *SecEd*, November 2017: http://bit.ly/2i1kKHq).

But what else can we do to help increase the storage and retrieval strength of the information we've taught our pupils?

One answer is to test them. But "test" and "exam" are four-letter words that provoke anxiety. Perhaps it's time to replace "test" with another, less offensive, four-letter word: "Quiz."

Quizzing

In 1909, a doctoral pupil at the University of Illinois demonstrated that practice quizzes improve pupil performance, and more than 100 years of research has shown that taking practice quizzes (versus merely re-reading study notes) can substantially boost pupil learning.

Consider two pupils who have just read a chapter in a textbook. Both pupils review the most important information in the chapter, but one pupil just reads the information again, whereas the other pupil hides the information and attempts to recall it from memory.

> **Pupils should also be encouraged to 'get it right' on more than one occasion, for example by returning to the deck of flashcards on another day and relearning the materials**

Compared with the first pupil, the second pupil, by testing herself, is boosting her long-term memory. Unlike simply reading a text, when pupils correctly retrieve an answer from memory, the correct retrieval can have a direct effect on memory.

But that's not all – practice quizzes can also have an indirect effect on pupil learning because when a pupil fails to retrieve a correct answer during a practice quiz, that failure signals that the answer needs to be restudied. In other words, practice quizzes can help pupils to make better decisions about what needs further practice and what does not.

Quizzes in practice

So how might pupils use quizzes to best harness the power of retrieval practice? First, pupil learning can benefit from almost any kind of practice, whether it involves completing a short essay where pupils need to retrieve content from memory or answering questions in a multiple-choice format.

Research suggests, however, that pupils will benefit most from quizzes that require recall from memory, rather than from tests that merely ask them to recognise the correct answer from a list of options. Although they may need to work a bit harder to recall key materials (especially lengthy ones) from memory, the pay-off is greater in the long-term.

Pupils should also be encouraged to take notes in a manner that will foster practice quizzes. For instance, as they read a chapter in their textbook, they should be encouraged to make flashcards, with the key term on one side and the correct answer on the other. Also, when taking notes in class, teachers should encourage pupils to leave blank space on each page (or on the back pages of notes) for practice quizzes later.

In both cases, as the material becomes more complex (and lengthy), teachers should encourage pupils to write down their answers when they are testing themselves.

For instance, when they are studying concepts on flashcards, they should first write down the answer (or definition) of the concept they are studying, and then they should compare their written answer with the correct one. For notes, they can hide key ideas or concepts with their hand and then attempt to write them out in the remaining space; by using this strategy, they can compare their answer with the correct one and easily keep track of their progress.

Third, and perhaps most importantly, pupils should continue testing themselves, with feedback, until they correctly recall each concept at least once from memory. For flashcards, if they correctly recall an answer, they can pull the card from the pack; if they do not recall it correctly, they should place it at the back of the pack.

For notes, they should try to recall all of the important ideas and concepts from memory, and then go back through their notes once again and attempt to correctly recall anything they did not get right during their first attempt.

If pupils persist until they recall each idea or concept correctly, then they will enhance their chances of remembering those concepts in an actual exam. Pupils should also be encouraged to "get it right" on more than one occasion, for example by returning to the deck of flashcards on another day and relearning the materials.

Using practice quizzes may not come naturally to pupils, so we should play an important role in convincing them of the power of practice quizzes and in teaching them how they apply to the content we're covering in class.

Quizzes in class

Not only can pupils benefit from using practice quizzes when studying alone, we can also use practice quizzes in the classroom. The idea here is that we choose the most important ideas and then take a couple of minutes at the beginning or end of each lesson in order to quiz pupils.

After all our pupils have answered a question, we can provide the correct answer and give feedback. The more closely the practice questions test pupils on the same information that will be tested in the exam, the better pupils will do.

Once we have taught pupils curriculum content and they have practised it in spaced and interleaved ways, and then have been quizzed – or have quizzed themselves – on the information, they should be encouraged to engage in some elaborative interrogation...

Elaborative interrogation

Imagine a pupil reading an introductory passage on photosynthesis: "It is a process in which a plant converts carbon dioxide and water into sugar, which is its food. The process gives off oxygen." If the pupil were using elaborative interrogation while reading, she would try to explain to herself why this fact is true...

