UNDERSTANDING MEMORY AND LEARNING

REFLECTING ON GREAT TEACHING

Evidence Based Education

INTRODUCTION

Evidence Based Education's **Model for Great Teaching** (page 2) highlights the importance of students' thinking. The model, derived from the best available research evidence on effective teaching, dedicates an entire dimension to this. Dimension 4 of the model argues that great teachers "activate hard thinking" in their students (Coe et al., 2020). The importance of thinking should come as no surprise to any educator (or indeed anyone who has ever been to school!); it is, of course, at the core of learning.

Thinking is something we do all the time—without really thinking about it, somewhat ironically. We think when we talk to people, listen to the radio, watch television, or even just look out of a window. You're thinking as you read this. And of course, our students think when in our class (hopefully about the lesson and intended learning).

We know that if we "think hard," then learning can take place. But how does this happen? What is the link between thinking, learning, and remembering?

This eBook discusses the very basics of these concepts. The science of learning is an extensive field that draws from research in disciplines like psychology, education, neuroscience, and even sociology and computer science. This eBook will not extend into every detail of learning and cognition; instead, it does offer an introduction that every teacher can use as a starting point.

We know that learning is absolutely crucial to education—therefore teachers can use their understanding of how it happens to better consider their classroom practice. This eBook concludes with some practical steps and considerations for teachers to implement on a daily basis.

A Model for **Great Teaching**

1. Understanding the content

1 Having deep and fluent knowledge and flexible understanding of the content you are teaching

2 Knowledge of the requirements of curriculum sequencing and dependencies in relation to the content and ideas you are teaching

3 Knowledge of relevant curriculum tasks, assessments and activities, their diagnostic and didactic potential; being able to generate varied explanations and multiple representations/analogies/examples for the ideas you are teaching

4 Knowledge of common student strategies, misconceptions and sticking points in relation to the content you are teaching

2. Creating a supportive environment

1 Promoting interactions and relationships with all students that are based on mutual respect, care, empathy and warmth; avoiding negative emotions in interactions with students; being sensitive to the individual needs, emotions, culture and beliefs of students

2 Promoting a positive climate of student-student relationships, characterised by respect, trust, cooperation and care

3 Promoting learner motivation through feelings of competence, autonomy and relatedness

4 Creating a climate of high expectations, with high challenge and high trust, so learners feel it is okay to have a go; encouraging learners to attribute their success or failure to things they can change

3. Maximising opportunity to learn

1 Managing time and resources efficiently in the classroom to maximise productivity and minimise wasted time (e.g., starts, transitions); giving clear instructions so students understand what they should be doing; using (and explicitly teaching) routines to make transitions smooth

2 Ensuring that rules, expectations and consequences for behaviour are explicit, clear and consistently applied

3 Preventing, anticipating & responding to potentially disruptive incidents; reinforcing positive student behaviours; signalling awareness of what is happening in the classroom and responding appropriately

4. Activating hard thinking

1 Structuring: giving students an appropriate sequence of learning tasks; signalling learning objectives, rationale, overview, key ideas and stages of progress; matching tasks to learners' needs and readiness; scaffolding and supporting to make tasks accessible to all, but gradually removed so that all students succeed at the required level

2 Explaining: presenting and communicating new ideas clearly, with concise, appropriate, engaging explanations; connecting new ideas to what has previously been learnt (and re-activating/checking that prior knowledge); using examples (and non-examples) appropriately to help learners understand and build connections; modelling/demonstrating new skills or procedures with appropriate scaffolding and challenge; using worked/part-worked examples

3 Questioning: using questions and dialogue to promote elaboration and connected, flexible thinking among learners (e.g., 'Why?', 'Compare', etc.); using questions to elicit student thinking; getting responses from all students; using high-quality assessment to evidence learning; interpreting, communicating and responding to assessment evidence appropriately

