THE SCIENCE OF LEARNING

A summary of evidence about how children learn

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better purpose

FOREWORD

While access to education has significantly increased worldwide, hundreds of millions of children are still not achieving the level of learning that they should. A major contributor to the lack of progress in learning is an implementation gap between what the theory tells us about how children learn most effectively and the practices deployed by teachers in classrooms; this gap is particularly acute in low-income contexts.

In recent years, advances in the sciences of the brain have built a compelling body of knowledge about how children learn. This report presents a summary of key evidence about how children learn, drawing on research from neuroscience, behavioural sciences, and cognitive sciences. It provides an overview of useful frameworks which translate the science of learning into implications for teaching. It also highlights some leading organisations who are shaping this field and provides references for further learning.

In compiling this report we have drawn upon the work of leading researchers from all over the world, whose publications cover both high and low-income contexts. Our assumption is that while the core principles of how children learn apply universally, more research is needed to examine how the application of these principles differs across contexts. We hope that this report provides a useful reference point for learning and practice.

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ABOUT BETTER PURPOSE

At Better Purpose, we shape and accelerate the work of educational organisations that want to make a positive difference to learning outcomes. We bring insight, expertise and practical delivery experience of important issues in the international education sector, to help our clients design and run effective organisations and educational initiatives.

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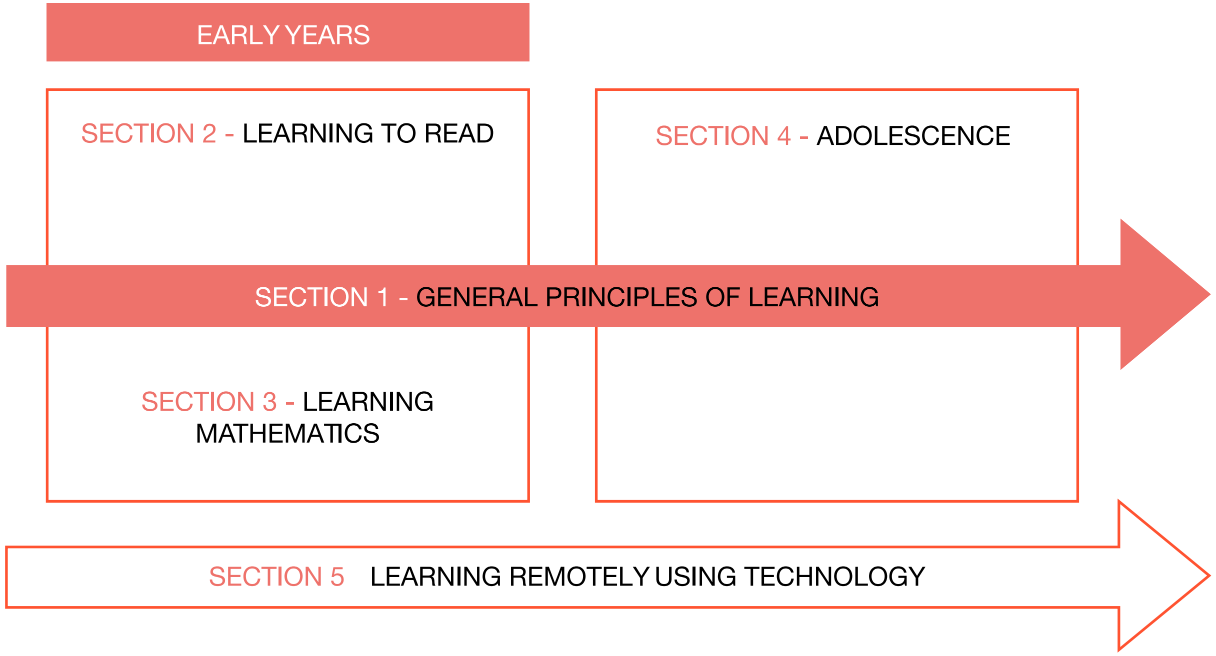
CONTENTS AND BACKGROUND

The report looks at general principles of learning (Section 1) which could inform teaching approaches across any phase of schooling and in later life. Deep dives (Sections 2 to 5) explore what else is known about learning in different contexts (early years, adolescence, and remote learning using technology) to understand additional nuances about the learning process.



WHAT DO WE MEAN BY LEARNING SCIENCES?

The report draws on research from the fields of neuroscience, cognitive, and behavioural sciences. In bringing these scientific disciplines together, this research aims to improve educational practices and learning outcomes through a deep understanding of the brain mechanisms, thoughts, and actions that underlie quality learning.
These disciplines are outlined below:

Summary

WHAT IS NEUROSCIENCE?

- Neuroscience is the science of the whole nervous system, and most research concerns the brain.
- Neuroscience concerns the mechanical, functional and systematic functions of the brain. It observes the anatomy and physiology of the brain, from major structures to neurons and molecules (see Appendix 1 for a summary of the structure of the brain). Through this study, it gives us an understanding of the brain mechanisms involved in learning.
- It is a branch of biology that has stemmed from the study of the anatomy and physiology of neural tissue.
- Research areas include: the neural mechanisms of reading; attention; learning difficulties such as dyslexia, dyscalculia, ADHD as they relate to learning.

WHAT ARE COGNITIVE SCIENCES?

- Cognitive Science concerns the study of thought and stemmed from human psychology.
- It involves understanding the processes of the human mind (e.g., language, memory, perception, cognition, reasoning, decision making, and problem solving).
- This shows us 'how' people learn (versus neuroscience which observes the mechanisms of the brain), and how the mind determines subsequent behaviour (versus behavioural sciences which explore the actions and motivations of behaviour).
- It is a highly inter-disciplinary field, which pulls from psychology, computer science, linguistics, philosophy, and neuroscience.
- Research areas explore teaching methods that help children learn effectively, retain new information, and best understand new and abstract ideas.

WHAT ARE BEHAVIOURAL SCIENCES?

- Behavioural Science explores human behaviour and behavioural change.
- It primarily deals with human behaviour as it relates to society.
- It is interdisciplinary and includes aspects of psychology, psychobiology, anthropology, and cognitive science.
- Research areas focus on how we want learners and educators to behave to be successful, which can help to inform impactful interventions. For example, this might include the impact of, and motivations for, pupil and teacher activities, such as why pupils might not attend class or how teachers can use rewards in lessons.

Focus

BRAIN MECHANISMS

- Observes data from the brain, and its biological components, in the central nervous system.
- Understands what happens in the brain when children learn.

References: Churches, Dommett & Devonshire (2017); Weinstein & Sumeracki (2019).

THOUGHTS

- Interprets thought using theoretical and psychophysics observations.
- Informs approaches to education and planning learning.

References: MIT (2020); Weinstein & Sumeracki (2019).

ACTIONS

- Focuses on physical activities through behavioural observation.
- Informs practical guidance for teaching and learning actions, and driving motivation in the classroom.

References: LSE (2020).

GENERAL PRINCIPLES OF LEARNING

THIS SECTION EXPLORES GENERAL PRINCIPLES FOR HOW CHILDREN LEARN

WHAT DOES THIS SECTION COVER?

A What do we know about **how children learn** in general?

B What does this mean for **classroom practice** and what common misconceptions should be avoided?

C Which **organisations** are doing interesting work in the Science of Learning?

D What **resources** and **references** could support further learning in this area?

Key Definitions:

- Cognitive Load: The amount of working memory resources used
- Cognitive Psychology: The study of mental processes – this gives us an understanding of 'how' people learn
- Differentiated Instruction: A way of teaching that provides individual children with instruction that matches their readiness to learn that material
- Domain: An area of learning.
- Executive Functions: Mental processes that help us plan, focus attention, remember instructions, and juggle tasks. More information can be found in Appendix 2
- Exposition: A comprehensive description and explanation of an idea or theory
- Learning Difficulty: A neurological condition that affects a pupil's ability to process information
- Learning Disability: A reduced intellectual ability resulting in challenges with everyday activities
- Learning Sciences/Science of Learning: What cognitive sciences tells us about how children learn
- Long-term Memory: Permanent store of knowledge
- Metacognition: The ways learners monitor and purposefully direct their learning
- Neuroscience: The study of what happens in the brain – this gives us an understanding of what learning looks like in the brain
- Schema/Schemata: A way of organising knowledge; a mental structure of already learnt and available knowledge, skills, and even ideas that is used for organising and perceiving new information. They are unique to each individual, constantly changing, and built through experience. Units of knowledge in a schema do not contain much detail, but the more connections and experiences in the schema, the more powerful it is.
- Science of Teaching: The practical implications of what cognitive science tells us about how children learn on teaching
- Spaced Study: A study technique where students review material over a long period of time. This gives their minds time to form connections between the ideas and concepts so knowledge can be developed and recalled later
- Working Memory: Short-term memory (usually 15-30 seconds) required for processing and thinking
- Zone of Proximal Development (ZPD): The difference between what a learner can do without help and what they can achieve with instruction from a teacher. The term 'proximal' refers to skills a learner is close to mastering. (Vygotsky, 1978)

SECTION SUMMARY

The same cognitive processes are relevant to learners of all ages and contexts; however, the way they interact can vary by individual. This has implications for learning which will be explored in more detail in this section.

In ‘Understanding How We Learn’, Weinstein and Sumeracki highlight three key human cognitive processes that inform learning:

- Perception: Individuals make sense of the world differently and they apply prior knowledge when understanding a situation: this is called top-down processing. Each learner will make sense of things differently depending on their home context and experiences.
- Attention: Children have limited capacity for attention and can only process a limited amount of information at any one time *(Cognitive Load Theory).* This has implications on how we should design teaching and learning materials, introduce processes in manageable steps, and be focused when giving explanations.
- Memory: Children need to encode information in a deep and meaningful way in order to develop long term memory and draw upon this information to make meaning of the world around them. Development of procedural memory (the part of long-term memory responsible for knowing how to do things) is key to automating certain actions.

Key take-aways:

Key take-aways	
Learners make sense of the world differently and apply prior knowledge to understand a situation	
Children have limited capacity for attention and can process a limited amount of information at any one time	
Emotional experiences substantially influence all cognitive processes, particularly attention	*Learning Theory*
Items stored in long-term memory are known as knowledge; new knowledge is more likely to stick when it can be linked to existing knowledge	*Learning Theory*
Long-term memories are formed when information in the working memory is actively thought about	*Learning Theory*
Children need to encode information in a deep and meaningful way to develop long-term memory	*Learning Theory*
Novices and experts solve problems differently because of how they engage with prior knowledge and skill	
Incorrect prior knowledge can pose challenges to the process of learning new knowledge	
Processing information is challenging and requires specific support from teachers	
Teachers should be knowledgeable about common factors that can impact the way pupils process information	
Long-term learning can be promoted by applying specific strategies for learning and teaching	*Classroom Teaching*
Specific strategies for learning and teaching can be applied which promote long-term learning	*Classroom Teaching*
Rosenshine’s ‘principles of instruction’ sets out specific strategies teachers can use to transmit and embed knowledge	*Classroom Teaching*
Teachers can structure learning to ensure that pupils become independent in their use of knowledge	*Classroom Teaching*
Connecting research to practice has practical implications for teaching and learning that all educators should consider	
Despite an abundance of research into how learning happens, misconceptions and myths about learning still persist	
There are also several myths surrounding the purpose of knowledge in schools and the role of the teacher	

References: Weinstein & Sumeracki (2019).

LEARNERS MAKE SENSE OF THE WORLD DIFFERENTLY AND APPLY PRIOR KNOWLEDGE TO UNDERSTAND A SITUATION

PERCEPTION:

- **Perception allows us to make sense of the world and is subjective. What we perceive differs from person to person, and from situation to situation.**
- **When considering perception, we distinguish between 'bottom-up processing' and 'top-down processing':**
  - Bottom-up processing starts and ends with sensory information (a sight, sound, smell etc.), also known as a stimulus– you focus on information about the stimulus and try to understand it without drawing on prior knowledge.
  - Top-down processing involves using prior knowledge to help interpret the input you are receiving.
- **Humans tend to mostly engage in top-down processing; therefore, background knowledge and learners' perspectives have a big role in the classroom.**
  - Students' top-down processing has a significant impact to their learning, as they bring different experiences and types of knowledge to the classroom, which affects how they perceive certain information.
  - Teachers need to be aware of students' differing levels of understanding and how students will process information.
- **Perception relies on making inferences to understand the world.** Humans question their own perception when completing tasks, so that they can complete tasks more accurately. Monitoring and guiding one's own thinking is a process referred to as metacognition (see right).

METACOGNITION:

Metacognition refers to the ways learners monitor and purposefully direct their learning. It involves "thinking about thinking" and a pupil's own "judgement of learning".