In this case, she might think that it must be true because everything that lives needs some kind of food, and sugar is something that she eats as food. She may not come up with exactly the right explanation, but trying to elaborate on why a fact may be true, even when the explanations are not entirely accurate, can increase understanding and improve retention. If the pupil were also using a second, related strategy called self-explanation, however, she would then try to explain how this new information is related to information that she already knows...

In this case, she might consider how the conversion to oxygen is like how her own body changes food into energy and other fumes.

Self-explanation

Self-explanation, then, is about retrieving information from memory and is far more effective than simply re-reading. As such, when pupils read a text or study notes, we need to teach them to pause periodically to ask themselves questions – without looking in the text – such as:

- What are the key ideas?
- What terms or ideas are new to me? How would I define them?
- How do the ideas in this text relate to what I already know?

One reason for the success of elaborative interrogation and self-explanation in promoting learning is that they encourage pupils to actively process the curriculum content they are paying attention to and integrate it with their prior knowledge.

Even young pupils should have little trouble using elaborative interrogation, because it simply involves encouraging them to ask the question "why?" when they are studying.

The difference between this type of "why" and the "why" asked in early childhood (when this is a common question to parents) is that pupils must take the time to develop their own answers.

Other approaches

What else, in addition to practice quizzes, elaborative interrogation and self-explanation, can pupils do as part of their self-directed revision in order to improve the storage and retrieval strength of the information in their long-term memories?

Well, according to Paul C Brown et al in *Make It Stick*, the following study skills have been proven to be particularly helpful...

Generation

Generation is when pupils attempt to answer a question or solve a problem before being shown the answer or the solution. The act of filling in a missing word (the cloze test) results in better learning and a stronger memory of the text than simply reading the text. Before reading new class material, we should ask pupils to explain the key ideas they expect to find and how they expect these ideas will relate to their prior knowledge.

Reflection

Reflection involves taking a moment to review what has been learned. Pupils ask questions such as:

- What went well? What could have gone better?
- What other knowledge or experience does it remind me of?
- What might I need to learn in order to achieve better mastery?
- What strategies could I use next time to get better results?

Calibration

Calibration is achieved when pupils adjust their judgement to reflect reality – in other words, they become certain that their sense of what they know and can do is accurate. Often when we revise information, we look at a question and convince ourselves that we know the answer, then move on to the next question without making an effort to actually answer the previous one.

If we do not write down an answer, we may create the illusion of knowing when in fact we would have difficulty giving a response. We need to teach our pupils to remove the illusion of knowing and actually answer all the questions even if they think they know the answer and that it is too easy.

In addition, we might wish to explicitly teach students how to anticipate test questions during lessons, how to copy out key terms and their definitions into a notebook and test themselves on them, and also how to re-organise class material into a study or revision guide.

We might also set a weekly homework whereby pupils create crib sheets (perhaps a side of A4) on which they summarise the previous week's learning in text, annotated illustrations, or graphic organisers. The purpose of this task is to stimulate retrieval and reflection, and to capture the previous week's learning before it is lost.

Next week, in the final part of this series, we will discuss the use of graphic organisers, daily free-call and recall, weekly quizzes and end-of-topic tests as the foundations of an effective classroom. SecEd

• *Matt Bromley is an education journalist and author with more than 18 years' experience in teaching and leadership. He is the author of best-selling books for teachers including* Making Key Stage 3 Count *and* Teach. *His latest book,* The New Teacher Survival Kit*, is available in paperback and various ebook formats. Visit www.bromleyeducation.co.uk or follow @mj_bromley.*

Further information

This is the ninth in Matt's series of 10 articles focusing on how learning works. The final part of the series will publish on Thursday, November 23. To read the previous articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl

