PRAISE FOR THIS BOOK

'As a school leader with a passion for teaching and learning, this book gives much to think about.'

Jo Fox, Deputy Headteacher, Ian Ramsey Church of England Academy

'McGill has truly brought together the science behind teaching AND learning.'

Sam Martin, Senior Assistant Headteacher (Teaching & Learning), Kennet School

'Ross has done it again! Grounded in cutting-edge neuroscience, his book turns fMRI research into practical, inclusive strategies that educators can use immediately in their classrooms to support all learners.'

Trudi Fisher, Lead Practitioner, Harrow Way Community School

'For years, as a teacher trainer, I have recognised, and taught, the importance of neuroscience, but we have generally lacked a clear, simple and up-to-date book. Ross Morrison McGill is now about to launch what is set to be one of the most definitive guides to cognitive science.'

John Viner, Adept Education Associates

'Reading this book was like being given the best advice from your most admired colleague. It opens your eyes to the treasure trove of scientific research into learning and gives you the confidence to use this in your everyday practice.'

Laura Marshall-Smith, Assistant Headteacher, Fakenham Academy

'[The book] does not disappoint, grounded in a deep understanding of how students think and learn. Ultimately, it doesn't ask teachers to do more, it helps us do what we already do, better.'

Kate Monin, Science teacher

‘This is the kind of book that should be part of every teacher training course and found in every staffroom library.’

Harsha Patel, Headteacher, Acton Gardens Primary School

‘As more students are identified as neurodivergent, this book offers a truly informative and practical approach to supporting all learners in the classroom. It’s already changed my teaching practice and how I help other teachers develop.’

Emma Chadwick, Assistant Headteacher, The Maple School, Synergy Education Trust

‘Ross expertly connects the art and science of teaching, making neuroeducation clear, practical and immediately useful for educators, leaders and CPD leads who want to better understand how learning happens and how this can strengthen classroom practice.’

Rebecca Bierton, National Director of Primary and Safeguarding, Ormiston Academies Trust

‘The beauty of this book is that it breaks down and supports how we learn. As ever, Ross has given really clear models that are easy to understand and apply, to work with driving improvement at a whole school level!’

Chris Stainsby, Deputy Headteacher, Queen Elizabeth School

‘Ross has produced something that allows us to fully understand how we learn with tangible and focused opportunities to put it into practice. A helpful and informative book that reminds me why I teach, while showing how to make processes simpler.’

Victoria Ayres, SEND teacher, Esland Bedford School

‘The connection between neuroscience and practical pedagogy is blended seamlessly, from the “debunking board” to useful classroom checklists. This guide stands out by offering educators an entirely different way to understand thinking, memory and learning.’

Kate Jones, Education adviser, former teacher and leader, and author

THE TEACHER TOOLKIT
GUIDE TO THE SCIENCE OF LEARNING



ROSS MORRISON McGILL

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ACKNOWLEDGEMENTS

This book represents the culmination of several years of curiosity, reading and conversations with teachers and researchers. What began with a simple question – how does learning happen? – has evolved into a much deeper exploration of what might be happening in the brain when we teach. It is perhaps one more connection formed in my own long-term memory, bringing together what works, why, how, where, and when.

I remain hugely grateful to the community of neuroscientists, psychologists, and researchers whose work has helped shape my thinking. In particular, those who have published research using fMRI and other neuroimaging tools. Their work continues to fire new ideas, challenge assumptions, and strengthen neural pathways that underpin this book. While I have attempted to translate these complex ideas into something practical for teachers, it is their research that provides the prior schema!

To the many schools and colleges who continue to invite me to work alongside their staff, thank you. Your trust and support sustain my work and give me the time and space to think, research, and write. Every training session, conversation, and classroom visit adds another layer to this process – like a kind of professional retrieval practice that continues to shape my understanding. Thank you also to the thousands of teachers who engage with my work. Your questions, reflections and challenges have helped encode and sharpen the ideas throughout this book.

I would also like to thank Emily Evans and Susannah Fountain for their editorial expertise. Their attention to detail, thoughtful questioning and guidance have helped organise a manuscript that may have overloaded working memory into something coherent for teachers.

Finally, to my family, Jenni and Freddie, for your love. You have been part of every book publication to date, providing the humour, perspective and emotional regulation that keeps everything in balance.

INTRODUCTION

HOW fMRI SCANS CAN TELL US MORE ABOUT WHAT IS HAPPENING IN THE CLASSROOM

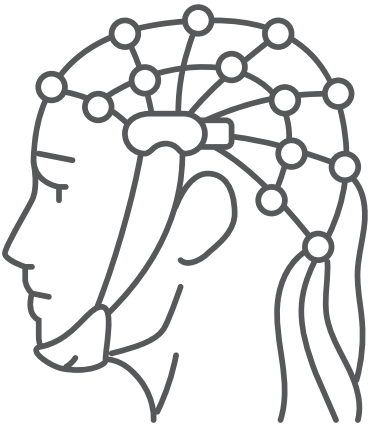
Over the last 15 years, I have been increasingly absorbed by the world of **cognitive science**, **cognitive neuroscience**, **psychology**, and **neuropsychology**. In this book, my intention is to explore the intersection between these different disciplines, their importance, how they can help you understand the ways in which students learn, and how you can make that learning effective and efficient.

In my work supporting teachers in schools and colleges across the UK, and in the contextual research I have undertaken, one key question persists: *How does learning happen in the classroom?* What are the processes taking place when you, as teachers, do this, or do that, at a particular point in the lesson, or in response to students at another point?

While many of you are, without doubt, becoming increasingly exposed to the concepts of **working memory** and **cognitive load theory (CLT)**, I would argue that this is likely to be only at a superficial level. In my training sessions, I have enjoyed showing teachers the practical applications to help bring teaching concepts alive by unpicking the decisions they make in the classroom that may either *support* or *hinder* the learning process. There has been significant traction gained over the five years following the COVID-19 pandemic; the world has become better connected, ideas have spread further, and it is possible to access improved professional development, even outside your own workplace, simply through online communication.

For definitions of key terminology, please consult the **Glossary** on page 149. Glossary terms are highlighted in **bold** the first time they appear in the book.