Metacognition can impact pupil learning success, as learners can develop a clearer understanding of successful cognitive strategies and can reflect on the success of their learning processes. In turn, teachers can have a clearer understanding of what learners may need when they struggle on particular tasks.

To promote metacognition, teachers should:

- Acquire the professional understanding and skills to develop their pupils' metacognitive knowledge.
- Explicitly teach pupils metacognitive strategies, including how to plan, monitor, and evaluate their own learning.
- Model their thinking to help pupils develop their metacognitive and cognitive skills.
- Set an appropriate level of challenge to develop pupils' self-regulation and metacognition.
- Promote talking about learning in the classroom.
- Be supported by schools to develop their knowledge of these approaches to apply them appropriately.

References: Weinstein & Sumeracki (2019); Quigley et al. (2018); Churches et al. (2017); Dunlosky & Bjork (2013); Schwartz & Efklides (2012); Bjork & Bork (2011).

CHILDREN HAVE LIMITED CAPACITY FOR ATTENTION AND CAN PROCESS A LIMITED AMOUNT OF INFORMATION AT ANY ONE TIME

ATTENTION:

- **Attention is a cognitive process that is hard to define.**
  It is thought of as a 'limited-capacity resource' (Moray, 1967) – people have a certain amount of attention and apportion it to different tasks.
- **Cognitive Load Theory (see right) has helped teachers focus on the efficiency of their explanations to avoid any inadvertent overload on students' attention.**
  - An important feature of attention is the ability to selectively focus on one stimuli at a time. A learners' ability to do this relies heavily on their executive functions (see Appendix 2). Switching between two tasks decreases efficiency and slows down reaction speeds in both tasks.
  - The likelihood that a student will pay attention is determined in part by the saliency of thematerial. While saliency can come from many sources, teachers can influence saliency through promoting the meaning of information, and the way information is presented (i.e. colours, format and sounds).
- **Both individual and situational interest affect the extent to which we pay attention in a learning situation.**
  - Mind-wandering involves getting distracted from a task by your own thoughts. It can be problematic as it can result in students missing important information.
- **Emotion also has a particularly strong influence on attention.**
  See slide 10 for more details.

COGNITIVE LOAD THEORY:

When cognitive load is too high it can be difficult for students to focus their attention.

Cognitive Load Theory refers to the way that we process information:

- The cognitive load involved in a task is the amount of information processing required by a person to perform the task.
- During learning, information must be held in working memory until it has been processed sufficiently to pass into long-term memory.
- However, the theory suggests that the working memory has limited ability to code information. As a result, learning is hampered when working memory capacity is exceeded in a learning task.

Cognitive Load Theory distinguishes between three types of cognitive load:

- Intrinsic – effort associated with a topic.
- Extraneous – the way a task or information is presented.
- Germane – the amount of work necessary to transfer the information into a permanent store in long-term memory.

All three types of cognitive load should be considered when teachers are planning and delivering content.

References: Weinstein & Sumeracki (2019); Tyng et al. (2017).

References: Churches, Dommett & Devonshire (2017); Kirschner & Hendrick (2020); Sweller (1988).

EMOTIONAL EXPERIENCES SUBSTANTIALLY INFLUENCE ALL COGNITIVE PROCESSES, PARTICULARLY ATTENTION

- **The impact of different emotions on learning is not clear and there is mixed evidence on the link between learning and 'positive' or 'negative' emotions.**
  - While some studies report that 'positive' emotions can facilitate learning and contribute to academic achievement, others have revealed that stress (a negative emotional state) can both facilitate and/or impair learning and memory, depending on its intensity and duration.
  - The role of emotion in learning is also challenging to assess given that emotion has no single definition, and the range of emotional states are also not clearly defined among academics.
- **However, there is evidence that of a strong link between emotion and attention which suggests that emotions make a learner's attention more focused.**
  - For example, an emotional stimulus, such as a violent picture, will focus a learner's attention more quickly, and for longer, than neutral stimuli. This has a positive impact on learning because focused attention means that the information that gets processed is of a higher quality and more likely to be stored in long-term memory.
  - On the other hand, when attention focuses on emotional stimuli, it may impact the quality of processing of other non-emotional stimuli that occurs at the same time.
- **The impact of specific emotions on attention, memory, and learning remains unclear,** despite recent studies that explore the link between emotions and attention using neuroimaging techniques.
  - A literature review by Tung et al (2017) proposes that a specific emotional state ('seeking') is responsible for positive learning outcomes. This is outlined on the right.

Tyng et al. (2017) present 'seeking' as the most fundamental primary emotional state for learning and memory

Tyng et al. outline the key seven primary emotional states as: seeking, rage, fear, lust, care, panic/grief, and play. 'Seeking' is defined as an emotional state that motivates the individual to seek out and learn things that they need, crave and desire.

- According to Tyng et al., seeking encourages humans to explore activities that result in acquiring behaviours necessary for survival, and is linked to the dopamine-reward systems in the brain.
- Although learners' emotions often involve a complex interplay between all emotional states, Tyng et al. argue that 'seeking' is crucial for learning and memory, because learners in the 'seeking' state are more likely to focus attention on learning.
- The link between greater learning and seeking was shown in a recent study which found that confused pupils were more likely to experience impaired learning if they felt frustrated with their poor understanding of subject matter, resulting in a 'rage' emotional state. However, pupils with higher levels of seeking, and lower levels of rage or fear, were more likely to stay motivated to complete the task. This is because they responded to confusion by seeking new understanding and doing additional cognitive work, which ultimately enhanced learning.

References: Tyng et al. (2017); Brosch et al. (2013).

ITEMS STORED IN L-T MEMORY ARE KNOWN AS KNOWLEDGE; NEW KNOWLEDGE IS MORE LIKELY TO STICK WHEN IT CAN BE LINKED TO EXISTING KNOWLEDGE

- **Every item stored in our long-term memories is known as knowledge.**
  - Knowledge is a collection of facts about the world and procedures for how to solve problems.
- **A key feature of learning is when these facts and procedures are stored into a learner's long-term memory.**
  - Learners are more able to store knowledge when they can link new knowledge to existing knowledge – reactivating 'prior knowledge' before new information is learned. The new information, and their existing knowledge, should also be linked.
  - Simpler facts and procedures should be learned first, followed by progressively more complex facts and procedures.
- **Lots of items of knowledge together create 'schemas.'**
  - Once a schema of knowledge is held, new knowledge can be acquired both quickly and easily as learners can better predict, explain, and respond to abstract scenarios.
- **Teachers should know and transmit important knowledge to pupils.**
  - As 'more knowledgeable others', teachers should guide pupil learning. Without direct teacher instruction, learners will struggle to make sense of the information they are working with, which will lead to working memory overload.
- **Knowledge and skills cannot be separated, and learning knowledge securely enables more complex skill-based responses.**
  - To develop ability in areas such as analysis and evaluation, knowledge needs to be securely committed to memory.
  - A 'knowledge-rich' curriculum, and sequence of learning, should be designed which clearly identify what information pupils need to learn, and to help pupils remember what they have been taught over time.

Deep Dive: Knowledge-rich curriculum and "powerful knowledge"

Without a good curriculum, the power of classroom instruction and memory are weakened. Young (2014) states that knowledge taught in schools is most powerful when it is:

- Distinct from every day 'common sense' knowledge which is limited, and learned through contexts we live in. Schools should give knowledge learners wouldn't otherwise have access to, especially in disadvantaged contexts to promote social mobility.
- Systematic – related in groups like subjects, allowing learners to generalise and think beyond particular contexts.
- Specialised – developed by experts in that field.

Knowledge organisers (KOs) can help schools use these principles and create a 'knowledge rich' curriculum.

KOs map out knowledge to ensure it is:

- Focused – KOs can systematically outline the content knowledge, purpose, and pedagogy for each subject and topic, to ensure all teachers are clear on the invaluable knowledge they want their pupils to know. They can also support teachers to inform their planning, topic review processes, and 'read around' the subject to secure their own subject knowledge.
- Sequenced – KOs can be used to structure learning cumulatively across year groups, revisited, built on, and not repeated.

An example of a KO, and its key features, can be found in Appendix 5.

References: Miller (2018); Young et al. (2014); Sawyer (2015); Christodoulou (2014); Hirsch (2011).

LONG-TERM MEMORIES ARE FORMED WHEN WE ACTIVELY THINK ABOUT INFORMATION IN THE WORKING MEMORY

MEMORY:

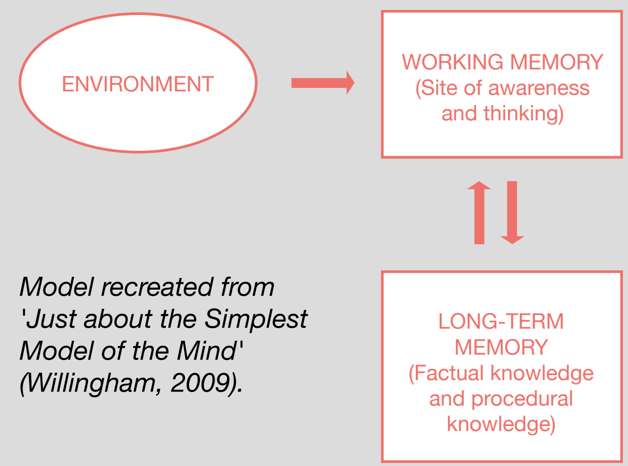
- **Everything humans do requires memory of some form or another.**
  - Memory is reconstructive – every time memories are retrieved, they are reconstructed, activated and altered.
  - Memory is therefore not objective. Details from imagination can become part of memory. Things are remembered in ways that fit individuals' 'schema' (or pre-determined catergorisations of the world), and their perception of how objects and people behave (Tversky and Marsh, 2000).
- **Multiple processes make up the experience of memory.**
- **Short-term memory, or working memory, refers to a very brief period of time (15-30 seconds).**
  - For memory to be recalled later, it needs to go from working memory to long-term memory – to do this it must be actively thought about.
- **Long term memory is equivalent to knowledge.** There are two main types of long-term human memory:
  - Declarative memory (explicit) – this is the memory of facts (factual knowledge) and events; knowing what information is consciously recalled during retrieval.
  - Non-declarative memory (implicit) – this is accessed without consciousness, or implicitly through performance. Procedural knowledge is included in this area.

Dan Willingham's 'Just about the Simplest Model of the Mind' (2009)

This model depicts how learners of all ages process thinking into their long-term memory.

Willingham states :

- Working memory is limited; thinking gets difficult as it becomes overcrowded.
- A large schema of associated knowledge in long-term memory can help free up working memory and make thinking more efficient and effective.
- The more you think about something in working memory, with the right balance of cognitive load and long-term knowledge to support this thinking, the more likely the information will be retained in a schema of long-term memory.



Model recreated from 'Just about the Simplest Model of the Mind' (Willingham, 2009).

References: Weinstein & Sumeracki (2019); Willingham (2009); Willingham (2008); Mccrea (2017).

References: Willingham (2009).

CHILDREN NEED TO ENCODE INFORMATION IN A DEEP AND MEANINGFUL WAY IN ORDER TO DEVELOP LONG-TERM MEMORY

- **A goal in teaching is to build powerful long-term memory.**
  - Long-term memory is equivalent to knowledge, and working memory is equivalent to processing and thinking.
  - What students think about is what they remember in their long-term memory; teachers should help students actively think about, and make sense of, the information in their working memory.
- **The better we think, the more we know. The more we know, the better we can 'think'.**
  - This unique relationship between working memory and long-term memory is called The Matthew Effect *(see Appendix 3)* and is the reaction engine of education.
  - The theory of the Effect states that those who know more can think more effectively. It is a teacher's job to catalyse this reaction; great teachers manage what learners think.
- **Willingham (2008) offers three principles to help students commit knowledge to memory:**
  - *Memories are formed as a residue of thought:* To remember what things mean, you must select a mental task that will ensure that you think about its meaning. For example, rather than remembering the formula and result of 2+2=4, pupils are more likely to remember the answer and process if they have thought conceptually about what it means and used concrete objects, such as counting cubes, to understand the relationship between the numbers.
  - *Memories are also prompted by cues (a signal or stimulus).* If there is no perceivable connection between the cue and its target memory (e.g., 'rojo' (target memory) is the Spanish word for 'red'(cue), you can form memories through use of mnemonics - learning something by rote memorisation through stories, songs and rhymes, or acrostics.
  - *Memories are lost mostly due to missing or ambiguous cues:* Make your memories distinctive, distribute your studying over time, and 'plan to forget' by continuing to study even after you know the material.
- **Individuals' assessments of their own knowledge are fallible.** Students should not internally gauge whether they have studied enough, but test themselves using the same type of test they will take in class.