Total recall

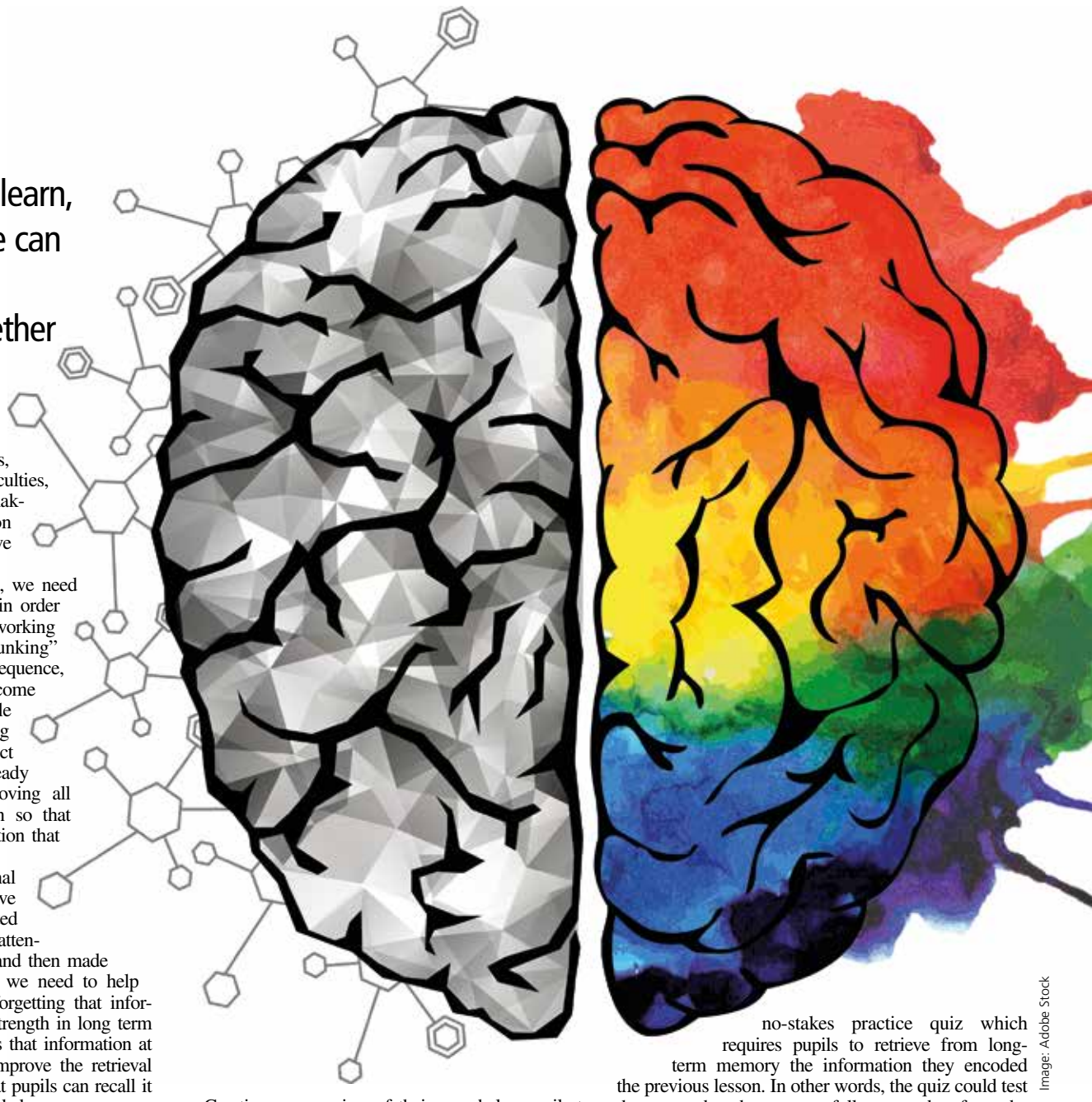

Image: Adobe Stock

In the final instalment of our series on how students learn, **Matt Bromley** recaps his key messages on how we can improve pupils' recall abilities and offers some useful classroom routines to bring many of these ideas together

I started this 10-part series by asking the ostensibly simple question, what is learning? It's only ostensibly simple because it isn't as easy to answer as we might at first assume.

Learning, after all, is multifaceted. Some forms of learning, like learning to ride a bike for instance, are immediate and observable but other types of learning are neither of these things. The immediate demonstration of knowledge or skill could be mere performance, mimicry rather than mastery, a poor proxy for learning.

There's nothing necessarily wrong with mimicry if it helps a pupil pass a test and get a qualification, but assuming we want to do more than "teach to the test" and assuming we regard education as something meaningful and life-long, a way of becoming an engaged and active citizen, and an inquisitive, cultured adult, then surely we must aim to move beyond mimicry and towards mastery?

We must, therefore, teach in such a way as to ensure our pupils not only acquire new knowledge and skills but can apply those knowledge and skills at a later time and in a range of different contexts.

With this in mind, the definition of "learning" I shared at the start of this series was as follows: learning is the acquisition of knowledge and skills, and their application at a later time and in a range of contexts.