The 'what', the 'why', and the 'how' inside this book



My key objective for this book is to wrap the 'what', 'why', and 'how' of **neuroimaging** altogether, grounding these questions in research from relatively new interdisciplinary areas of study: **neuroeducation** and **neuroliteracy**. These are still emerging as fields for educators and researchers who are particularly interested in the brain and how these fields relate to classroom environments. I have spent time studying research from **fMRI scans (functional magnetic resonance imaging)** to see what impact specific conditions have on students with, for example, **attention deficit hyperactivity disorder (ADHD)**. I have also explored how neuroscientists use **electroencephalograms (EEGs)** to record brain activity using electrodes to detect electrical signals in the brain.

Analysing this brain activity helps us to understand not only the decisions we all take, but also what is happening in the brain, and how it responds to different stimuli. For example, when you deliver a **retrieval practice** activity, or a sequence of quick-fire questions in the class to groups or individuals, what is happening with students' attention? Which parts of their brains 'fire up' neurologically? My hope is that my research into some of the brain's functions will help classroom teachers understand what is *really* happening inside the brain during everyday classroom scenarios.

Is teaching an art or a science?

The 'art or science' debate pervades across social media, and it has made me think deeply about the art of teaching, and the science behind that teaching. It is also worth exploring what 'art' or 'science' are in practical and academic terms before we immerse ourselves in the details of this book; this is something I will look at in Chapter 1.

Why write this book?

I wanted to write this book for the following four reasons:

1 Since the publication of *The Teacher Toolkit Guide to Memory* (2022), the book and its resources have been the most popular training topic I have delivered in schools and colleges across the country. Each time I deliver sessions, I delve more deeply into how the strategies I have created evolve to suit a variety of contexts. This macro-understanding, and range of experiences, have widened my research and have informed *this* book.

I have analysed the varying levels of expertise among primary teachers, secondary or further education teachers, and lecturers. I have also analysed what pedagogy looks like in classroom settings. But what does the science of learning look like across these institutions and in individual classrooms? The science of learning now provides the basis of training for all new teachers across England, but even experienced teachers are still playing catch-up.

As a follow-up from *The Teacher Toolkit Guide to Memory* (2022), I began to think increasingly about one of the greatest assets you, as teachers, have – your voices. This led me to publish my next book, *The Teacher Toolkit Guide to Questioning* (2023). Asking numerous questions in class doesn't necessarily mean that we are actually *good* at asking questions! Having posed a question in class, knowing then how to respond or adapt in the moment, is something we could truly define as 'adaptive teaching'. I believe that this understanding of how to respond is missing if teachers are unaware of '*how* learning happens', explicitly at a neurological level.

2 Secondly, and more importantly for this book, I want to provide you with a bank of evolving neuroliteracy – key neuroscientific terms that blend fields of study, but with clear connections to the classroom (hence, neuroeducation).

What is still evolving is the relationship between cognition and the functions of the brain and, importantly, what this looks like in the classroom. Expert knowledge in this area is still lacking across the teaching profession. What's even more concerning is that we are still unclear about what cognitive **neuroscience** can actually do to improve teacher performance and student outcomes.

3 In this book I want to go further to explain some of the most popular strategies and prevailing **neuromyths**, to provide you with a personal or whole-school implementation plan to help make changes to your teaching practice. I will also provide you with an overview of working memory and, in particular, attention, and how (as teachers) we can manage students' focus in the classroom, with consideration for neurodivergent learners.

4 While my books are always aimed at the general teaching population, as a former school leader, I always consider how these ideas should be received strategically. This is especially the case for schools and colleges that want to consider how to embed concepts across the whole school, with clear implementation plans that are embedded into weekly teacher training sessions that you host in-house. As such, this book will help teachers, leaders, and schools and colleges unlock the power of cognitive science.

Defining terms

Circling back to the start of this introduction, here are introductory definitions to some of the terms you will encounter in the book within the context of cognitive science, cognitive neuroscience, psychology, and neuropsychology.

- **Cognitive science** is the study of thought and mental organisation; there is a large community of English teachers already confident in this area who are working in this space. It is an interdisciplinary field, concerned with attention, memory, reasoning, language, and emotion.
- **Cognitive neuroscience** is more focused on the biological aspects of all of the above, using EEG and fMRI scans to see what happens neurologically (physically) in the brain when various conditions are applied. This field also draws on brain injury, growth, or decline. *Applied* neuroscience considers the mechanisms and treatments of various diseases of the brain and our nervous system.
- **Psychology** is the study of our emotions and behaviours, using scientific methods to explain our conscious and subconscious decisions.
- **Neuropsychology** is a field of psychology focusing on how a person's cognition and behaviour is related to the brain and the nervous system – specifically brain injury responses and functions.
- **Neuroeducation** draws from cognitive neuroscience, developmental cognitive neuroscience, psychology, technology, and other related disciplines to explore the interactions between biological processes and learning.

Put simply, this book is about neuroeducation – all of the above disciplines – and what we do in the classroom, what is potentially happening in the brain at that point in time, and why.

What the book will cover

My aim is to help you move to a stage of confidence with your understanding of cognitive science. There is an enormous body of work and, as it is a relatively new field of academic study, it continues to grow at a rapid pace. My intention is to signpost some of the material I have been researching, outlining the key questions I've asked along the way, what I've discarded, and what I keep revisiting and exploring in greater depth. This book will give you the confidence you need to discuss these concepts with your teaching colleagues.

We will cover key concepts and also dispel some popular neuromyths. I have read and researched topics about memory and learning, attention, **cognitive load**, and processing, particularly with **neurodiversity** and associated ethical implications in mind. This included analysing how fMRI scans and EEGs can help us to understand teacher decision-making, and student attention span.

In *The Teacher Toolkit Guide to Memory*, I stated that the adolescent brain was 'approximately between 13 to 25 years old' (as defined by Blakemore, 2019); that this 'differs from those of children and adults' and that 'neural synapses are [still] forming' (McGill, 2022, p. 51). Yet emerging research (Mousley et al., 2025) from the University of Cambridge suggests that the brain goes through five distinct phases, and adolescence actually spans into your early 30s!

This means that you are not entirely your adult self until your brain is fully rewired for adulthood. The topology in your brain 'is particularly distinct, indicating that the network is becoming both more globally efficient and more locally specialized with age' (Mousley et al., 2025, p. 7). This remains stable until your mid-60s, after which a gradual decline in brain efficiency begins. The research identifies key neurological changes and 'these turning points define five major epochs of life' (Mousley et al., 2025, p. 4):

1. Childhood – from birth to nine years.
2. Adolescence – from nine to 32 years.
3. Adulthood – from 32 to 66 years.
4. Early ageing – from 66 to 83 years.
5. Late ageing – from 83 onwards.