References: McCrea (2017); Willingham (2008); Willingham (2009); Stanovich (1986)

Theory of Disuse

*The Theory of Disuse states that an item of knowledge in the long-term memory can be characterised by its **storage strength,** which measures how well this item has been learned.*

- For learning to happen, information must be processed in working memory, and then encoded and stored in long-term memory.
- There is no limit on storage capacity, and it has no direct effect on performance. How well an item is learned can only increase.

*An item's **retrieval strength** measures how well that item of memory can be recalled or accessed.*

- In order to be applied to a novel task, learned information must be retrieved from long-term memory.
- How easy an item is to retrieve can go up and down at any time. There is also a limit on retrieval capacity, and the number of items that can be recalled at one point in time.

Storage strength, and retrieval strength, can be increased by:

- Re-studying an item
- Retrieving it from memory
- Retrieval has a greater impact than re-study

References: Bjork & Bjork (1992); Desy et al. (2018).

NOVICES AND EXPERTS SOLVE PROBLEMS IN DIFFERENT WAYS BECAUSE OF HOW THEY ENGAGE WITH PRIOR KNOWLEDGE AND SKILL

NOVICES AND EXPERTS:

- **Novices and experts solve problems in different ways. This is because how people categorise problems depends on previous experience with similar problems.**
  - 'Experts' have acquired deep knowledge about problems and their solutions which are stored in long-term memory. They have rich knowledge schemata and can 'see' the underlying concepts that sit beneath problems.
  - Novices lack knowledge, experience, and the interconnected schema which allows experts to overcome the limits of their working memory.
- **For optimal learning, new knowledge must be related to knowledge students have already acquired and integrated into existing schemata.**
  - Beginners have much weaker schema which are incomplete, shallow and may contain misconceptions. They are less able to solve problems well, or quickly.
  - What might work well for an 'expert' (e.g. discovery learning, problem-based learning, inquiry learning) may not work well for a novice who needs to be provided with a more structured approach to solving a problem.
  - There should only be a slow reduction in guidance once learner expertise is increased.

Note: The concept of novices and experts applies to teachers as well as students and should be considered when thinking about teacher education.

References: Chi, Feltovich & Glaser (1979); Chi, Glaser & Rees (1982); Kirschner & Hendrick (2020).

Deep Dive: When do novices become experts?

A learner's level of expertise is fluid and varied across topics and subjects. High-attaining pupils can be novice in some areas of learning, and low-attaining pupils can be experts in some areas of learning.

Teachers should think about how to support pupils to become more advanced, and ensure pupils build up the relevant schemas required for more advanced problem-solving.

- What's effective at helping students to acquire schema becomes unhelpful once schema have been acquired. Novices will benefit from explicit explanations, worked examples, and fully guided instruction. These techniques are unhelpful to experts and increase their cognitive load.
- Experts are not free from cognitive work; experts and novices both experience cognitive overload, but differently.

In order to minimise cognitive load, instructional design should address the needs of three broad groups of expertise:

- *Novice level* – detailed, direct instructional support in preferably in integrated or dual-coded formats.
- *Intermediate level* – a mix of direct instruction and problem-solving practise with reduced support.
- *Advanced level* – minimally guided problem-solving tasks that provide cognitively optimal instructional methods.

References: Sweller et al. (2011); Kalyuga (2007).

INCORRECT PRIOR KNOWLEDGE CAN POSE CHALLENGES TO THE LEARNING PROCESS

- **When learning new knowledge, learners need to build on prior knowledge.** This can occur in two ways:
  - *Assimilation* – when new information is agreeable with the knowledge the learner has already learned, and fits within the schema of knowledge they have in their long-term Memory.
  - *Accommodation* – when new information is not consistent with what learners already know, as their knowledge may contain misconceptions or errors. Learners will need to change what they know, which is cognitively more challenging and must be explicitly identified and led by teachers.
- **Misconceptions are beliefs that contradict current evidence.** Misconceptions of previous knowledge must be identified by the teacher, challenged, and then explicitly retaught.
- **Teachers can use the instructional strategies identified in the table,** which were compiled by Lucariello and Naff (2013) following a review of evidence of effective classroom strategies.

Addressing misconceptions	What does this look like in the classroom?
Assess preconceptions	*Ask pupils to write down their pre-existing knowledge of the material being covered. This allows them to overtly assess their preconceptions.*
Bridging analogies	*Use pupils' correct conceptions as a base to build new knowledge, and present a bridge of examples that steps from a misconception to new concept.*
Present new concepts of theories	*Present new knowledge as valuable and important. Learners must also be able to conceptually understand it, and use it to solve a range of new problems.*
Model based reasoning	*Present correct knowledge in a new way, through use of models, representations or analogies, to guide pupil understanding.*
Diverse instruction	*Collect a range of common misconceptions identified in class, and use them to guide new pupil knowledge. Knowledge change is more likely if learners are presented with a few examples that challenge multiple assumptions.*
Student metacognition	*Support learners to challenge misconceptions through interactive discussion, open exchange, and debate of ideas.*
Cognitive conflict	*Present students with data and texts that directly challenge their misconception, and offer the preferable alternative.*
Interactive conceptual instruction	*Regularly assess pupil misconceptions through ongoing pupil dialogue and assessment. Also share with students the key knowledge and likely misconceptions within a unit of learning.*
Develop pupil thinking about knowledge	*Guide students believe that knowledge is complex and constantly changing, and learning is a gradual, slow process that can always be proved.*
Use case studies	*Provide examples that align with a pupil's new knowledge once a misconception has been corrected. This helps pupils embed this thinking.*
Self-repair	*Prompt students to explain their thinking if corrected misconceptions re-appear. This gives learners opportunities to correct their thinking.*
Engage them in argument	*Lead pupil discussions to support pupils to strengthen their newly acquired correct knowledge.*

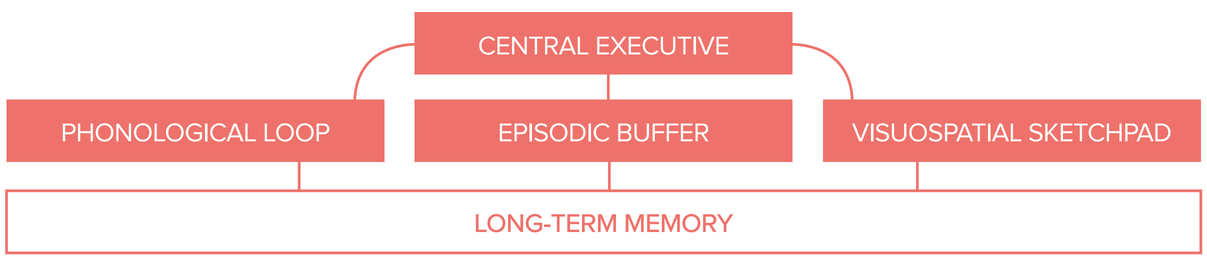
References: Ghosh & Gilbroa (2014); Lucariello & Naff (2013).

PROCESSING INFORMATION IS CHALLENGING AND REQUIRES SPECIFIC SUPPORT FROM TEACHERS

Processing information can be challenging, as it relies on different structures in the brain working together. These structures are:

1. *Central Executive* – Focuses attention to information, selects one stimulus over another when they are competing, not entirely under conscious control.
2. *Phonological Loop* – Processes verbal explanations and text and gets overloaded if both are used at the same time. It stores around two seconds worth of verbal information before it decays (often referred to as 'inner voice'), and quickly decays unless rehearsed.
3. *Visuospatial Sketchpad* – Briefly holds visual information, and quickly decays unless rehearsed. The phonological loop and visuospatial sketchpad can be used at the same time, which increases the chances of encoding information in long-term memory (e.g., showing a descriptive image alongside a complex verbal explanation.)
4. *Episodic Buffer* – Is a temporary store that integrates information from the other components with information already stored in the long-term memory, and maintains a sense of time so that events occur in a continuing sequence.

The Components of Working Memory:



Adapted from 'What every teacher needs to know about… Psychology' p. 36 (Didau & Rose, 2016)

References: Didau & Rose (2016); Baddeley & Hitch (1974).

The 5 principles of enabling working memory:

In order to reduce cognitive load in pupil thinking, teachers can:

1. **Streamline Communication:** Be as direct, clear and concise as possible in all written, spoken, and visual information.
2. **Manage Information:** Be mindful of information that is not adding to learning (e.g., displays, music, interruptions, teacher narration).
3. **Expedite Elaboration:** Make it clear to pupils what they should be focusing on:
   - Set their filter – tell your students what to look for in advance
   - Stress the information – emphasise important things
   - Accentuation – pausing/tone change to highlight key information
   - Gestures – using our hands or a pointer to focus attention
   - Highlighting – using format/colour to draw attention to portions of a text
   - Pose questions – ask a question that directs their attention
4. **Regulate Load:** Manage the amount of information pupils need to process
5. **Orient Attention:** Plan how you will ensure that new information is tied to existing information, through:
   - Priming – recalling relevant prior knowledge
   - Tethering – anchoring new knowledge to existing knowledge
   - Mnemonics – learning techniques that aid information retention or retrieval through use of song, rhyme, acronym, image, phrase, or sentence.

References: Didau & Rose (2016).

TEACHERS SHOULD BE KNOWLEDGEABLE ABOUT COMMON FACTORS THAT CAN IMPACT THE WAY PUPILS PROCESS INFORMATION

- **Brain function is influenced by a variety of genetic factors in addition to environmental conditions; this process of continuous evolution is known as neuroplasticity.**
  - Brain function is highly malleable, and is affected by education and daily experiences. Although the brain forms during foetal development, it continues to rebuild a map of neural connections throughout the whole of life.
  - Neuroplasticity is therefore the biological explanation for how we learn.
- **Recent evidence highlights how educators can influence the neuroplasticity process.**
  - When designing learning interventions, teachers should be knowledgeable about any neurological challenges their pupils may face. This will help them to make sure activities meaningfully target specific needs for subject understanding.
- **Neurological challenges can include learning difficulties or learning disabilities. These are neurological, rather than psychological, and will affect someone for their whole life.**
  - Learning disabilities are often confused with learning difficulties. Distinguishing between them is a complex issue. An explanation of the difference is available on the right.
  - No two people with a learning disability or difficulty will have the same set of strengths and weaknesses. Learning disabilities and difficulties can be caused by underlying genetic causes, events that happen before birth to foetal central nervous systems, or events that happen after birth such as illnesses, accidents, and seizures.
  - Some people may exhibit signs of more than one learning difficulty or disability, and it is possible for a person to have both a learning disability and a learning difficulty.

References: Bueno (2019); Mencap (2020).

Learning difficulties and disabilities

- *Learning difficulties affect the way pupils learn and process information and does not affect general intelligence.*
- They can significantly impact education outcomes, learning, and the way pupils acquire literacy and numeracy skills. The most common learning difficulties (outlined in Appendix 4) include:
  - Dyslexia
  - Dyspraxia
  - Dyscalculia
  - Dysgraphia
  - Attention Deficit Hyperactivity Disorder (ADHD).
- *Learning disabilities stem from reduced intellectual ability, leading to overall cognitive impairment and difficulty with everyday activities.*
- People with learning disabilities take longer to learn and need special support to learn and develop new skills, understand complicated information, and interact with other people. The most common learning disabilities include:
  - Autism and Asperger's syndrome
  - Down's Syndrome
  - William's Syndrome
  - Cerebral Palsy.

References: Mencap (2020).

LONG-TERM LEARNING CAN BE PROMOTED BY APPLYING SPECIFIC STRATEGIES FOR LEARNING AND TEACHING

In 'Understanding How We Learn', Weinstein and Sumeracki highlight three key human cognitive processes that inform learning: Perception, Attention, and Memory. Based on these, they present six evidence-based strategies for teaching, which derive from what we know about how children learn:

Learning strategy	Description
Spaced practice	• Learning a topic in shorter lessons and across longer periods of time is more effective for developing long-term memory than trying to digest large amounts of material in a confined time period.
Interleaving	• Switching between ideas or types of problems rather than studying one idea or type of problem for too long encourages better distinction between ideas and procedures.
Elaboration	• The process of connecting new information to pre-existing knowledge is necessary for understanding to happen.
Concrete examples	• Illustrating abstract ideas with concrete examples makes them easier to understand.
Dual coding	• Combining relevant pictures with words/concepts can provide an additional memory cue.
Retrieval practice	• Deliberately recalling learned information to mind from long-term memory is more effective at promoting long-term learning.

PERCEPTION

ATTENTION

MEMORY

References: Weinstein & Sumeracki (2019).