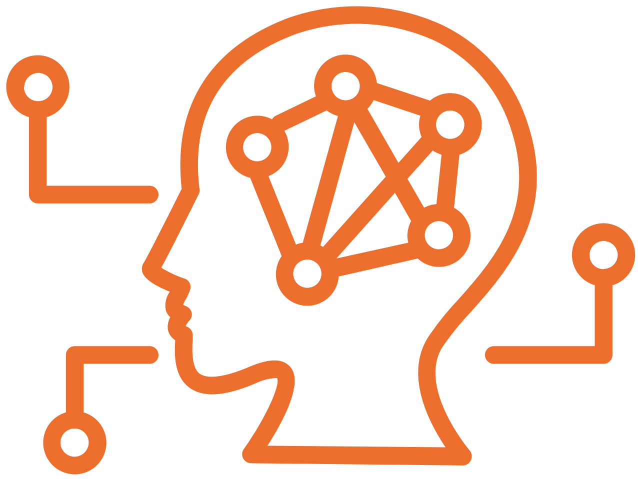
4 Interacting: responding appropriately to feedback from students about their thinking/knowledge/understanding; giving students actionable feedback to guide their learning

5 Embedding: giving students tasks that embed and reinforce learning; requiring them to practise until learning is fluent and secure; ensuring that once-learnt material is reviewed/revisited to prevent forgetting

6 Activating: helping students to plan, regulate and monitor their own learning; progressing appropriately from structured to more independent learning as students develop knowledge and expertise

WHAT IS LEARNING?

When we talk about learning, we may think about our brain creating mental models, connecting concepts, ideas, and information together into knowledge structures.



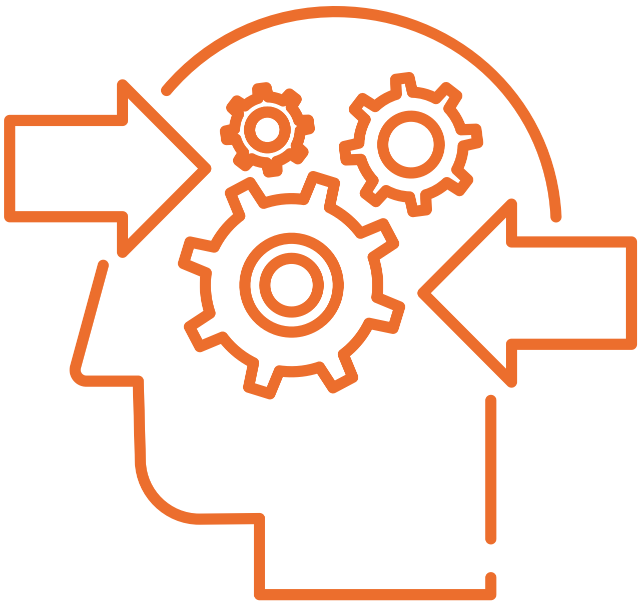
For example, a student can develop a mental model of the mathematical concept of pi (π). This may include the knowledge that $A = \pi \times r^2$, the digits of pi. More developed mental models may recognise how pi is derived or its relation to trigonometric functions.

Learning then refers to the relatively permanent changes to these mental models, which are available to us for future use. These changes include the addition of new information, the change of existing knowledge, or the connection to other mental models.

We say that learning should be relatively permanent—the changes to the mental model should persist over time. If we taught this student more about right triangles, we'd want them to remember it in subsequent days, weeks, months, and even years. If they came in the next day and did not remember it, of course we would not say they had learned it, even if they had understood the day before.

HOW DOES LEARNING HAPPEN?

The human brain is incredible—it has the processing power of a modern supercomputer, but fits inside your head and can run for a few hours on just a banana (Wu, et al., 2016). Aside from controlling our voluntary and involuntary movements, the brain has the primary responsibility for cognitive functions. These are processes relating to knowledge, thinking, and interpreting the world around us. Our brains allow us to continuously perceive, process, and respond to stimuli.