Having settled on this definition, I then set out to articulate the process by which learning occurs. It is, I argued, an interaction that takes place between our sensory memory (sometimes referred to as our "environment") and our long-term memory.

Our sensory memory is made up of: what we see (our iconic memory), what we hear (our echoic memory), and what we touch (our haptic memory). Our long-term memory is where information is stored and from which it can later be recalled when needed, but we cannot directly access the information stored in our long-term memory.

As such, this interaction between our sensory memory and our long-term memory, which is at the heart of learning, occurs in our working memory – the only place where we can think and do.

In order to improve this process so that our pupils are afforded the best opportunity to learn, I suggested we take the following three steps:

> **Develop a routine whereby pupils spend 10 minutes at the end of every lesson filling a blank piece of paper with everything they can remember from that lesson**

- Create a positive learning environment in order to stimulate sensory memory.
- Make pupils think hard but efficiently in order to gain the attention of – but cheat – working memory.
- Plan for deliberate practice in order to improve storage in, and retrieval from, long-term memory.

In terms of the first step, a positive learning environment, I said, is one in which all pupils:

- Feel welcomed.
- Feel valued.
- Are enthusiastic about learning.
- Are engaged in their learning.
- Are eager to experiment.
- Feel rewarded for their hard work.

But it is also one in which our pupils' iconic, echoic and haptic memories are stimulated (the first step) – by making ideas tangible, clear, satisfying, and concrete. Pupils' senses are also stimulated through the use of dual coding which helps utilise both verbal and visual processing in working memory.

In terms of the second step, making pupils think hard means giving them work to do that's challenging but achievable, because if the work's too easy, pupils will complete it through habit, and if the work's too hard, pupils will be unable to complete it. In both cases, learning will fail. Work should be pitched in pupils' "struggle zones" (what they can do with time, effort and support). We do this, in part, by creating desirable difficulties, by slowing learning down and making it harder to encode information initially so that it's easier to retrieve it later.

Once pupils are thinking hard, we need to help them to think efficiently in order to cheat the limited space in working memory. And this means "chunking" information, teaching in a logical sequence, over-teaching routines so they become automatic and require very little space in working memory, using analogy and metaphor to connect new learning to what pupils already know and understand, and removing all irrelevant, extraneous information so that pupils focus only on the information that matters.

In terms of the third and final step, once we have created a positive learning environment and stimulated pupils' senses in order to gain the attention of their working memories, and then made pupils think hard but efficiently, we need to help pupils reduce the likelihood of forgetting that information, and increase its storage strength in long term memory so that pupils can access that information at a later stage. We also need to improve the retrieval strength of that information so that pupils can recall it with ease and efficiency when needed.

In short, therefore, we need to help pupils practice what we've taught them and the art of effective practice is that, each time a pupil revisits prior learning, it must be as hard as it was the first time they learnt it.

The best forms of deliberate practice are spacing and interleaving, and the best study skills to teach pupils are: practice quizzing, elaborative interrogation and self-explanation, generation, reflection, and calibration.

To conclude this series, I'd like to set out a useful classroom routine that helps bring many of these ideas together: the use of graphic organisers, daily free-call and recall, weekly quizzes and end-of-topic tests.

Graphic organisers

Graphic organisers can help to focus pupils' attentions on the key concepts and vocabulary they need to learn.

Visual representations of information are by no means new – the use of graphs and charts to represent statistical information and time-lines showing a sequence of historical events have long been accepted teaching and learning tools, and graphic organisers in the form of mind-maps are common aides to brainstorming what pupils know about a topic.

However, the realisation that pupils can cheat their limited working memories by accessing both verbal and visual processes at once, and the increasing recognition of the importance of retrieval practice, has meant that graphic organisers have become more commonplace.

Graphic organisers are usually one side of A3. Sometimes they are given to pupils pre-populated, at other times – especially when used for retrieval purposes – they are given with blank spaces for pupils to complete. Often, the information contained in a graphic organiser could just as easily be written as a list, but the organiser offers certain advantages:

- Graphic organisers provide pupils with a different way of seeing and thinking about information.
- Graphic organisers help to remove language barriers so that pupils can focus on connections between information.
- The visual nature of graphic organisers helps convey complex information in a simple-to-understand manner because they show (rather than tell) pupils how information is structured and this facilitates their deeper understanding.
- Graphic organisers help develop pupils' analytical, critical and creative thinking skills because, to create an organiser, pupils have to identify relationships between items, examine the meanings attached to them, and prioritise information in order to decide where each item should be placed on the page.
- Graphic organisers enable a lot of information to be converted into a structured, easy-to-read, visual display. This helps to provide the "big picture" of a topic.
- Changes can easily be made to allow pupils to take different perspectives and clarify their thoughts. Organisers are easy to edit, revise, and add to.
- Creating an organiser of their own helps pupils to generate ideas and see the possibilities associated with a topic as the visual grows.