ROSENSHINE'S 'PRINCIPLES OF INSTRUCTION' SETS OUT SPECIFIC STRATEGIES TEACHERS CAN USE TO TRANSMIT AND EMBED KNOWLEDGE

Barak Rosenshine's Principles of Instruction (2012) presents ten research-based principles of instruction, and suggestions for classroom practice which have been widely adopted across high-performing education systems. These principles also draw from observations of the classroom practices of master teachers:

Principle of instruction	What does this look like in the classroom?
Daily review	*Reviewing previous learning helps strengthen the connections of the material that has been learned. It helps learners to recall words, concepts and procedures more automatically, making more space available in working memory for new information.*
Present new material using small steps	*A teacher should clearly and concisely introduce instructions and learning success criteria to pupils. Working memory is small and can only handle small bits of information at one time; presenting too much information at once can confuse learners because they are unable to process it.*
Ask questions	*Answering questions enables teachers to determine how well information has been learned or understood. It also gives learners the opportunity to practise new material.*
Provide models	*Modelling and having the teacher 'think aloud' provide essential cognitive supports to learners to help students learn how to use knowledge to solve problems.*
Guide student practice	*Providing learners with plenty of opportunities to practise using, summarising and rephrasing new knowledge helps them to retrieve information more easily from their long term memory. It also helps them to use this material to support new learning.*
Check for student understanding	*Checking if students are learning the new material provides an opportunity for learning to be processed and moved into long-term memory. It also provides an opportunity for teachers to identify if students are developing misconceptions.*
Obtain a high success rate	*Pitching tasks to have an appropriate level of challenge can build learners confidence, fluency and motivation to complete them. A high success rate during guided practice leads to a higher success rate when students are learning on their own.*
Provide scaffolds for difficult tasks	*Providing scaffolds, which are temporary support to assist learners with difficult tasks that can be gradually withdrawn (this is a form of guided practice). This has been called 'cognitive apprenticeship,' as students are learning strategies that help them master processes or concepts.*
Independent practice	*Enabling independent practice is necessary for students to become fluent and automatic in a skill. It is important to 'overlearn' material so it can be recalled automatically and doesn't take up space in working memory.*
Weekly and monthly review	*Rehearsing and reviewing information strengthens the connection between information. This makes it easier for learners to solve new problem because they have a well-connected body of background knowledge to draw from.*

TEACHERS CAN STRUCTURE LEARNING TO ENSURE THAT PUPILS BECOME INDEPENDENT IN THEIR USE OF KNOWLEDGE

- **Planning is an important process teachers can use to ensure pupils learn what is needed to take them from novices to more advanced learners.**
- **Before a lesson, teachers should plan a lesson learning objective, which describes what students should know and be able to do at the end of the lesson that they couldn't do before.**
- Teachers should then:
  - Map out:
    - *What to teach* – what knowledge needs to be learned?
    - *When to teach it* – how can this be structured over a group of lessons?
    - *How to teach it* – what strategies should be used within a lesson?
  - Plan a lesson backwards and subdivide complex knowledge into component tasks and knowledge.
- **Clear objectives for each lesson are essential as they help teachers to ensure their lessons are focused and to measure the success of the lesson.**
  Good lesson objectives are:
  - *Manageable* – of a size & scope to be taught in a single lesson.
  - *Measurable* – success can be determined by the end of a lesson.
  - *Made first* – all lesson activities should be designed to consider how the intended objective can be achieved. Knowledge should guide activities.
  - *Most important* – focused on the most essential learning of the topic and are a pivotal next step on the path to becoming more advanced learners.
- *An example of a lesson objective: "To be able to add 3-digit whole numbers accurately using column addition".*

References: Knight & Benson (2013); Lemov (2015).

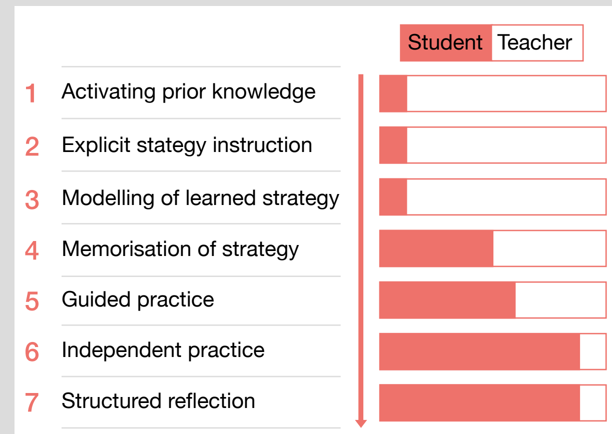
Scaffolded learning:

The *guidance fading effect* involves the gradual reduction of support structures - or scaffolding - as students move from novice to more advanced level learning and become more confident at tackling problems within a topic.

This scaffolded learning helps teachers reduce cognitive load, and guides pupils from being dependent to independent in their application of knowledge. Over time, thinking becomes habitual, acting as 'internal scaffolding' that will support future learning.

Drawing on a review of the evidence about self-regulated learning and metacognition, the Education Endowment Foundation (EEF) proposes the following model for scaffolded teaching and learning strategies (Quigley et al. 2018; p.17). This can support learning different subject content at different phases and ages. It involves:

1. Activating prior knowledge
2. Explicit strategy instruction
3. Modelling of learned strategy
4. Memorisation of strategy
5. Guided practice
6. Independent practice
7. Structured reflection



Recreated from 'Metacognition and self-regulated learning: Guidance report' p. 17 (Quigley et al., 2018).

References: Quigley et al. (2018); Bjork & Bjork (2011);Bollinger et al. (2012); Sweller (2006).

CONNECTING RESEARCH TO PRACTICE HAS PRACTICAL IMPLICATIONS FOR TEACHING AND LEARNING THAT ALL EDUCATORS SHOULD CONSIDER

Deans for Impact (2015) believe that, as part of their preparation, every teacher should grapple with, and be able to answer, key questions about learning. In addition, teachers' answers should be informed and guided by the existing scientific consensus around basic cognitive principles.

The key questions include:

How do students understand new ideas?	• Students learn new ideas through reference to ideas they already know. • Students must transfer information from working memory (where it is consciously processed) to long-term memory (where it can be stored and later retrieved). • Students have limited working memory capacities that can be overwhelmed by tasks that are cognitively too demanding. Understanding new ideas can be impeded if students are confronted with too much information at once. • Cognitive development does not progress through a fixed sequence of age-related stages. Mastering new concepts happens in fits and starts.
How do students learn and retain new information?	• Information is often withdrawn from memory just as it went in. We usually want students to remember what information means and why it is important, so they should think about meaning when they encounter to-be-remembered material • Practise is essential to learning new facts, but not all practise is equivalent. Teachers can alternate practise of different types of content (e.g., practising different problem types to learn different mathematical operations).
How do students solve problems?	• Each subject area has a set of key facts; if committed to long-term memory, these aid problem-solving by freeing working memory resources and illuminating contexts in which existing knowledge and skills can be applied. The size and content of this set varies by subject matter. • Effective feedback is often essential to acquiring new knowledge and skills.
How does learning transfer to new situations in or outside the classroom?	• We understand new ideas via examples, but it is often hard to see the unifying underlying concepts in different examples. • The transfer of knowledge or skills to a new problem requires both knowledge of the problem's context and a deep understanding of the problem's underlying structure.
What motivates students to learn?	• Beliefs about intelligence are important predictors of student behavior in school. • Self-determined motivation (a consequence of values or pure interest) leads to better long-term outcomes than controlled motivation (a consequence of reward/punishment or perceptions of self-worth). • The ability to monitor their own thinking can help students identify what they do and do not know, but people are often unable to accurately judge their own learning and understanding. • Students will be more motivated and successful in academic environments when they believe that they belong and are accepted in those environments.

DESPITE AN ABUNDANCE OF RESEARCH INTO HOW LEARNING HAPPENS, MISCONCEPTIONS AND MYTHS ABOUT LEARNING STILL PERSIST

There are many misconceptions and myths in education. Although they likely result from well-intentioned educators and research, evidence simply does not exist to back up their claims. Although these misconceptions may appear to be harmless, it is important that they are not used in the learning process, as they can misinform and incorrectly steer classrooms, or even have a negative impact on pupil attainment, cognitive development, or socio-emotional development. Some of the most common misconceptions are explained in the statements shown below, which are aligned with current evidence:

Misconception:	*Truth and underlying evidence:*
Every child has an individual learning style	*Students do not have different 'learning styles' and do not learn, receive, process and retain information best when it is delivered in a mode suited to their style.* The theory of individual learning styles is not rooted in evidence, researchers are not able to reach a consensus of the number and types of learning style, and the theory may pose potential harm in the classroom.
Humans only use 10% of their brains	*Sophisticated scientific technology has proven that the entire brain is constantly active, even in periods of sleep.* People with degenerative neural disorders also still use more than 10% of their brains.
People are "right-brained" or "left- brained" in the use of their brains	*The belief that creative abilities are based in the right hemisphere of the brain, and logical faculties in the left, is untrue.* The evidence contradicts this belief, and shows that the hemispheres work together in collaborative, complex ways, and that polarising personality types based on crude generalisations is wrong.
The 21st century fundamentally changes everything.	*Science, technology, and economics have not become so far advanced that they have changed the fundamental purpose of the education system.* However, advances in science and technology build on previous knowledge, rather than replace it. Therefore, new thinking still requires a good understanding of the basic systems and facts.
Teaching emotional intelligence improves attainment	*There is no correlation between nurturing emotional intelligence and high academic test scores or pupil behaviour.* This idea stems from multiple intelligence theory, which is not supported by evidence of how the brain works. Multiple intelligence theory is the belief that there are 9 different types of human intelligence that can be strengthened or weakened (e.g. musical intelligence or existential intelligence).
Brain Gym exercises improve cognitive ability	*There is no evidence to suggest Brain Gym programs improve intellectual development.* Brain Gym is a commercial enterprise that claims to improve intellectual development through a routine programme of body movements. There is no evidence to suggest that it works, and the programme is considered to be rooted in pseudoscience.
Growth Mindset is the secret to self-esteem	*Growth mindset should be used as a tool for learning and improvement, and not as a vehicle for self-esteem.* This makes learners feel good about any effort they put in, whether they learn or not. It should also not be used for the purposes of accountability, or as an excuse to explain why learning has not happened. See Appendix 6 for more on Growth Mindset.
Pupils cannot learn from teachers they don't like	*Learners can and do learn from people they don't like, and our brain do not shut down due to our appraisal of where information comes from.*

References: Bozarth (2018); Christodolou (2014); Dweck (2015); Hirsch (2006); Hughes et al. (2013); Landy (2005); Spaulding at al. (2010); Willingham (2006, 2017).

THERE ARE ALSO SEVERAL MYTHS SURROUNDING THE PURPOSE OF KNOWLEDGE IN SCHOOLS AND THE ROLE OF THE TEACHER (1 OF 2)

Common methods of classroom practice can also contradict basic scientific principles surrounding knowledge and instruction. The following statements contradict some of these common methods, but are aligned with what the evidence suggests, and should be considered when planning learning:

Misconception:	*Truth and underlying evidence:*
Direct instruction is a passive form of learning and does not work	It is common misconception that teacher led instruction does not work and obstructs pupils from independently being able to learn. The myth also states that students will learn with minimum teacher talk, a lot of pupil discussion, and no introduction of new knowledge from a teacher. The myth is rooted in in the "Learning Pyramid" model, that presents a hierarchy of learning strategies, which result in differing rates of knowledge retention. The model is a misrepresentation of Dale's Cone of Experience, is not rooted in evidence, and contradicts evidence informed principles of differentiation and scaffolding to support pupil learning.
All learners think in the same way	Novices and experts cannot think in all the same ways. Experts have more knowledge, which makes them more able to automate basic tasks in order to free up cognitive space to tackle more complex aspects of a problem. They're also able to see patterns, and organise knowledge, differently than novices. For teachers, understanding the difference in how novices and experts think will help them support their students in gaining knowledge. It is not realistic or practical to expect school age children to be an 'expert' at anything; 'experts' in a particular field have studied that subject for many years.
The brain has fixed stages of development	Scientists used to think that brain connections developed at a rapid pace in the first few years of life, until a mental peak in one's early 20s, levelling off around middle age, and then starting to gradually decline. We now know this is not true. Scientists now see the brain as continuously changing and developing across the entire life span. There is no period in life when the brain and its functions just hold steady; some cognitive functions become weaker with age, while others actually improve.
Learning facts is pointless and stops pupils from learning real or complex skills	This myth states that 'fact learning' creates passive learners who are able to retain information but are unable to retain reasoning. The idea that knowledge is less preferable, and 'evaluation' and 'analysis' are more preferable– is wrong. In fact, we now know that knowledge is a highly valuable, necessary precondition for putting these skills and abilities into practice.
Knowledge and skills are separate things and learning skills is more important	We cannot teach transferrable skills without a focus on knowledge. They cannot be separated; by learning knowledge securely, more complex responses become possible. If teachers want pupils to learn how to think critically, they must have something to think about. For example, the best readers are not necessarily the ones that practise the skill of reading the most; they are those that can immediately understand the text, and it's content, a lot quicker and easier.