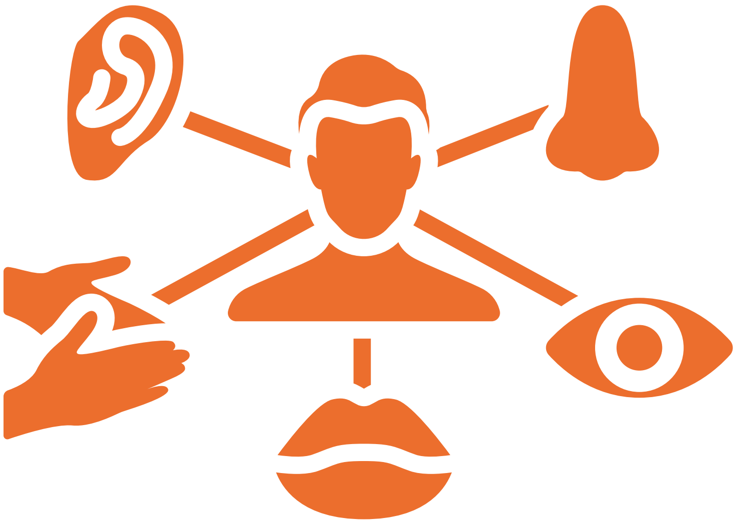


To describe how brains learn, we can use a model of cognitive functions and processes to describe what happens. In this model, there are three cognitive functions that are particularly relevant; there are three related cognitive systems that provide these functions:

- The attention system selects the most relevant information.
- Working memory processes the information.
- Long-term memory stores the information.

The attention system

Our senses are constantly bombarded by stimuli. Of course, this includes the senses we regularly think of—sight, hearing, smell, taste, and touch—but our bodies rely on even more senses. We also have a sense of balance, temperature, proprioception (i.e., a sense of body position), pain, and internal senses (e.g., hunger, thirst, nausea), to name a few.



The attention system selects information from the environment. Some things we choose to focus on; for example, we may focus attention on someone we're speaking to in a noisy room. Some stimuli draw our attention—think of what happens when you hear a ping from your phone.

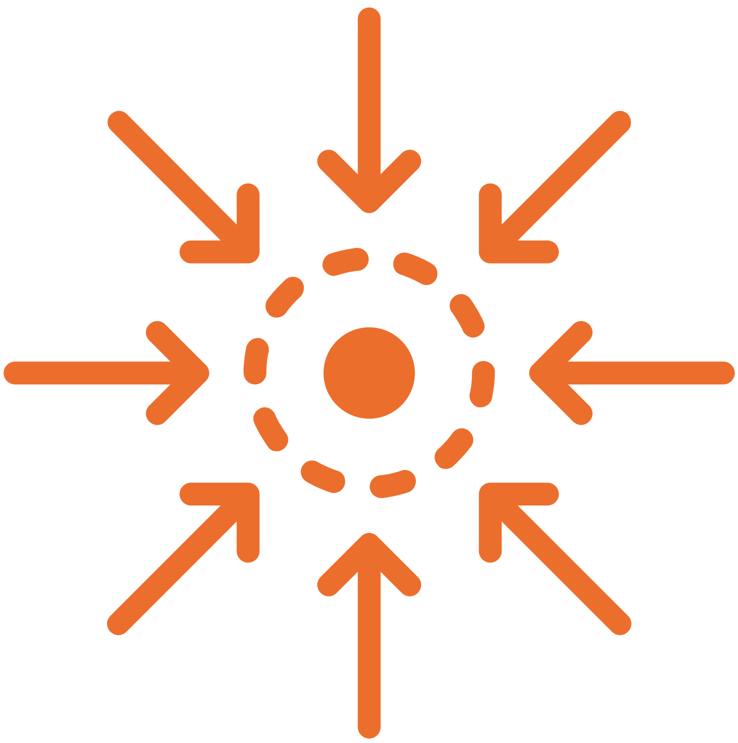
The attention system is an effective filter; most stimuli are either not attended to or are quickly lost. Think of an annoying hum in the background—often, your attention system can "tune out" the noise and allow you to focus on other stimuli.

The attention system's capacity is limited. Think about how that ping from your phone draws you away from what you were doing; you may no longer notice what someone is saying to you or what is happening around you. In particularly noisy settings, we may need to devote extra attention to focus on relevant stimuli. Furthermore, our attention naturally wanes over time. When this happens, we could make a conscious decision to renew it, but this requires a reason for us to do so.

When we use any of our cognitive systems for the goal of learning, we naturally would want to maximise their effectiveness. We can do this for our attention system with various simple techniques—whether for our own learning, or within our classrooms:

- Avoid and actively reduce external distractions in learning environments. Silence phones and minimise background noises. Anything that isn't relevant to the learning can be a source of distraction.
- Find ways to draw attention to, and focus on, the most relevant information. Say phrases like, "This is important!" or place written instructions clearly front and centre. Point to key components of diagrams.
- Acknowledge that we are only aware of some of the information in our environment. Don't assume a student noticed something just because it was on the board.

The information we do successfully attend is then passed to our working memory.