I will also help bring the concept of **metacognition** to life. It's a phrase I have grappled with for quite some time, but now have an understanding of its value across a variety of classroom settings. Interestingly, the etymological meaning of the word 'meta' means 'beyond', but it also means a 'change' in condition. In simple terms, metacognition is being aware of your own thinking: recognising your capabilities, understanding the problem in hand, and deciding which strategies might help you solve it. Metacognition involves drawing on prior knowledge and experience to plan, monitor, and evaluate your approach:

- What happens when we do things automatically?
- What happens when we transfer what we already know and apply it to a new situation?
- How do we describe this?
- What does it look like practically in the classroom?
- How does it translate into practical resources and techniques for students?

Like me, I suspect these are important questions you have also asked.

Bringing this all together, we will then consider how students can develop **self-regulation**, and unpick the science behind motivation and emotion in learning – all essential ingredients to the learning process. I will offer you a neuroscience curriculum that you can use in your classroom, including ways to develop your own neuroliteracy confidence. It is my hope that the teaching profession can develop more 'evidence-informed' approaches grounded in cognitive science and neuroscience.

What you will take away from this book

In past publications, I challenged outdated ideas about the way students study and I unpacked the cognitive science behind knowledge retention. This book goes one step further and critically revisits the research that underpinned *The Teacher Toolkit Guide to Memory* (2022).

With more practising teachers publishing work, there is an abundance of research now available. It's important to ask what still holds up, what needs rethinking, and what, if anything, we have missed altogether?

For example, **MRI (magnetic resonance imaging)** is still relatively new in the grand scheme of the history of the brain. MRI scans provide a snapshot of brain anatomy using a still picture to understand physical structure. However, fMRI (functional magnetic resonance imaging)

is largely unknown; it relies on a **blood oxygenated level dependent technique** to generate fMRI images, and 'relies on regional differences in cerebral blood flow' (Atabek et al., 2022, p.2) to understand dynamic changes in brain activity.

We have learned more from brain visualisations in the last 50 years from MRI and fMRI scans than we have as a human species across 4,000 years of written history. I believe the ultimate question to answer is not 'How does learning happen?', but 'What happens to learning when teachers do X, Y or Z?'; fMRI research can offer some guidance.

I will provide you with enough research information, explained in pragmatic terms, to help unpick complex language for non-specialists. I'll provide you with the data, a balanced argument, a large number of reflection questions as well as some practical strategies and blank templates throughout this book. As always, the message from me is not *what* or *why* you do something in the classroom, but *how you do it*, considering *when* and *where* any of my recommendations are suggested, and how they should be tweaked to apply when working with a four or 44-year-old student in the classroom.

The Teacher Toolkit Guide to the Science of Learning explores how study strategies can be adapted for all learners, across all subjects, in real classrooms. This is not a 'revision' guide – it's a guide for teachers who want to make evidence-informed decisions about how students learn best, especially **neurodivergent** students, and how to bring this to life across the entire teaching sector.

When you reach the book's conclusion, you will understand why all teachers should be provided with a general overview of neuroeducation in any teacher training qualification. Managing behaviour and commanding your subject knowledge isn't enough in today's classroom landscape. If we want to encourage absent students back into class and address increasing home-learning demands, we, as teachers, must better understand *attention* to meet increasing neurodiverse needs. With the endless, and unknown, implications of artificial intelligence (AI), there is a potential existential crisis about the purpose of school, whether or not we need students to collectively gather inside a building, or if knowledge should be taught when students have Google or ChatGPT. My belief is that explicit knowledge should be taught by a human expert, in person, and that the emerging research on using AI suggests that relying on AI to do the thinking for you increases **cognitive debt** – a condition that develops if a person relies on AI, rather than using cognitive effort required for thinking. In a recent study, people who used

their brain 'reported higher satisfaction and demonstrated higher brain connectivity' (Kosmyna et al., 2025, p.153). Put simply, when you stop using your brain to solve problems, the neurological connections that you have put in place weaken over time.

Abbreviations



It's worth sharing a few abbreviations and key terminology used throughout the book. I suggest bookmarking this page for reference as you move through the chapters.

- **CLT:** Cognitive load theory
- **CPD:** Continuing professional development
- **EEG:** Electroencephalogram
- **EYFS:** Early years foundation stage
- **fMRI**: Functional magnetic resonance imaging
- **IQ**: Intelligence quotient
- **KS1–KS5:** Key stages 1 to 5
- **LTM:** Long-term memory
- **MRI:** Magnetic resonance imaging
- **NFC:** Need for cognition
- **SEND:** Special educational needs and disabilities

I hope this book brings you hope, joy, and the reassurance to make your working life in the classroom that little bit easier.

Don't forget to share your views using #**GuideToLearning**.

HOW TO USE THIS BOOK

What you'll find in each chapter

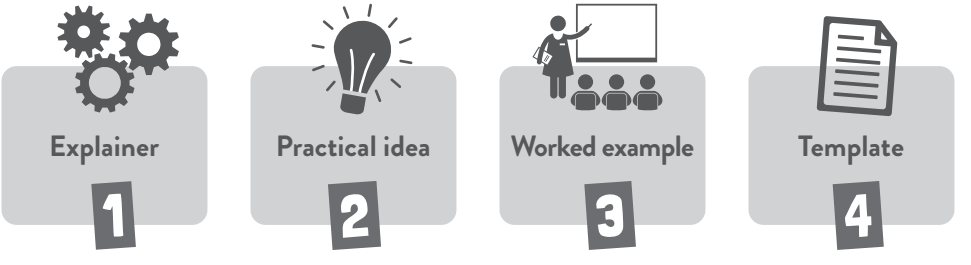
In this book, I will share with you the conclusions I have drawn not only from my classroom experience and my training sessions with teachers, but also from the ideas pulled from the academic research I have read. This includes research into 'how learning happens' by examining, at a biological level, the anatomical changes that occur in the brain.

I will also explain why understanding the science of learning has the power to transform what we all do in the classroom. I'll show you how this knowledge of basic neurology can help you make more informed teaching decisions which will support your students. Taking a closer look at fMRI scans allows us to have a better understanding of what is happening when the blood flow changes during brain activity.