Continues overleaf

THERE ARE ALSO SEVERAL MYTHS SURROUNDING THE PURPOSE OF KNOWLEDGE IN SCHOOLS AND THE ROLE OF THE TEACHER (2 OF 2)

Misconception:	*Truth and underlying evidence:*
'Enquiry based learning' is the best way to learn	The idea behind this is that in the 'real world', pupils will be faced with challenges that will require them to pull together knowledge and skills from different domains, rather than a school subject, and that project based learning will lead to 'independent learners'. However, enquiry based learning in isolation usually doesn't guide pupils to think about the right things, as it does not guarantee that their activities link to the topic of learning, or that they are developing new knowledge and changing any embedded misconceptions. Project based activities can therefore be successful once pupils are taught the knowledge that is required to guide their thinking and processes, and could therefore occur at the end of a unit of work, once pupils have been taught how to find missing knowledge and structure their investigations.
The existence of the internet makes learning knowledge unnecessary	This misconception states it is more important to have good knowledge of strategies for finding information than knowing the information itself. However, domain specific knowledge is still essential in good research skills, and requires knowledge of complex vocabulary, and other complex concepts. Secure knowledge helps learners to discern the credibility of information on the internet, and can help to make more reliable inferences that are used to continue to build their knowledge base. The ability to analyse and solve problems, and new information, also uses most of our working memories, so we need to be able to recall basic facts easily without continually needing to "look-up" information.

References: Deans for Impact (2015); Christodolou (2014); Tricot & Sweller (2014); Letrud & Hernes (2018).

KEY ORGANISATIONS IN THE SCIENCE OF LEARNING

Deans for Impact

A US-based organisation committed to transforming teacher education so it's grounded in the latest research about how children learn. Deans for Impact believe that all teachers' practice should be informed by the existing scientific consensus around basic cognitive principles and being able to connect these to their practice.

Key publications:

The Science of Learning
(see summary on Slide 21)

Website: Deansforimpact.org

SGSE

A university leading in research exploring how people learn at the most fundamental levels; how learning differs across individuals, cultures and content; and the conditions that best foster educational success. The institution prioritises the science of learning as one of key challenges, and promising opportunities, facing education.

Key publications:

The ABCs of How We Learn

Website: ed.stanford.edu

CTTL

An incubator that supports publications, programmes, networking and research in the field of mind, brain, and education science. The organisation aims to ensure teachers understand how every student's brain learns, in order to maximise teacher effectiveness and guide students toward their greatest potential.

Key publications:

Think differently and deeply
Neuroteach

Website: thecttl.org

ResearchEd

A grass-roots, teacher-led project that aims to make teachers research-literate and "pseudo-science proof", by convening researchers, teachers, and policy makers at weekend conferences. The project has sparked an international movement that has spanned three continents and six countries.

Key publications:

Think differently and deeply
Neuroteach

Website: thecttl.org

KEY ORGANISATIONS IN THE SCIENCE OF LEARNING

Ambition Institute

A graduate school for educators serving children from disadvantaged backgrounds. The Institute identified a lack of guidance for how to teach teachers principles of the science of learning. They have coded their experiences and ideas into a handbook, and the document is periodically revised in response to new evidence.

Key publications:
The Learning Curriculum
The Learning Curriculum 2.0

Website: ambition.org.uk

Chartered College of Teaching

Impact, the College's peer-reviewed, termly journal, connects the latest research findings to classroom practice. It features articles centred around four themes: memory and cognition, cognitive research and teacher development, metacognition and self development, and strategies to support learning.

Key publications:
Impact

Website: impact.chartered.college

Learning Scientists

A platform run by cognitive psycho-logical scientists who research the science of learning: Megan Sumeracki, Cindy Nebel, Carolina Kuepper-Tetzel, andAlthea Need Kaminske. They aim to increase the use of effective learning strategies by making free downloadable resources, podcasts, and workshops for students and educators.

Key publications:
Understanding How We Learn

Website: learningscientists.org

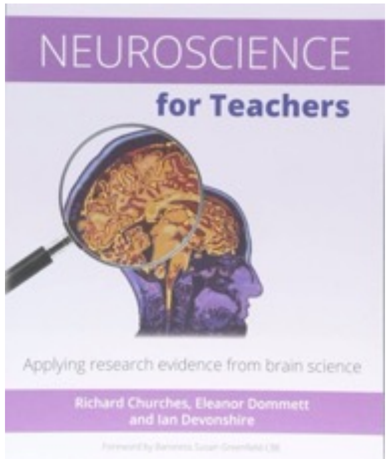
Society for Neuroscience

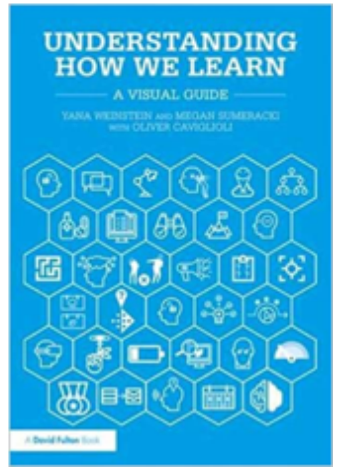
The world's largest organisation of scientists and physicians devoted to understanding the brain. One of their four public engagement initiatives focuses on public education programmes. The society runs a website where educators can access a wide-range of free resources, activities, and teaching materials.

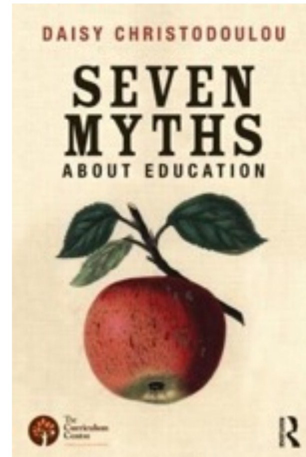
Key publications:
Brain Facts: A Primer on the Brain and Nervous System

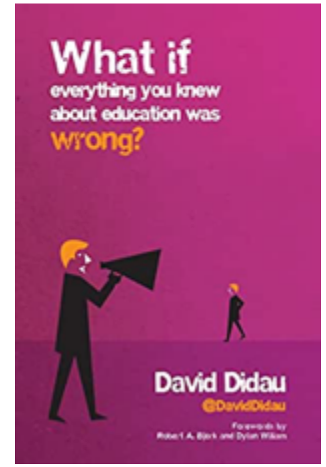
Website: sfn.org

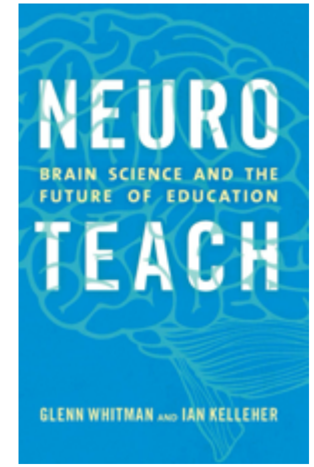
FURTHER READING

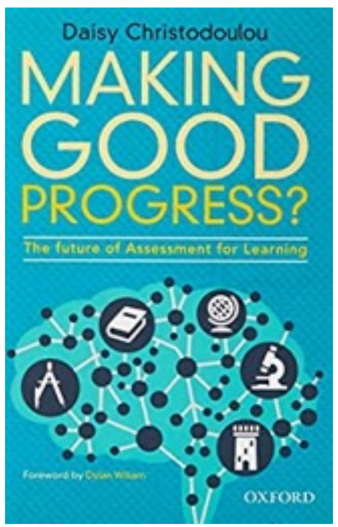


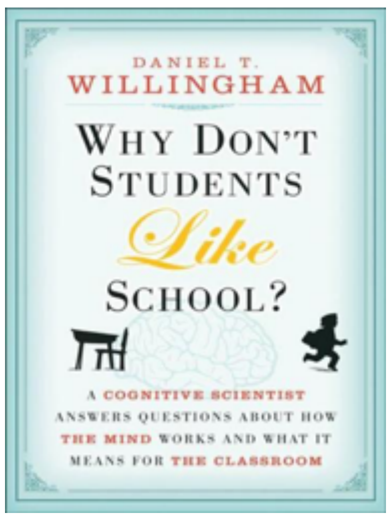


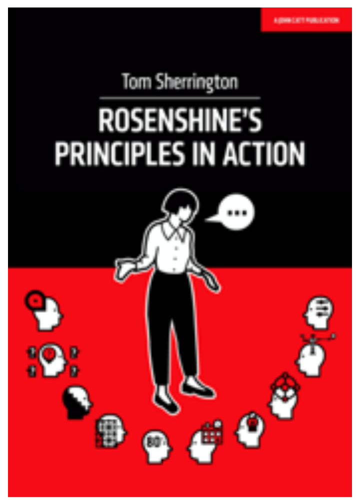


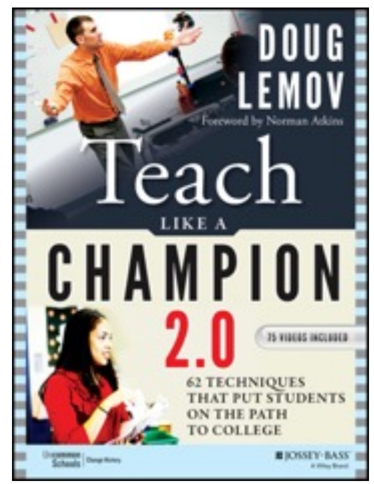


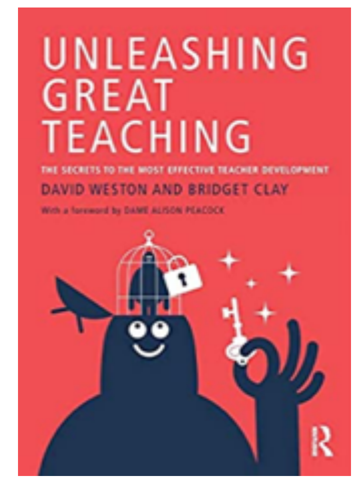












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LEARNING HOW TO READ IN THE EARLY YEARS

THIS SECTION EXPLORES GENERAL PRINCIPLES FOR HOW CHILDREN LEARN TO READ IN THE EARLY YEARS

WHAT DOES THIS SECTION COVER?

A What do we know **about how children learn to read** in the early years and what this means for **classroom practice**?

B Which **organisations** are doing interesting work in early reading?

C What **references** could support further learning in this area?

Key Definitions:

Speaking

- Domain: In reading, the Global Proficiency Framework (2019) highlights these to be: aural language comprehension, decoding and reading comprehension.
- Blending: The ability to build words from individual sounds by blending the sounds together in sequence
- Meta-linguistic Awareness: The ability to reflect upon and manipulate the structural features of spoken language
- Oral Language: Knowledge of spoken words and their meanings
- Phonemes: A letter or a group of letters that represent the smallest units of sounds in our speech (e.g., the word 'hat' has 3 phonemes – 'h' 'a' and 't')
- Phonological Awareness: Enables children to recognise and manipulate the sounds of spoken language

Writing

- Segmentation: The ability to break words down into individual sounds
- Graphemes: Visual symbols involved in writing
- Orthography: The conventional spelling system of a language
- Phonics: Method of initial reading instruction whereby pupils are taught the relationship between spelling and sound explicitly (e.g. S -/s/; SH -/tS/).

Comprehension

- Morphology: The study of how parts of words have meanings (e.g., the meanings of suffixes and prefixes)
- Reading Comprehension: The ability to understand a written text
- Syntax: Arrangement of words and phrases to create well-formed sentences in a language
- Working Memory: Capacity limited memory store

SECTION SUMMARY

This section explores what is known about learning to read with a focus on learning to read in the early years.

- Reading is the basis for the acquisition of knowledge, cultural engagement, democracy, and success in the workplace. Low literacy presents an economic and development challenge around the world.
- Despite how critical reading is to all aspects of modern society, many children still lack the baseline reading skills to participate fully in life.
- The Science of Reading is one of the most researched topics in education and yet there is still a lot about the cognitive processes involved in reading which is not yet clear.
- There is a lot of consensus around what is known; however, this doesn't always transfer to teaching practices in the classroom.