Working memory

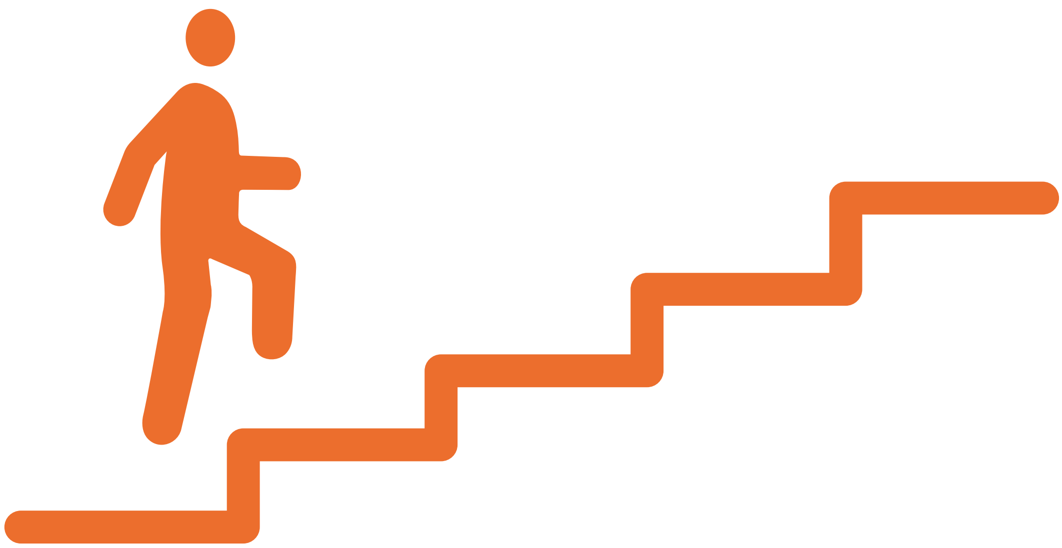
Working memory is the space where we work with memory - it's responsible for processing information. This information either comes from the attention system or from long-term memory. Processing information requires a conscious effort—it's the thinking that is crucial for memory formation to take place. When it comes to deliberate learning, if something is not processed by working memory, it has very little chance of successfully being encoded into long-term memory.

Our working memory has a very limited capacity (especially if you are a novice learner of something). If our working memory's capacity is exceeded, information is lost. Obviously lost information is not conducive to learning, so we want to minimise overtaxing working memory!

Novices and experts

Novices and experts on a topic handle new information differently. Experts' mental models are more developed; they contain greater amounts of knowledge which is better organised. They also have greater experience of using this knowledge—perhaps even to the point of automaticity. An individual's place on the novice-expert continuum varies by domain, content, and topic.

Regardless of where someone falls between novice and expert, these cognitive processes still work the same way. However, differences remain in how we handle new knowledge. A novice learner in a topic has a less developed mental model; as a result, their working memory can get taxed more readily. Experts are also able to use their existing prior knowledge to help "chunk" information.



Working memory capacity does vary between people; while you can't do "brain exercises" to expand this capacity, adults' working memory is naturally greater than that of children. Research suggests that when dealing with unfamiliar items, most people's working memory capacity is around 3-4 items (the psychologist George Miller first posited it may be 7 items, plus or minus 2; but later studies refined this down to our modern estimate).

Three or four items is not a lot, given that an item is a small piece of information! However, our brains are able to **chunk** information—we can combine a number of items into a new, single item. Having prior knowledge related to items allows us to group them together. They could be grouped together by related meanings (e.g., when remembering a grocery list, we can think of apples and bananas as one item: fruit) or by familiarity (e.g., L-M-N-O-P is more familiar than a random assortment of five letters).

As an illustration, imagine the difficulty in trying to remember this alphanumeric string:

M I 6 C I A 0 0 7 K G B

You may have a good deal of difficulty if each character were its own item in your working memory! Perhaps you noticed some familiar combinations or characters—maybe you even noticed some shared meanings between these letters. Is it different trying to remember the same sequence, but chunked into familiar concepts?

M I 6   C I A   007   KGB

Chunking does not just refer to numbers or letters, but any information or concept. Processes or sequences of events, hierarchies of knowledge, or related ideas can all be chunked. Simply chunking information does not mean that we will remember it—it is a way to lighten the load on our working memory's limited capacity. However, this does mean that we are less likely to lose information due to over-capacity.