You'll be introduced to fMRI data that shows changes in blood oxygenation associated with neural activity and might help to explain what goes on in the brains of teachers and learners in the classroom. For example, if I give you a non-verbal 'glower' or a 'finger-wag' across the classroom, I may be wrongly assuming that you are misbehaving and not paying attention. I believe this could be critical knowledge for teachers working with neurodivergent learners, and for those managing student anxiety.

Another key objective is to show you how you can become an even better teacher by understanding what the available research can offer. I have condensed the academic research into pragmatic language, key recommendations, and practical ideas that you can adopt and implement immediately.

Each chapter is divided into four key sections.



1 Explainer

The first part of each chapter covers *what you need to know* about the discussed topic. We'll delve into fMRI research and examples of good (and bad) cognitive science. We will look at cognitive load theory, dual coding, retrieval practice, and working memory limitations.

2 Practical idea

After the explainer, we'll consider a practical idea that turns the science of learning *theory into practice*. There will be examples of how to use retrieval practice, reduce extraneous cognitive load, and how to design tasks that support **encoding** into **long-term memory (LTM)**. At the end of the idea, you'll find a set of *toolkit tips*, which are practical takeaways to support you when putting the idea into practice in your classroom.

3 Worked example

I'll give you a *clear example* of how the practical idea could work in practice. In these sections, I will provide you with classroom scenarios (from early years, primary, secondary, and further education) that show how you might adapt your lesson using knowledge of **working memory**, and how you might build a mixed approach to, for example, retrieval practice.

4 Template

At the end of each chapter, a *blank template* is provided to help you plan how to implement the practical idea in your classroom. Use the template to contextualise the idea for your students. When you're delivering the practical ideas or using the templates with your students, it's helpful to name the technique you are using, for example, the Debunking Board (see Chapter 3) or the Five Minute Inclusive Planner (see Chapter 7). This will help your students, or colleagues you are working with, identify each technique and enable them to learn how to respond and understand what is expected of them. Blank versions of the templates are also available online, so you can download and print them. Scan the ***QR code*** next to each template for access.

Bringing it all together

In the final part of the book, I will explain to you how to integrate all the practical ideas into your long-term curriculum plans and professional development. By embedding these ideas over time, and linking them to how the brain works, you can develop deeper neuroliteracy, improve retention, and enhance long-term student outcomes.

CHAPTER 1
THE SCIENCE OF LEARNING

I've come to believe that the best teaching methods blend both *art* and *science*. The *art* of teaching evolves from your lived experiences, whereas the *science* of learning uses academic evidence to validate your decisions. As teachers, we observe each other's teaching across the curriculum, and how we work with different age groups; this collective observation helps us to develop experience about what works best in our own classroom, with our own students. Teachers have always been learners, but the phrase 'science of learning' is now everywhere – in **continuing professional development (CPD)** sessions, teacher blogs, books, and even political agendas. But what does it actually mean in practice?

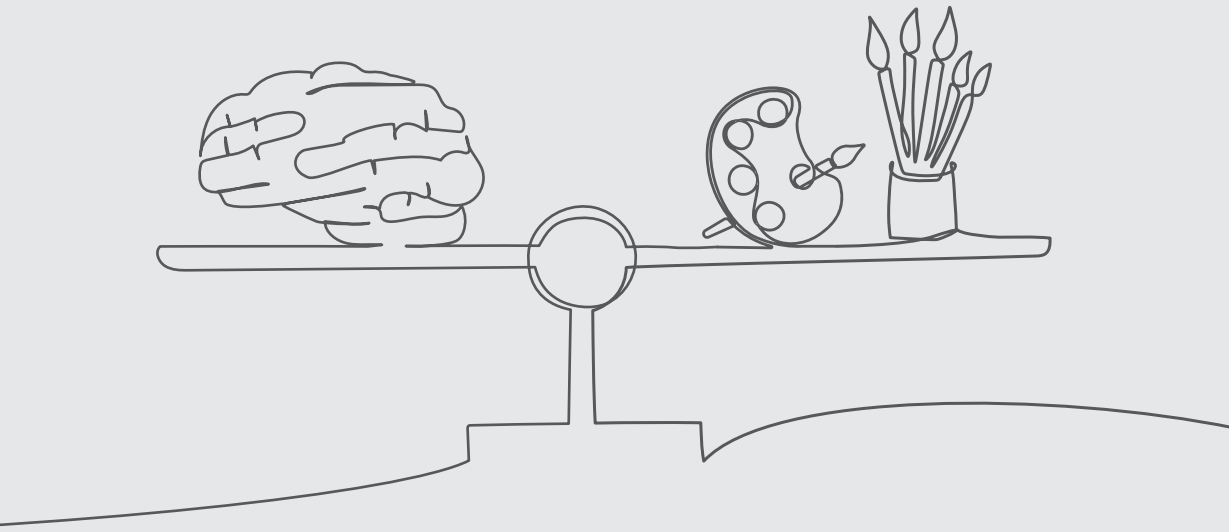
In this chapter, I will unpack the core ideas behind 'the science of learning' (cognitive science). I'll signpost you to some key pieces of research in this field that will help bridge the gap between research and classroom reality. I'll also discuss one of the most influential studies of the last decade (*Improving Students' Learning with Effective Learning Techniques* – Dunlosky et al., 2013) to examine how its recommendations shape policy and practice, and what has changed since then. If we are to be evidence-informed as a teaching profession, we must first understand the science behind the claims. I encourage you to be a critical consumer of research to inform your practice.

In the next chapter, we'll dive deeper into the specifics of memory, motivation, and attention, but for now let's step back and ask: What do we mean by the *science* of learning, and how does it relate to the *art* of teaching?

For centuries, teaching has been considered a craft – a series of instincts and improvisations shaped by experiences and intuition that respond to the moment. Today, we are surrounded by a growing body of cognitive science research that claims to show us how learning *actually* works. Over the last five years, I've taken a closer look at fMRI scans (functional magnetic resonance imaging) to see if there is neurological evidence that shows what happens during learning, specifically in the context of teacher decisions, or from various experiences, such as stress. The English government, and school inspectors, also have an interest in this area, and this has resulted in their recommendations for teacher training, classroom practice, and evidence-based policies. As a result, schools, colleges, and teachers restructure their

thinking and actions around these teaching recommendations, but can scientific evidence ever truly capture the messiness of a real classroom?