Key take-aways:

Reading is a complex task requiring the acquisition of different skills
Reading involves multiple mental processes and requires explicit instruction and practise
Research points to the effectiveness of systematic phonics in teaching early reading
Learning the spelling-sound relationship is a necessary foundation for learning word meaning
Several factors affect how readers effectively comprehend what they are reading. These include the role of vocabulary, background knowledge, morphology, syntax, accuracy of decoding, and reasoning skills including logic and inference
Teachers can develop reading comprehension by using several strategies that align with core principles of how children learn
The relationship between reading and writing, and how best to integrate them through instruction, is not yet clearly understood
Simple frameworks have been created which attempt to summarise the multi-faceted skills and knowledge needed for reading and writing
Literacy skills can also support learning in other subjects

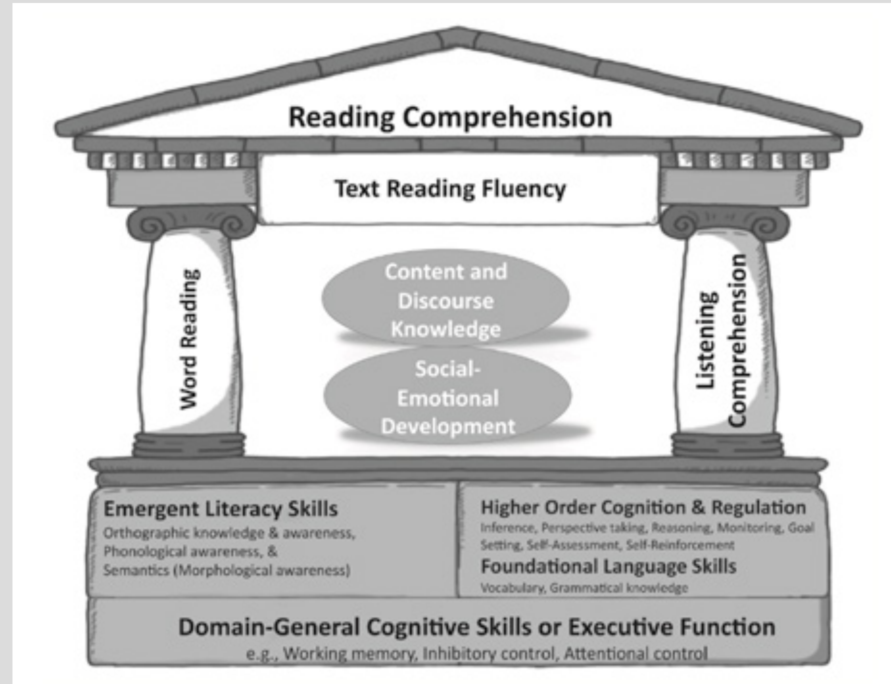
READING IS A COMPLEX TASK REQUIRING THE ACQUISITION OF DIFFERENT SKILLS

- **Reading is a complex task that involves many skills.** The National Reading Panel Report (2000) identified 5 key skills involved in reading: *phonological awareness, phonics, reading fluency, vocabulary, and reading comprehension.*
  - These skills are not sufficient on their own to produce successful reading. They build on one another to reach the ultimate goal of reading: comprehension.

- **These components of reading are widely acknowledged, and align with the Early Grade Reading Assessment (EGRA).** EGRA is used globally as a measurement framework of the most basic foundational skills for literacy acquisition in early grades.

- **The diagram on the right illustrates the necessary areas of skill that are needed to achieve reading comprehension.** It is taken from USAID's review of empirical evidence on early grade literacy acquisition and instruction in developing countries.
  - It depicts that successful reading comprehension requires reading fluency, which is achieved by connecting skills of word reading and listening comprehension.
  - Word reading and listening comprehension are built on a complex set of foundational skills. The key components (outlined in diagram) are:
    - *Emergent Literacy Skills:* knowledge of sound structure, writing systems, and meaning used for word reading.
    - *Language and Cognitive Skills:* knowledge of vocabulary and grammar and drawing conclusions from the text meaning.
    - *Foundational Cognitive Skills:* the ability to hold and manipulation information, suppress and initiate responses, and control attention.

Component skills of reading comprehension and their structural relations:



'Taken, with permission, from 'The simple view of reading unpacked and expanded: The direct and indirect effects model of reading' (Kim, 2020).'

References: National Reading Panel (2000); Castles et al. (2018); Kim et al. (2016); Kim, (2020); Rose (2006); Rastle (2019).

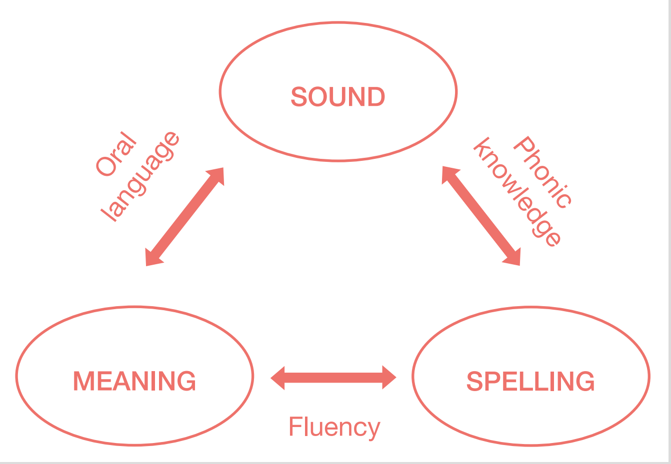
READING INVOLVES MULTIPLE MENTAL PROCESSES AND REQUIRES EXPLICIT INSTRUCTION AND PRACTISE

- **Though many children will learn to speak and understand relatively easily, through experience with spoken language, reading is a more complex skill requiring reconfiguration of neural systems – it requires instruction and practise.**
  - Spoken language is not sufficient alone and children require additional instruction to map the visual symbols that make up printed words onto oral language knowledge (see Figure 1).

- **Reading involves a myriad of mental processes. These include:**
  - Visual processes – analysis of lines, curves, dots that make up letters and words (small visual differences in shape yield large differences in meaning).
  - Use of background knowledge and inference – to determine meaning from the text.
  - Eye-movement system – to facilitate rapid text comprehension.

- **Children must first master basic skills – initial reading instruction should provide the support system for children to build basic word recognition skills that will be necessary for higher-level text comprehension.**
  - Reading begins with oral language – research shows that vocabulary, grammar and narrative ability before reading acquisition predict later reading comprehension ability. As such, oral language interventions impact on later reading comprehension.
  - Narrative skills involve understanding how stories work, and their structure. Being able to describe things and tell events in structured order, as well as being able to re-tell stories, give children a clearer understanding of the meaning of the texts when reading.

Figure 1: Taken from 'The Journey to Skilled Reading' (Rastle, 2019)



Model recreated from 'The Journey to Skilled Reading' (Rastle, 2019).

- *The link between spelling and meaning is arbitrary (e.g. cut, cat, can may look similar but are not similar in meaning)*
- *Learning the link between sound and spelling is more systematic – learning how one-word sounds will help learning another (although alphabetic systems vary in the regularity of the spelling-to-sound relationship)*
- *Systematic learning is easier than arbitrary learning, so researchers recommend focusing early reading instruction on spelling-to-sound relationship as a pathway to meaning*

References: Rastle (2019).

RESEARCH POINTS TO THE EFFECTIVENESS OF SYSTEMATIC PHONICS IN TEACHING EARLY READING

- **There has been much debate around how children learn to read (termed 'the reading wars').**
  - Some argue for a phonics approach, where sounds that letters make are taught explicitly
  - Others argue for a whole-language approach, where children discover meaning through experiences in a literacy-rich environment
- **Phonics is a way of teaching children how to read and write.** It helps children hear, identify and use different sounds that distinguish one word from another.
- **Through phonics, children learn the spelling-sound relationships between the sounds of spoken language (phonemes) and the visual symbols (graphemes).**
  - Children are taught to use grapheme-phoneme relationships to read, and blend sounds with other sounds to form words.
  - Research shows that the spelling-sound relationship is a necessary foundation for reading. Despite research pointing to the effectiveness of systematic phonics, high-quality instruction in this area is still lacking.
  - In addition, several comprehensive government reviews of teaching early reading point to the importance of systematic phonics instruction: e.g., The National Reading Panel (2000) in the USA, the Rose review (2006) in the UK and the Rowe review (2005) in Australia. Despite this, systematic phonics instruction is still underused and underrepresented in education policy.

Best practice in phonics – The Rose Review, 2006 (Department for Education and Skills, England)

The Rose review highlighted best practices in systematic phonics instruction.

- The report states that phonics should be taught systematically, as the relationships between sound and letters are more complex in English than in other languages. This can make it challenging to learn to read, as children are unlikely to work out the sound-letter relationship themselves.
  - Instruction is systematic when all the grapheme-phoneme relationships are taught and covered in a clearly defined sequence.
  - Pupil knowledge of spelling-sound relationships is essential when they attempt to read unfamiliar words. On its own, it is insufficient to develop skilled readers; best practice in phonics instruction involves direct mapping between printed words and their meanings.
- Word meaning can be taught by decoding words in three ways:
  - Visual cues: probing knowledge of word parts (i.e. root words, prefixes and suffixes), letter combinations and associated sounds.
  - Syntactic cues: probing knowledge of sentence structure and word order.
  - Semantic cues: inferring word meaning within the context of a sentence or developing meaning with pictures.
- Phonics instruction should:
  - Include teaching short, discrete daily sessions designed to progress from simple elements to more complex aspects of phonic knowledge, skills and understanding.
  - Include brisk, involved multi-sensory activities, drawing on a range of stimulating resources and lots of praise for effort and achievement.
  - Teach:
    - Grapheme/phoneme (letter/sound) correspondences (the alphabetic principle) in a clearly defined, incremental sequence
    - The highly important skill of blending (synthesising) phonemes in order, all through a word to read it
    - The skills of segmenting words into their constituent phonemes to spell
    - That blending and segmenting are reversible processes.

References: National Reading Panel (2000); Castles et al. (2018); Kim et al. (2016); Rose (2006); Rastle (2019).

LEARNING THE SPELLING-SOUND RELATIONSHIP IS A NECESSARY FOUNDATION FOR LEARNING WORD MEANING

- **Teaching children the rules of the alphabetic code, and the spelling-sound relationships of printed words, is essential for the acquisition of reading skills. Once children are clear on how words are read, they can then start to develop knowledge of their meaning.**
  - Evidence from neuroscience indicates that mapping between printed words and their meaning involves a repurposing of the brain regions built for object and face recognition, so that neurons in those regions become tuned to orthographic stimuli. Research suggests that the intensity of the response of these regions to printed words continues to change at least into adolescence.
  - Stored knowledge about the meanings of printed words arises gradually as a result of text experience over many years - this process is sometimes referred to as 'orthographic learning'.
  - Reading increasingly relies on direct mapping between spelling and meaning; phonic knowledge acts as the foundations to get to that point.
- **Beyond oral language and systematic phonics instruction – the most important ingredient of skilled reading is text experience.** This varies widely, with significant variation between the number of printed words adult readers have encountered.
  - Behaviour-genetic modelling has found a causal relationship between reading well and reading often – phonics knowledge enables reading for pleasure which is vitally important to become a skilled reader.
- **Understanding morphological structure is important for learning direct spelling-meaning because it makes the link less arbitrary – therefore knowledge reduces orthographic learning challenge.** Morphology provides information about the likely meaning of words. Evidence suggests that some morphological instruction could be beneficial to children but there is insufficient evidence to say when this should take place and what form it should take.

References: Rastle (2019).

The Challenge of the Vocabulary Gap

A seminal study by Hart and Risley in America popularised the idea of the 'vocabulary gap'. The study is often described as the 'Early Catastrophe' and describes the differences between language experiences of young children. They estimated that **before children even got to school, there could be a difference of language experience from 'word rich' or 'word poor' families** with children from 'word rich' households potentially hearing 30 million more words than their peers from 'word poor' households.

The research has been the subject of criticism given that it only looked at 42 families and included contested judgements about social class and language experience. Nevertheless, it triggered much research in this area leading to **consensus that a vocabulary gap does exist which teachers need to understand.**

New research shows that a vocabulary gap does exist but may be smaller than Hart and Risley suggested, and that **rich, cumulative experiences with words at an early age matter.** Teachers report that a vocabulary gap can impede on children's learning and ability to access the school curriculum.

References: Quigley (2019).