Examples of "chunks"

Making a cup of tea	• Put water in kettle • Turn on kettle • Take out mug • Put tea bag in mug • Wait for kettle to boil • Pour water in mug • Let steep • Remove teabag • Add a dash of milk
Commute to work	• Exit front door • Turn right • Walk 200 metres to bus stop • Board #7 bus • Travel 12 stops • Get off bus • Turn right • Walk 50 metres to the school
Taxonomy	• Kingdom • Phylum • Class • Order • Family • Genus • Species

Long-term memory
Unlike working memory or the attentional system, our long-term memory has no limit (as far as we know). It is responsible for storing our memories and knowledge. The information it stores can be categorised as one of two types of memory: declarative (or explicit) memory and nondeclarative memory.

Declarative memory is memory of facts, events, and concepts; they're the items in our memory we can explicitly declare or say that we know. We can further divide declarative memory into episodic memory and semantic memory. The former refers to our ability to remembers specific events or episodes. Semantic memory describes general knowledge—that is, concepts, facts, or ideas that can be explicitly communicated.

Nondeclarative, or implicit, memory is knowledge that is based on prior experiences: procedures and processes that we can draw on without the relevant information entering our consciousness. In fact, one significant type of nondeclarative memory is procedural memory: knowing how to do things.

While distinct types of memory, they are closely linked. For example:

- You can hold an episodic memory of an afternoon when someone taught you how to play chess.
- You can hold semantic memory of the rules of the chess pieces' movement.
- You can hold procedural memory of how to play chess.

Not all information that our brains receive will enter our long-term memory. We say that information is encoded into long-term memory when we process it in our working memory. Even then, our long-term retention of that information is not guaranteed!

The cognitive systems and learning

Learning allows us to register information from life experiences in our memory and to react more effectively in the future. We can think of learning as a goal: the long-term retention of information and the ability to transfer it to the novel situations we find ourselves in during the course of life.

We can think of the attention system, working memory, and long-term each as “insufficient but necessary” parts of the whole process. Each system is crucial for learning to happen; each system is also dependent on the others to work.

Key to this model of learning is the idea of forming connections between information. This means that learners must be able to make connections between new information and what they already know. Without secure prior knowledge, learners struggle to be able to place incoming knowledge and form connections in long term memory. Readily accessible prior knowledge also helps alleviate the load on working memory. Learners with more expertise and prior knowledge on a topic can more easily select which relevant information to attend to in their environment. We know that learning does not occur in a vacuum—prior knowledge is a key additional factor that is required.

You may be aware of topics or principles related to memory and learning. Cognitive load theory, Rosenshine’s principles, or Mayer’s principles are popular among educators. These are not in competition, but can offer teachers practical considerations or understandings based on this model of memory and learning. Many of these use the limitations of working memory as a key foundation of their framework. This knowledge of how the cognitive systems work for memory and learning can help you better implement these in your practice.

Final thoughts
With this awareness of the cognitive systems that work together for memory and learning, you may find yourself modifying your instructional design. As you do, consider the following key points:

- Only information that we consciously attend to in our environment can pass into working memory for processing.
- The process of learning in the brain happens continuously (most of the time we're not even aware of this). If we want to learn something deliberately though, we have to select the specific information needed for processing to give us a chance at developing it into knowledge.
- If we want to learn something deliberately but we attend to irrelevant information, not only do we risk developing misconceptions, but we also use up vital working memory capacity—which then can't be used to process the accurate, relevant information.
- Cognitive overload prevents relevant information being properly processed in working memory, items that are not properly processed are not encoded into long-term memory.

It is also crucial for teachers to remember that learning is invisible. These cognitive processes are unseen, by both teachers and learners. Furthermore, just because we incorporate these understandings of cognitive systems into our instruction does not mean that learning will automatically take place. Teachers still must employ high-quality assessments to build an understanding of what learning has actually taken place.

As The Great Teaching Toolkit: Evidence Review argues, anyone can get better at anything—including teachers (Coe et al., 2020). Developing your understanding of models of learning and memory are a great step in becoming an even greater teacher.

Applying these understandings to your own practice are a feature of being an evidence-informed teacher. And in doing so, you can increase student learning and outcomes in your classroom.

References & further reading

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