How have the ideas around cognitive science entered the classroom? The review of learning techniques outlined in the research carried out by Dunlosky et al. (2013) spoke of renewed interest in evidence-informed teaching, but it also led me to question what works, for whom, and in what context. The research paper tended to draw conclusions from high schools and college classrooms, typically outside creative subjects. I was left with the question: What advice could I give a primary teacher, or someone who taught a creative subject?



EXPLAINER



It has only been over the last few years that I have been able to articulate the differences between the art of teaching and the science of teaching. In layperson terms, the art of teaching is often associated with judgement, adaption, and responsiveness, whereas the science of teaching draws on research into instruction, memory, attention, and learning.

Alexander Makedon defined the *art* of teaching as 'an attempt to help our students learn' based on how we have observed them (1990, p. 13). Having read the available research, I now realise that learning is likely more of a science than an art. However, if teaching simply conveys information with no particular emphasis on *how well* students learn, then teaching becomes an expression of feelings, whether learning is effective or not. One could therefore argue that teaching is an art form.

The art of teaching

To simplify this further, I often describe the *art of teaching* as experiences gathered over time, which are difficult to measure. As teachers, we make so many idiosyncratic decisions using our internal database, that much of it becomes automatic over time, thus reducing our workload.

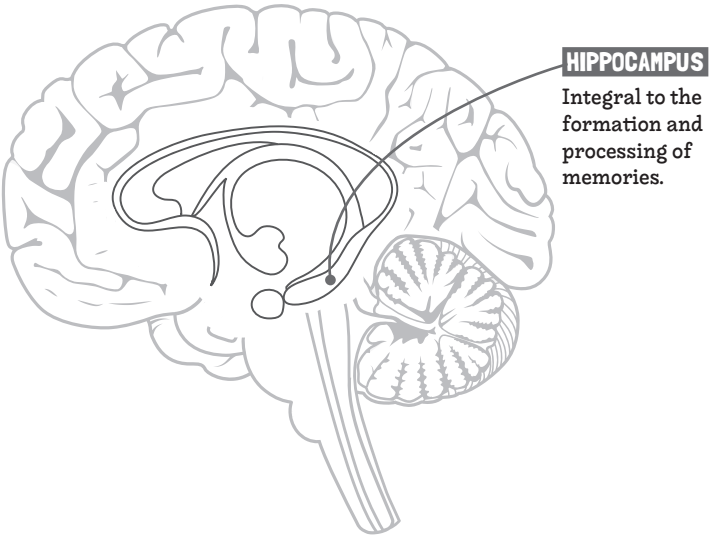
As an example, let's say that you're sitting in my classroom misbehaving. I look across the classroom directly at you, pause from my whole-class instruction, raise my eyebrows and gesture a pointed finger, while wagging my hand at you. You know that the 'finger wag' means I won't tolerate any nonsense. As a teacher, I know it works and it improves your behaviour, and as the student you know that you're now being closely monitored. There's no science here to back up this experience, but it's a valid classroom experience that all teachers rely on.

The science of teaching

In contrast, the *science of teaching* is rooted in evidence: the cognitive science, psychology, and neuroscience that tells us how memory works, how attention is captured, and how knowledge is best stored and retrieved.

The science of teaching is about understanding the research on:

- **retrieval** (see Chapter 2), actively bringing information to mind from memory
- **dual coding** (see Chapters 2 and 8), combining words with visual images to enhance understanding
- **spacing** (see Chapter 9), a learning technique that spreads studying evenly
- **cognitive load** (see Chapter 4), the mental effort required at any given time.



This study of teaching is critical in finding out why certain strategies work (or don't), for whom they work (or don't), and under what conditions they work (or don't). This book focuses predominantly on the science of teaching, but uses some of what we might describe as the art of teaching, backed up with scientific evidence. Recent neuroimaging research shows that when students retrieve knowledge, instead of just reviewing it, greater activity is observed in the **hippocampus**, a region strongly involved in memory formation and retrieval; they are more likely to be able to make connections across regions of the brain. In neurodivergent students, these activations may differ between individuals, reinforcing the need to evaluate how study strategies work for different learners rather than assuming one uniform response.

Two fMRI studies

Two separate fMRI studies help to explain what is happening in the brain when we experience high stress (workload), and how we process language.

High stress

From an fMRI perspective, what impact does workload have on teachers beyond their mental health, wellbeing, general health, and teacher attrition? According to research by Jang et al., 2025, overwork might structurally change areas of the brain linked to problem-solving and emotion, providing a 'biological basis for the cognitive and emotional challenges often reported in overworked individuals' (p. 110). This is preliminary evidence that teachers being overworked results in emotional drain and poorer performance.

Processing language

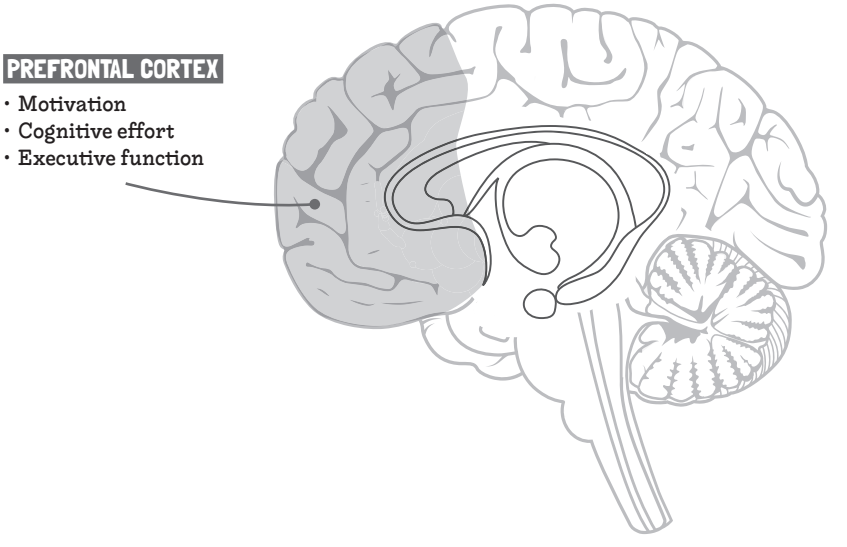
In the second study, infants' brain responses to speech analysis of auditory and motor systems were used to understand how infants process language (Kuhl et al., 2014). They used **magnetoencephalography (MEG)** – a non-invasive neuroimaging technique to measure faint magnetic fields produced by electrical currents in the brain. The purpose was to determine the value of gestures and speech modelling in classroom teaching, especially among young or neurodiverse learners. The researchers were particularly interested in whether babies simply *hear* the sounds or if their brains also stimulate the act of speaking them. The research found that even before infants can talk, they 'use prior speech production experience to generate internal motor models of speech as they listen to us talk' (Kuhl et al., 2014, p. 7). Their brains are preparing for language by internally rehearsing how to produce those sounds.