A 2003 review study by the Institute for the Advancement of Research in Education at AEL concluded that using graphic organisers improves pupil performance in the following areas:

- Retention – pupils retained information better and could more easily recall it when it was represented and learned both visually and verbally.
- Reading comprehension – the use of graphic organisers helped improve pupils' reading comprehension.
- Pupil achievement – pupils with and without learning difficulties and disabilities were found to improve their grades when using graphic organisers.
- Thinking and learning skills, and critical thinking – when pupils developed and used their own graphic organisers, their higher order thinking and critical thinking skills were judged to be enhanced.

Crucially for our purposes, the content of graphic organisers can be used to frame practice quizzes. Indeed, it is good practice to only test pupils on the content of the graphic organiser for that topic. In this sense, graphic organisers can become the "bible" of curriculum content – the only source of information we need our pupils to pay attention to and learn, thus removing extraneous and irrelevant information and focusing pupils' attentions on what we need them to think about.

Graphic organisers are also useful planning tools for the teacher – they help us to focus on the curriculum content that's most important for pupils to learn and therefore they help us to keep the main thing the main thing in our lessons.

Daily free-call

Once we have created our graphic organisers for a given topic, a useful revision technique to teach pupils is to get them to engage in a daily "free recall" (or free-call) activity. This requires you to develop a routine whereby pupils spend 10 minutes at the end of every lesson filling a blank piece of paper with everything they can remember from that lesson.

This helps pupils to recall from long-term memory what they've just been taught, thus beginning the process of retrieval immediately, and it helps to make explicit what information they have taken on-board and encoded. The result can then be used to help pupils revise for the following lesson which we could start with a short recap quiz.

The idea of free-call can be extended into a weekly homework whereby pupils create summary sheets for the previous week's learning. These could be annotated notes, perhaps with diagrams. The purpose of this task is to stimulate retrieval and reflection and to capture the previous week's learning before it is lost.

Daily or weekly practice quizzes

Every lesson could start with a short, low-stakes or no-stakes practice quiz which requires pupils to retrieve from long-term memory the information they encoded the previous lesson. In other words, the quiz could test them on what they successfully remember from the previous day – and, just as usefully – highlight what they have forgotten. These quizzes could make use of spacing and interleaving, too, if questions are from mixed topics and some questions are returned to after a suitable period of time has elapsed. The daily recap quizzes could be weekly if this is more feasible but should test pupils on the information they were taught in every lesson that week.

Topic tests

At the end of each topic, the questions from the low-stakes quizzes – which in turn are taken from the graphic organiser for that topic – could be combined to create a more formal end-of-topic test.

This test could serve two purposes: first, it could highlight to pupils what they have and have not remembered, thus focusing their attention on what needs to be practised some more (while also engaging them in another round of retrieval practice).

Second, it could provide the teacher with crucial assessment data to inform future planning. For example, it could highlight for them which aspects of the topic were not as well taught as others and which aspects may need recapping or completely reteaching. It can also highlight pupils' common misconceptions.

Conclusion

And that brings us to the end of our learning journey. We have explored ways of creating a positive learning environment in order to stimulate sensory memory, of making pupils think hard but efficiently in order to gain the attention of, but cheat, working memory, and of planning for deliberate practice in order to improve storage in, and retrieval from, long-term memory.

By so doing, we should help ensure our pupils not only acquire new knowledge and skills but can also apply those knowledge and skills at a later time and in a range of different contexts. And, thus, we can truly say that we haven't just taught, but that our pupils have also learnt. SecEd

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Further information

- This is the final article in Matt's series of 10 articles focusing on how learning works. You can download a pdf of all 10 articles for free via www.sec-ed.co.uk/supplements/
- To read the individual articles in the series or Matt's archive of best practice articles for *SecEd*, visit http://bit.ly/1Uobmsl