SEVERAL FACTORS NEED TO BE CONSIDERED FOR READERS TO EFFECTIVELY COMPREHEND WHAT THEY ARE READING

- **Despite the ‘reading wars’, there is consensus that comprehension is the ultimate goal of reading.**
- **Several factors contribute to developing good comprehension, including:**
  - *Background knowledge* – knowledge is essential to draw logical conclusions and pick up inferences in a text
  - *Vocabulary* – greater knowledge of words helps understand the different meanings words may have (reading more, and increasingly more challenging texts is required to encounter and infer the meanings of new words)
  - *Language structure: morphology and etymology* – morphology studies how parts of words have meanings (e.g., suffixes and prefixes), and etymology studies the origin of words. Both help students with likely spelling and to understand meaning.
  - *Main idea* – comprehending a text requires understanding the ‘main idea,’ and which other ideas are less key to understand.
  - *Inference* – three types: logical implications, which must be true (e.g., ‘if I invited 5 people camping and 2 didn’t come’, then logic says that 4 people went camping, including myself); and probable and possible inferences, which require the reader to draw from personal knowledge and experiences (‘the boy ate 4 sandwiches when he got home’ - the probable inference is that he was hungry; the possible inference could be that he had not had lunch or is greedy).
  - *Reasoning, including logic and inference* – reasoning draws on logical patterns; readers draw conclusions that reflect the patterns and sequences of information, narratives or experiences that they have encountered before.
  - *Memory* – comprehension requires knowledge to be stored in long-term memory.
- **A reason for poor reading comprehension is poor reading at the level of single words.**
  - When children recognise words quickly, they can focus limited working memory resources on comprehension.
  - In addition, oral fluency (how easily one communicates through speech) can also impact reading comprehension, as fluent readers are able to focus less on decoding words, and more on understanding the text.
- **Understanding text relies on spoken language ability but text is typically more complex and uses higher-level vocabulary and syntax.**
  - Text, therefore, exposes children to more language knowledge and there may be reciprocal benefits of literacy on spoken language. Spoken language, therefore, helps reading and reading helps spoken language.

References: Rastle (2019); Willingham (2007); Murphy (2016).

TEACHERS CAN DEVELOP READING COMPREHENSION BY USING SEVERAL STRATEGIES THAT ALIGN WITH CORE PRINCIPLES OF HOW CHILDREN LEARN

In The Usefulness of Brief Instruction in Reading Comprehension Strategies (2007), Daniel Willingham points to three things that readers need to be able to do in order to comprehend what they are reading:

- Monitor their own comprehension so they are aware of when they do not understand a text
- Relate sentences to one another
- Relate sentences to things they already know

The paper highlights the findings of a comprehensive review of 481 studies on reading strategies conducted by the National Reading Panel, and identifies the effectiveness of different strategies in helping children to do those three things:

Strategies designed to encourage students to monitor their comprehension

Strategy	No. studies	Evidence of effectiveness	Strategy description
Comprehension monitoring	22	YES	Readers are taught to become aware of when they do not understand, for example by formulating what exactly is causing them difficulty.
Listening actively	4	INCONCLUSIVE	Students learn to think critically as they listen and to appreciate that listening involves understanding a message from the speaker.

Strategy	No. studies	Evidence of effectiveness	Strategy description
Prior knowledge	22	YES	Students are encouraged to apply what they know from their own lives to the text, or to consider the theme of the text before reading it.
Vocabulary-Comprehension relationship	4	INCONCLUSIVE	Students are encouraged to use background knowledge (as well as textual clues) to make educated guesses about the meaning of unfamiliar words.

Continues overleaf

Strategy	No. studies	Evidence of effectiveness	Strategy description
Graphic organiser	11	YES	Students learn how to make graphic representations of texts, for example, story maps.
Question answering	17	YES	After students read a text, the teacher poses questions that emphasise the information students should have obtained from the text.
Question generation	27	YES	Students are taught to generate their own questions, to be posed during reading, that integrate large units of meaning.
Summarisation	18	YES	Students are taught techniques of summarising, e.g., deleting redundant information and choosing a topic sentence for the main idea.
Mental imagery	7	INCONCLUSIVE	Students are instructed to create a mental visual image based on the text.
Cooperative learning	10	YES	Students enact comprehension strategies—for example, prediction and summarisation—in small groups, rather than with the teacher.
Story structure	17	YES	Students are taught the typical structure of a story and learn how to create a story map.
Multiple strategy instruction	38	YES	Multiple strategies are taught, often summarisation, prediction, question generation, and clarification of confusing words or passages.

Strategies designed to encourage students to relate sentences to one another

Strategy	No. studies	Evidence of effectiveness	Strategy description
Curriculum	8	INCONCLUSIVE	Instruction is carried to the curriculum beyond reading. Thus, students might study story structure during reading time, apply the structure themselves during writing time, and look for story structure during social studies.
Mnemonic	2	INCONCLUSIVE	Students are taught to associate a keyword with some aspect of the text to help memory for that aspect; it is designed for use with very unfamiliar texts.
Psycholinguistic	1	INCONCLUSIVE	Students are taught language conventions that will help comprehension; for example, how to find the antecedent of a pronoun like “she.”
Teacher preparation	6	INCONCLUSIVE	Teachers learn techniques by which to teach reading strategies.

Other strategies

THE RELATIONSHIP BETWEEN READING AND WRITING, AND HOW BEST TO INTEGRATE THEM THROUGH INSTRUCTION, IS NOT YET CLEARLY UNDERSTOOD

- **There are similarities in skill and knowledge between reading and writing.**
  - Both involve knowledge of vocabulary (words, their internal morphology, and their meanings in context) and syntax (sentence structure, complex sentences, and how usage can change the intended message).
  - At more advanced levels, these areas require reasoning, critical thinking, and analytic ability, and all draw upon background knowledge.
  - In addition, skilled writing and reading are complex processes, and require extensive self-regulation of flexible, goal-directed, problem-solving activities; genre knowledge; and effective use of strategies
- **Although many agree that a child's literacy development is dependent on an interconnection between reading and writing, little research addresses that relationship, or when and how best to integrate these two critical areas instructionally.**
  - Reading and writing development are related in important ways; without one the other cannot exist. Developing either area can also promote positive outcomes in the other.
  - For example, research has found that children who read extensively are likely to become better writers, as they learn text and language structures, and knowledge of contexts and ideas, they can then transfer to their own writing.
  - Research has also found that practise in writing can also help children to build their reading skills. This is especially true for younger children who develop phonics skills by exploring the links between the spoken and written forms of new words.
  - For older children, quality writing instruction can enable them to apply their knowledge of their own use of language, text structure or content in writing, to better understand a professional author's construction of his or her texts.

Talk for Writing: Teaching Writing

Though there is a substantial body of research on the components of reading, and reading instruction, less research has been conducted on writing and writing instruction.

Talk for Writing is a framework for teaching writing that is rooted in the mechanics of literacy, and aims to promote passion for purpose and integrity in learners' writing.

- It is based on the principles of how people learn, and can be adapted to suit the needs of learners of any stage.
- The method supports children to internalise the language structures needed to write through 'talking the text', based on their independent reading.
- The approach enables children to write for a variety of audiences and purposes, in a variety of genres, and within different subjects.
- The approach guides children from dependence towards independence.
- The teacher uses shared and guided teaching to develop the ability in children to write creatively and powerfully.
- The approach enables children to imitate orally the language they need for a particular topic, before reading and analysing it, and then writing their own version. Where the method has been introduced to schools,leaders have reported children to have initially doubled their rate of progress on average.

References: Miller et al. (2012); NCTE (2016, 2011, 2008).

References: Corbett & Strong (2011, 2016).

SIMPLE FRAMEWORKS HAVE BEEN CREATED TO SUMMARISE THE MULTI-FACETED SKILLS AND KNOWLEDGE NEEDED FOR READING AND WRITING

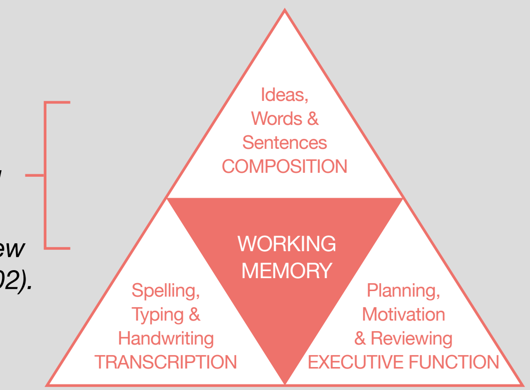
- **The Simple View of Reading is a formula that concisely summarises the widely accepted view that reading has two basic components:** word recognition (decoding) and language comprehension, and the primary aim is comprehension.
  - The formula is defined as: R = D x C
    - Reading comprehension (R) – involves not only producing the words (mentally or aloud), but also understanding the ideas of what have been read.
    - Decoding (D) – matching a sound with a letter, or letter group, in a word and blending sounds together, left to right, to sound out the word.
    - Language comprehension (C) – involves not only hearing words spoken by another, but also understanding what was just spoken.
- **The formula shows that strong reading comprehension cannot occur unless both decoding skills and language comprehension abilities are strong.**
  - Decoding ability varies directly with a reader's knowledge of letter-sound relationships. Skilled readers don't sound out words, and recognise the words immediately on sight.
  - Language comprehension relies on a reader's knowledge of vocabulary, and exposure to vocabulary in multiple contexts.
- **The model is not intended to produce instructional guidance for early reading and aims only to summarise the key components for reading. Although the model is 30+ years old, its principles align with evidence of teaching early reading, and it has informed numerous frameworks for research and programmes for teaching reading.**
  - One way to teach reading that aligns with the Simple View is synthetic phonics.
  - The model has also inspired new thinking in the area of writing, such as The Simple View of Writing (outlined on the right).

The Simple View of Writing

Though writing has attracted far less research attention than reading, it is an important area to consider as it is an essential method for pupils to process and record their learning.

- The *Simple View of Writing* provides a clear, useful framework for understanding how the components of writing are processed in the working memory.
- It is a simplified framework which focuses on identifying the more important domains for functional literacy, and emphasises:
  - *Transcription* – Skills needed for writing ideas, e.g. handwriting, typing and spelling
  - *Text generation* – Skills needed to develop ideas, and convert ideas into appropriate language
  - *Executive functions* – Cognitive processes needed to control behaviour (e.g., planning and working memory - see Appendix 2).
- As with reading, the model highlights the importance of the mechanics of literacy (e.g., word reading or decoding for reading, spelling and handwriting for writing).

The Simple View Of Writing



Recreated from 'The Simple View of Writing' (Berninger et al., 2002).

References: Gough & Turner (1986); Wagner et al. (2015); Corbett & Strong (2011, 2016); Berninger et al. (2002).

LITERACY SKILLS CAN ALSO SUPPORT LEARNING IN OTHER SUBJECTS

There can be a reciprocal relationship between literacy skills and improvement in all subjects. Explicit literacy teaching is essential in all classroom subjects as literacy skills are a strong predictor of outcomes across the curriculum. Literacy can be taught in other subjects through the following ways:

How do students understand new ideas?	• *Literacy skills enable pupils to communicate effectively about their learning.* This, in turn, will improve a learner's conceptual understanding of that subject. No matter their subject specialism, or the levels of literacy demanded within their subject, teachers should teach pupils how to read, write and communicate effectively in their subject.
How do students learn and retain new information?	• *Teachers should teach academic vocabulary that is frequently used across subjects, and subject specific vocabulary.* They can do this by: 1) explaining the definition 2) using examples 3) call and response activities 4) getting pupils to apply words to their own sentences 5) and then interactive activities to encourage pupils to use words in a range of ways.
How do students solve problems?	• *Students need to actively engage with what they are reading to learn in any subject. Reading strategies, such as activating prior knowledge, prediction and questioning, can support pupil comprehension.* They can be introduced through modelling and group work, before support is gradually removed to promote independence.
How does learning transfer to new situa-tions in or outside the classroom?	• *Writing is challenging and students in every subject will benefit from explicit instruction in how to improve; teachers can break writing down into stages of planning and evaluation, and can support students by modelling each step.* Targeted support should be provided to students who struggle to write fluently, as this may affect their writing quality.
What motivates students to learn?	• *Combining reading activities and writing instruction is likely to improve students' skills in both areas.* Reading helps students gain knowledge which leads to better writing, whilst writing can deepen students' understanding of ideas. Students should be taught to recognise features, aims and conventions of good writing within each subject.
Plan structured talk	• *Talk tasks can help students to think about and remember what they have learned, or to process their own thoughts and opinions*. High quality talk is typically well-structured and guided by teachers. Teachers can support students by modelling high quality talk, and provide key vocabulary and metacognitive reflections.

References: Quigley (2019).

KEY ORGANISATIONS IN THE SCIENCE OF LEARNING

Thinking Reading Writings

A blog on adolescent reading and writing, spearheaded by James and Dianne Murphy. Although the blog is specific to secondary school, much of the content can be applied across age groups.

Key publications:
Building on the Evidence
Various blog articles

Website: thinkingreadingwritings.word-press.com

ResearchEd

A grass-roots, teacher-led project that aims to make teachers research-literate and "pseudo-science proof", by convening researchers, teachers, and policy makers at weekend conferences. Has a strong focus on literacy.

Key publications:
The ResearchEd Guide to Literacy: An Evidence Informed Guide for Teachers

Website: researched.org.uk

Read Write Inc.

Read Write Inc. Phonics teaches children to read accurately and fluently with good comprehension. They learn to form each letter, spell correctly, and compose their ideas step-by-step.

Key publications:
Various resources available

Website: rithmiskin.com

USAID Global Reading Network

With support from USAID and other key donor and development partners, the Network collects, develops, and disseminates evidence-based practices to increase the impact, scale, and sustainability of primary grade reading programs.