Further evidence of using neuroimaging to inform classroom methods can be found in tracking real-world interactions in the classroom. If brain activity is synchronised across students, can it predict class engagement and social dynamics? In *Brain-to-Brain Synchrony,* Dikker et al. (2017) discovered 'the extent to which brain activity is synchronised across students [and] predicts both student class engagement and social dynamics' (p. 2). In the experiment, high-school students wore portable EEG devices to record brain activity during regular classroom activities over the course of a term. The research demonstrated that student engagement is reflected in *shared* neural activity, meaning that when students are genuinely engaged in an activity, their brain waves synchronise. This is robust evidence for classroom strategies to improve attention, emotional connection, and a shared focus.

In another MRI study that used infrared **spectroscopy** to look at how students responded to different instruction-giving methods, 'participants watching videos of peer interactive group discussions demonstrated stronger

brain activation than those watching videos of teacher-student interactions' (Zhang et al., 2025). Spectroscopy (the study of matter using wavelengths) was used to measure the changes in oxygenated blood flow in the brain – essentially those areas that are more active under different instructional strategies.

Students who engaged in peer discussions showed significantly more activation in the **prefrontal cortex**, situated in the front area of the brain. The prefrontal cortex is responsible for motivation, cognitive effort, and executive function (which coordinates with other brain regions to regulate attention, memory, and decision-making).

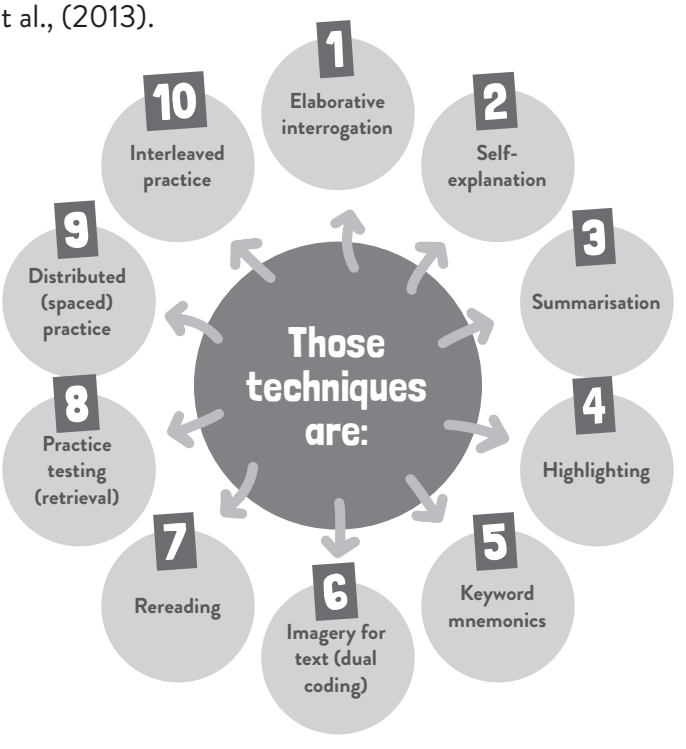


When students just watched a lecture, their brains worked harder; they used more effort and strain to sustain attention. The study observed that 'passive knowledge elicits aversive experiences' (Zhang et al., 2025, p. 17). However, when students were actively involved in questioning and dialogue, this 'activated brain regions linked to positive emotional experiences and mentalization' (Zhang et al., 2025, p. 21). Their brain activation pattern shifted, suggesting that there was more engagement rather than avoidance. This reinforces a growing body of evidence that critical thinking is not just a cognitive ideal; instead, it is something that leaves measurable neural footprints. It also suggests how higher-order thinking skills, like problem-solving and reasoning, rely heavily on our working memory capacity.

For teachers, this neuroimaging research in the classroom has practical implications. Interaction stimulates more neural activity than passive instruction. We therefore need to move beyond simply 'covering content'. Instead, we must create space for students to explain, discuss, and reason with one another – not just as a teaching strategy, but as a cognitive accelerator.

Post-COVID-19 pandemic, with rising anxiety levels and absenteeism, helping students actively engage in thinking is more than a pedagogical choice; it's a resounding necessity. Critical thinking needs to be taught, modelled, and practised – not just assessed.

Knowing that neuroimaging is already being used to determine what is working in the classroom, let's consider the ten study skills offered by Dunlosky et al., (2013).



With the use of fMRI, we can evaluate which of these techniques is used in our classrooms, when they are used, how they are used, and most importantly, what happens inside a student's brain. Teaching as an art (by experience) is no longer enough. We also need the science of teaching to inform our decision-making.

In the next section, we will explore what the science of learning looks like 50 years after fMRI scans became available, and how cognitive science can influence classroom teaching.

PRACTICAL IDEA



Classroom learning charter

Let's revisit some of the most popular teaching methods and pair those with strategies for learning. For example, when a teacher delivers instructions to the class, students might select self-explanation, elaborative interrogation, or retrieval as a study technique.

The aim is to create a classroom culture rooted in evidence-informed study strategies by developing a shared language of learning, underpinned by cognitive science.

What would happen if teachers created classroom norms based on evidence-informed principles? For example, in:

- **spaced practice** in which learning is spread out over time
- **retrieval** in which students actively recall information from memory
- **cognitive load**, which describes the mental effort being used in students' working memory.

With this in mind, it is critical that schools and colleges develop a language for learning and a lens for embedding learning activities throughout the year (see the example of an implementation plan in Chapter 10).

More than a decade after Dunlosky et al. (2013) first ranked the effectiveness of ten study skills (outlined on page 7), many teachers still haven't seen this research. The researchers plotted efficacy of the ten skills based on how they were used in classrooms across several high schools and colleges. The following step-by-step guidance demonstrates how Dunlosky's study skills come alive in real classrooms, and how recent research 'offered by fMRI has meant that [they have] swiftly become a primary tool for investigating the inner workings of the mind' (Smallwood and Schooler, 2015, p.3). Neuroimaging can offer additional clues about the neural processes associated with some learning techniques.

Step 1: How would you introduce the ten study strategies to students (e.g. in EYFS)?

1. Elaborative interrogation → explain why
2. Self-explanation → tell me in your own words
3. Summarisation → condensing content into memorable chunks
4. Highlighting → key concepts and terminology, for example grammar
5. Keyword mnemonic → creating a mental shortcut
6. Imagery for text (dual coding) → aligning images with words
7. Rereading → restudying again after initial reading
8. Practice testing (retrieval) → low-stakes quizzes; no grade
9. Distributed (spaced) practice → sequencing content over time
10. Interleaved practice → mixing similar topics to strengthen schema

Rather than labelling the strategies as 'good' or 'bad', the research goal was to evaluate each technique based on evidence from a wide range of learner profiles and academic contexts. Retrieval, spaced and **interleaving practice** were identified as the most impactful, but we should question the context. Do these ideas work in a primary classroom, in an art classroom, or for a mathematics student in a further education college tackling a maths resit for the third time?

The reality? Different techniques may work better for different subjects, different learner profiles, and different contexts. If we consider that 'combining fMRI data with anatomy information is tremendously helpful' (Seghier et al., 2019, p. 6), it becomes clear that *how* the technique is used is just as important as *which* technique is selected.

Step 2: Student audit (metacognitive reflection)

Here are three key questions you should ask your students:

1. Which technique have you used before?
2. Which do you find most helpful?
3. Which do you want to learn more about?

Use '**exit tickets**' (short end-of-lesson checks of understanding) for small-group discussions, or to help you systematically check students' understanding. Online, evaluation forms and QR codes can be used to gather student views about learning to build a picture of data and habits over time.

Step 3: Classroom charter co-creation

As a teacher, you are the expert, so there's some critical information at this stage that would be non-negotiable. However, if you want to help students enjoy being in your classroom, it's important to agree on a set of shared 'learning goals' and norms and allow them to be part of this process. These might include:

1. We will always use retrieval to review previous learning at the start of every lesson.
2. We will space out our practice throughout every lesson, and every week, instead of cramming it all in at the end. This means sometimes you would've seen things before, and the goal here would be to test if you actually know it.
3. We will explain our thinking aloud when solving problems.

Once you have agreed a set of principles with your class, display the charter and refer to it regularly with your students.

Note: Adaptations may be required for younger/older students.

Step 4: Teach the techniques in context

Model each study strategy explicitly – nothing should be open to interpretation!

- In maths: Use retrieval with a 'Do Now' starter activity.
- In history: Use elaborative interrogation with 'Why did this happen?' questions.
- In art: Use dual coding by sketching key concepts.

Let's consider two very popular teaching ideas:

1. 'I do, we do, you do'
2. Think-Pair-Share

Try using the **'I do, we do, you do'** scaffolding methodology, moving from teacher-led guided practice towards independent practice.

- The logic behind this simple, yet very powerful teaching principle is that the teacher models the task and solution first, talking through their decisions during the first stage, 'I do'.
- In step two, 'We do', the teacher guides the students through each stage, one step at a time, asking questions along the way. Modelling together reduces risk for students, and enables opportunities for questions and problem-solving queries along the way.
- In the final step, 'You do', the teacher steps back and asks students to complete the task on their own, perhaps offering some modified instructions to increase difficulty, or to adapt to a new problem. The teacher would navigate the classroom to provide support and challenge.



The **Think-Pair-Share technique** provides the students with valuable thinking time. I would always recommend setting the conditions for success during the setup. For example, 'I am about to ask you a question about the solar system.' You haven't told the students the question yet, but you are activating their prior knowledge (retrieval). You can then explain to the students what is going to happen. 'I will ask you the question, then I will finish with a long pause to give you time to think. During this stage, don't call out. Don't put your hand up, think first.'

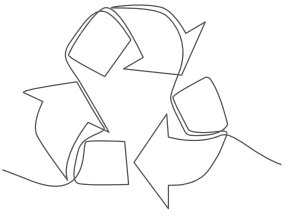
You then pose the question, insisting on silence where needed. A long pause is added before you say, 'Now, write down your answer.' Follow this with another brief pause. 'Okay, pair up with your partner and share your thoughts.' During this time, you can scan the room and start to check engagement and participation.

The final step requires you to state, 'Now, write down your final answer and be prepared to show me your replies on a mini-whiteboard.' Having something written down is concrete. Demanding that all students show their reply pulls the information out of the student's head. After a brief '3-2-1', the students raise their responses into the air and the teacher systematically checks at once before moving on.

Step 5: Practise, reflect, and refine

1. Each week/lesson, spotlight one study strategy for your students.
2. Model the strategy with a live example piece of work; use the 'how to do this' in stages. Show what happens, what works, what went wrong, and what options are available.
3. Help students to reflect at key stages: 'Did this strategy help me to remember more?'
4. Adapt your classroom charter as needed, based on student age, subject, and student feedback and outcomes.

Step 6: Review the impact



Nothing is worth pursuing without any evidence or impact. Ask: 'Are you better off since... [this was introduced]?' After a half-term, revisit your original checklist or classroom charter and ask:

1. Has student confidence improved?
2. What strategies are mostly embedded?
3. What impact does retrieval have on the start or end of the lesson?
4. How do mini-whiteboards build knowledge-confidence with my students?
5. How do low-stakes quizzes assess retention, not just performance?

I often describe Dunlosky's research in the context of teaching sex education. We don't necessarily use the nicknames of our body parts, even though some of these phrases might be used regularly at home; instead we teach students the biological names. We use the correct terminology to avoid developing further misconceptions.

I liken this example to the word 'revision'. Although there is nothing wrong with this word linguistically, it is *not* the language for learning. I would also add that the 'science' behind revision has not been explicitly taught, so depending on where you went to school, who taught you, and the circles around your education network, you may or may not have been taught 'how to learn'.

Instead, in today's classrooms we might use 'retrieval' as an evidence-based technique for building knowledge confidence. This word derives from the

French word, *retrouver* which translates 'to find again'. This is an expressive analogy to understand the science behind retrieval: 'What did you have for dinner last night?', 'What date is your birthday?' One of these questions you might struggle with, whereas the other I would expect you to easily answer within a couple of seconds. Why is that?

In essence, we are finding this information again, and pulling it from our long-term memory (LTM), manipulating this information in our working memory and pulling it out from our heads – either by writing it down (**procedural knowledge** – how to perform a skill or process), or saying it out loud (**declarative knowledge** – the conscious knowing of concepts, rules, and facts). The challenge is that if any information is not stored in our LTM, then it is likely to be forgotten, whereas information can be easily retrieved if it has been stored. When information is deeply embedded into our LTM (our schema), we can build on it – very much like *building a brick wall*. What we learn is built upon what we already know!

The term 'retrieval' is used in the field of cognitive science, and on my travels and visits into the classroom, I now hear this word being used by Year 3 and Year 4 students in classrooms. The message? Our teachers are beginning to teach our students the language of learning, and this links directly to Dunlosky's ten study skills cited earlier.



While this language isn't used everywhere, I do see an underground revolution taking place in many classrooms across the country. I am optimistic that the current generation of students are being given the tools for learning, yet we 'intermittently fail to take stock of where [our] minds are currently residing' (Schooler and Schrieber, 2004, p. 27). Increasingly, our teachers today are developing these tools to help sustain motivation and attention, and by understanding more about attention, this knowledge should start to ripple through each generation of teachers trained in the future.

Neuroimaging evidence can explain why certain techniques work, and knowing more about attention can help us understand how we focus or why we daydream, or from an fMRI lens, how some neurodivergent students may appear to struggle across aspects of our curriculum. Mind wandering 'experience is costly in educational contexts' (Smallwood and Schooler, 2015) and we need to understand how this happens. In the same research, Smallwood and Schooler state that, although the benefits of daydreaming are less understood, 'mind wandering may have some important functions including contributing to future planning and creativity' (p. 25). We know retrieval practice lights up memory centres in the brain, and dual coding links verbal and visual systems. How do we use fMRI to build neuroliteracy confidence for all teachers, families, and students? (We will touch further on neuroliteracy in Chapter 2.)



- **1.** Teach the language of learning explicitly. Move beyond generic terms like 'revision' and switch to cognitive vocabulary such as 'retrieval', 'spacing', and 'interleaving'.
- **2.** Pair your teaching methods with learning strategies. For example:
  - Direct instruction → self-explanation
  - Questioning → elaborative interrogation
- **3.** Co-construct a learning charter with your class. Create 2–3 non-negotiable norms, rooted in evidence.
- **4.** Model thinking out loud; avoid playing guesswork!

WORKED EXAMPLE



In this chapter, I have explained why introducing cognitive science principles to students and encouraging them to engage with the ten study strategies to create a classroom learning charter helps develop a shared language of learning and boosts student agency as learners. Through talking more about the learning experiences, both teachers and students see learning as an active, and iterative, process.

So now, here is an example of a teacher working with Year 8 students in a science classroom, developing a learning charter with the students.

Miss Patel teaches Year 8 science and wants to boost knowledge retention well before the summer exams. Guided by the teaching and learning team, educational research, and her developing understanding of memory processes, she constructs a 'learning charter' with her students.

Step 1: Audit existing strategies/diagnose existing habits

Miss Patel starts with a class discussion: 'How do you revise at home?' Students mostly state that they reread their exercise books and highlight text they have made from writing up additional notes. Some of them also say they like to complete some of the online quizzes, but sometimes they find it 'a bit boring'.

Step 2: Build a charter together

Over two lessons, Miss Patel introduces research-informed study techniques and asks students to discuss how many they are familiar with. She then leads her class to create three shared learning norms following a discussion on revision myths:

1. We use retrieval starters every Monday and Thursday.
2. We use dual coding to revise processes, combining flow diagrams with keywords.
3. We use elaborative questioning when working in pairs: 'Why does this happen?'

Step 3: Teach through practice

Miss Patel begins each lesson with a 'Do now' quiz. (Some schools and colleges might call this a retrieval practice exercise, a starter activity, or something similar.) She models self-explanation during the worked example demonstrations, for example, 'I am explaining this out loud because…' and sets homework to redraw diagrams from memory using dual coding.

Step 4: Review and reflect

After half a term, she revisits the charter with students. A student feedback survey reveals that students now feel more confident recalling processes like 'photosynthesis'. She adjusts the charter slightly, removing one strategy that wasn't working and adding interleaving between biology and chemistry topics. The updated charter is added to her slide deck, and is also pinned to the wall at the front of the classroom.

This process has helped to embed cognitive strategies into Miss Patel's classroom routines, with students owning the language for learning. For decades, we've used the word 'revision', but a more appropriate term for learning in this context would be 'retrieval'.

TEMPLATE

Science of Learning Classroom Charter

Use the template to help plan your own classroom charter. The template is practical, flexible, and deeply rooted in research, and it forms pedagogy without being overly academic. Ask yourself:

1. How will your charter be displayed or revisited?
2. How will students reference this charter during lessons?
3. How will you review its impact and when will you review it?

The balance you strike in your classroom will make a big difference to your students' motivation. I would strongly encourage you to involve students in the process, no matter how old they are.

Scan the QR code for a downloadable copy of this blank template.



Stage	Prompts and guidance	Your notes/ reflections
Strategy focus	Co-construct or select 1–3 strategies to embed in your classroom with students: ☐ Cognitive load reduction ☐ Dual coding ☐ Elaboration ☐ Engagement ☐ Highlighting ☐ Interleaving practice ☐ Motivation ☐ Mnemonics ☐ Rereading ☐ Retrieval practice ☐ Self-explanation ☐ Spaced practice ☐ Summarisation	Example: Retrieval and dual coding for half-term three
Context	Define your teaching context here.	Example: Year 8 science in the biology lab; aim is to use and apply photosynthesis knowledge and recall key process and stages
Learning norms (co-constructed with students)	Work with your class to agree on 2–3 learning principles linked to the appropriate strategies above. Remember, these need to be applicable to the students age, time of year, and subject .	Example: 1. We start every Monday with a retrieval quiz. 2. Draw diagrams from memory at the end of every lesson. 3. We use 'because' in every answer to explain our decisions and understanding.

Stage	Prompts and guidance	Your notes/ reflections
Weekly lesson routines	Plan how the strategies will appear regularly.	Example: ☐ Retrieval starter every Tuesday ☐ Strategy spotlight display ☐ Weekly sketch note task ☐ Peer pair share explanation ☐ Interleaved quiz across topics
Impact and review	Define how you measure impact: • Define what success looks like. • How will you gather feedback? • When will you review?	Example: ☐ Exit tickets and weekly quiz ☐ Student voice survey after six weeks ☐ Witness a change in data and improved long-term recall in the topic ☐ Student confidence ☐ Attendance