Key publications:
Ending Learning Poverty: What Will it Take?
Getting Early Grade Reading Right:
A Case for Investing in Quality Early Childhood Education Programs (Sheila Manji, USAID)

Website: globalreadingnetwork.net

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LEARNING MATHEMATICS IN THE EARLY YEARS

THIS SECTION EXPLORES GENERAL PRINCIPLES FOR HOW CHILDREN LEARN MATHEMATICS IN THE EARLY YEARS

WHAT DOES THIS SECTION COVER?

A — What do we know about **how children learn mathematics** in the early years and what this means for **classroom practice?**

B — Which **organisations** are doing interesting work in early mathematics?

C — What **references** could support further learning in this area?

Key Definitions:

- Abstract symbols: Symbols that do not resemble what they represent (e.g., numbers are abstract, tallies are less abstract)
- Base-ten: The most common numbering system used around the world that uses ten numerals, from 0 to 9. In many languages, base-ten is not explicit (e.g., English: eleven, twelve, thirteen; Spanish: once, doce, trece). In some languages, base-ten is explicit (Chinese: ten-one, ten-two, ten-three)
- Cardinal numbers: The number that indicates how many there are in a set, when counting.
- Concrete representations: Manipulatives/objects that students can hold, move, and put together as they reason with early mathematical ideas
- Developmental progressions: Describe how children's learning progresses from simple to more complex understanding within a single domain (e.g., number) or subdomain (e.g., cardinality)
- Domain: An area of learning. In mathematics, the Global Proficiency Framework (2019), highlights these to be: number knowledge, measurement, statistics and probability, geometry, and algebra
- Formal mathematics: Mathematical skills and concepts that are a focus of school instruction.
- Informal mathematics: A wide array of mathematical competences that children acquire outside the context of formal instruction
- Mathematical models: Refers to any picture, drawing, or object that represents targeted mathematical ideas
- Numerosity: The quantity or "how many" of a set/group
- Ordinal numbers: Number to tell us an item's position in a sequence. It is used to order numbers
- Quantity: The "how many" of a set/group
- Spatial relations: The relationships of objects in space. This includes the relationship of these objects to one another and their relationship to ourselves

SECTION SUMMARY

This section explores what is known about learning mathematics with a focus on learning mathematics in the early years.

- The importance of early grade mathematics and systematics mathematics instruction is clear.
- Early mathematics knowledge strongly predicts later mathematics achievement, even after controlling for differences in other academic skills, attention, and personal and family characteristics.
  - Research consistently shows that early mathematical proficiency is associated with later proficiency in mathematics (NAYEC, 2010; Claesens & Engel, 2013).
- Early mathematical proficiency has also been linked to reading fluency, and may even lead to higher graduation rates and progress to higher education.

Key take-aways:

- Mathematics is a tool to comprehensively represent and organise information and it must be systematically taught
- Learning mathematics draws on general cognitive skills, as well as cognitive skills associated specifically with mathematics
- Children bring different experiences and knowledge of mathematics to the classroom when they start formal schooling
- Mathematical anxiety can negatively impact mathematics performance
- Systematic mathematics instruction is required using specific strategies
  - Respecting developmental progressions
  - Using mathematical models to represent abstract notions
  - Encouraging children to explain and justify their thinking
  - Making explicit connections for children between formal and informal mathematics
- Manipulatives are powerful resources that can support young children to understand and engage with key mathematical ideas
- Developing a clear 'Number Sense' will provide pupils with the essential foundation of knowledge needed for future learning
- Seven components characterise a learner's number sense

References: Balhinez & Shaul, 2019; Ercikan et al. 2015; OECD, 2014; Shin et al. 2013

MATHEMATICS IS A TOOL TO COMPREHENSIVELY REPRESENT AND ORGANISE INFORMATION AND IT MUST BE SYSTEMATICALLY TAUGHT

- **Mathematics is a tool to comprehensively represent and organise information.**
  - In early grades, students do this by using number, shape, operating numbers and by measuring space and time. These skills help them solve problems, think abstractly and use numeracy signs and symbols.
- **Instead of learning mathematical procedures by rote, it is important that pupils build a deep conceptual understanding which will enable them to apply their learning in different situations.**
  - Mathematics concepts can be learned through play, and this can expand on what children learn through systematic instruction. However, play in itself does not ensure that learning is taking place.
  - Children should have access to intentional instruction time with clear goals. This doesn't mean that purposeful mathematics instruction can't be 'playful'.
  - Evidence shows that learners are more able to develop mathematical fluency and understanding when new learning builds on accurate prior knowledge in a way that is cumulative, and connected through each school year.
- **Pupils need to gain the reasoning skills they need to solve new problems in unfamiliar contexts in each area of mathematics learning.** Therefore pupil knowledge in the following areas should be developed and scaffolded:
  1. Conceptual understanding
  2. Language and communication
  3. Mathematical thinking
  4. Problem solving

In **'Improving Mathematics in the Early Years and Key Stage 1: Guidance Report' (2020),** the Education Endowment Foundation makes five recommendations to improve early years' mathematics:

1. **Develop practitioners' understanding of how children learn mathematics:** Professional development should be used to raise the quality of practitioners' knowledge of mathematics, of children's mathematical development and of effective mathematical pedagogy.
2. **Dedicate time for children to learn mathematics and integrate mathematics throughout the day:** Dedicate time to focus on mathematics each day and explore mathematics through different contexts, including storybooks, puzzles, songs, rhymes, puppet play, and games.
3. **Use manipulatives and representations to deepen understanding:** Manipulatives and representations can be powerful tools for supporting young children to engage with mathematical ideas. Children should understand the links between the manipulatives and the mathematical ideas they represent (see Slide 56 for more details).
4. **Ensure that teaching builds on what children already know:** It is important to assess what children do, and do not, know in order to extend learning for all children.
5. **Use high quality targeted support to help all children learn mathematics:** High quality targeted support can provide effective extra support for children.

References: Blausten et al. (2019); Sarama & Clements (2009); Farran et al. (2011); Clark et al. (2020).

LEARNING MATHEMATICS DRAWS ON GENERAL COGNITIVE SKILLS, AS WELL AS COGNITIVE SKILLS ASSOCIATED SPECIFICALLY WITH MATHEMATICS

- **General cognitive skills associated with learning mathematics include:**
  - Memory – better working memory is linked to better mathematics ability. Students who can store and process more information tend to have higher levels of mathematics performance. There is also some evidence that suggests regular memorisation training may improve pupil performance in calculating problems.
  - Inhibition – the ability to ignore and suppress unwanted distractions. For example, learners sometimes need to ignore distracting information from previous mathematics experience (e.g., to understand that ¼ is smaller than ½, you need to suppress your instinct that, in whole numbers, 4 is larger than 2).
  - Spatial skills – the ability to perceive the location and dimension of objects and their relationship to one another.
- **Specific cognitive skills associated with learning mathematics include:**
  - Number-processing skills – the way that numbers are internally stored and processed and mental representations of numbers.
  - The capacity to select appropriate strategies for solving problems – even simple arithmetic problems can be solved in a variety of ways. Individuals with a higher level of mathematics achievement don't necessarily have a different range of strategies to use, but adapt their choices to maximise accuracy and efficiency.
- **Understanding these cognitive skills involved in mathematics learning helps teachers plan their instruction.**
  - Any learning activity will include demands on pupils' working memory, inhibition, spatial skills.
  - Teachers may wish to reduce the demands on these skills when introducing new material or increase demands on these skills once content is more familiar.

References: Aubrey et al. (2006); Xenidou-Dervou et al. (2018); Lee & Bull (2016); Gilmore, Cragg & Simms (2020).

Cognitive principles

Learning mathematics applies the same basic cognitive principles as other subjects:

Principle	Basic description
Scaffolding	Having instructional support gradually faded enables learners to solve problems fluently
Worked examples	Studying (or explaining) worked out examples plus solving problems is better for refining knowledge than problem solving alone
Distributed practise	Spacing out practise leads to better memorisation than practising all at once
Feedback	Receiving feedback about responses improves achievement
Interleaving	Practising solving different types of problems in a mixed order is better for problem solving than practising the same type of problems in a row
Abstract and concrete representations	Linking between abstract and concrete representations yields increased learning and transfer
Error reflection	Thinking about errors improves problem representation and increases conceptual understanding
Analogical comparison	Comparing and contrasting multiple instances leads to better understanding than studying one instance

CHILDREN BRING DIFFERENT EXPERIENCES AND KNOWLEDGE OF MATHEMATICS TO THE CLASSROOM WHEN THEY START FORMAL SCHOOLING

- **Children are born with an innate sense of quantity that is refined and developed as they interact with the world.**
  - Informal mathematics develops when children encounter problems to be solved, for example sharing toys or getting change for something bought in the marketplace. That experience builds on this innate sense of quantity.
  - In low-resource contexts, some children continue to develop monetary skills through commerce, for instance through street selling
- **Across different cultures and contexts, children bring mathematical skills to school based on prior experiences, including:**
  - Counting skills
  - Using and understanding number words as numerical signifiers of objects
  - The ability to compare small sets of objects
  - Some understanding of addition and subtraction
- **Nevertheless, the level of skill that different children bring when they start formal schooling varies significantly.**
  - It is important for teachers to recognise a child's level of knowledge so they can present learning opportunities within a child's 'zone of proximal development (ZPD)', towards the construction of new knowledge.
- **A key instructional strategy in early mathematics classrooms is creating connections between children's formal and informal mathematics:** e.g., teaching children the name and properties of shapes using examples they have interacted with outside of school.
- **Formal mathematics learned in school through formal instruction is symbolic, using written numerals, symbols and other mathematical models.** Because it uses symbols and models, it can be generalised to solve new problems.

Formal and Informal Mathematics

- **Formal mathematics –** covers mathematical skills and concepts that are a focus of school instruction
- **Informal mathematics –** covers a wide array of mathematical competences that children acquire outside the context of formal instruction.

There are several key differences between formal and informal mathematics:

Formal mathematics	Informal mathematics
Learned in school through instruction	Learned through everyday experiences
Symbolic	Often non-symbolic
Often written	Often oral
Can be generalised	Not easily generalised
E.g., An algorithm to solve the problem 500 – 130, which in this case, involves borrowing	E.g., A strategy used to figure out how much change you will receive from a 500-shilling note for a purchase of 130 shillings.

Recreated from 'Instructional Strategies for Mathematics in the Early Grades' p.12 (Sitabkhan et al., 2019)

References: Sarama & Clements (2009); Mathematics Working Group (2019).

MATHEMATICAL ANXIETY CAN NEGATIVELY IMPACT MATHEMATICS PERFORMANCE

- **Mathematical anxiety and low self-confidence can negatively impact mathematics performance.**
  - Low self-confidence and low achievement can also reinforce one another: low self-confidence as a mathematics learner can result from low achievement but equally can result in low achievement.
- **Four potential factors affect self-confidence in mathematics:**
  1. Mathematics competence
  2. Others' perception of their ability
  3. Gender (girls are reported to have less confidence and attribute success more to luck than ability, the reverse is found in boys)
  4. Verbal ability
- **There is a body of research which explores links between mathematics anxiety and performance** (Foley et al. 2017; Ferguson et al. 2015; Gunderson et al. 2013; Ma, 1999).
- **Research by Peters et al. (2019) has found links between numeric confidence and better financial and medical outcomes.**
  - In addition, poor numeric confidence can significantly reduce the advantages of good mathematics skills, and that those who believe themselves to be numerically confident are more likely to enjoy doing number-related tasks, and persist through challenging numerical problems.
- **There are also links between pupil self-belief and metacognition in mathematics.**
  - A study by Stankov et al. (2014) found that pupils' beliefs in their own abilities can influence their maths performance. The study found the first three of the following'self-beliefs' are the best predictors of how well a child does in mathematics:
  - *Self-concept:* a pupil's belief in their overall ability in mathematics.
    - *Anxiety:* the apprehension a pupil experiences when learning mathematics.
    - *Self-efficacy:* the belief that a pupil is capable of producing future outcomes.
    - *Self-confidence:* how sure a pupil is about their abilities in particular tasks.

The myth of innately 'Mathematical People'

Mathematical ability is not innate. Like other subjects, it is developed and mastered through effort and practise.

- Anderson, Boaler & Dieckmann (2018) challenge the myth that 'mathematical people' exist who are pre-disposed to be successful in mathematics.
- Instead, they propose that a 'mathematical mindset approach' should be adopted which develops students as self-regulated learners, who are supported to acquire understanding of their cognition, meta-cognition and motivation.
- Teachers who support students to have a 'growth mindset' (see Appendix 6) and believe that intelligence is not fixed and can grow and change over time, can produce higher student performance and foster greater enjoyment of and engagement in mathematics amongst their students.

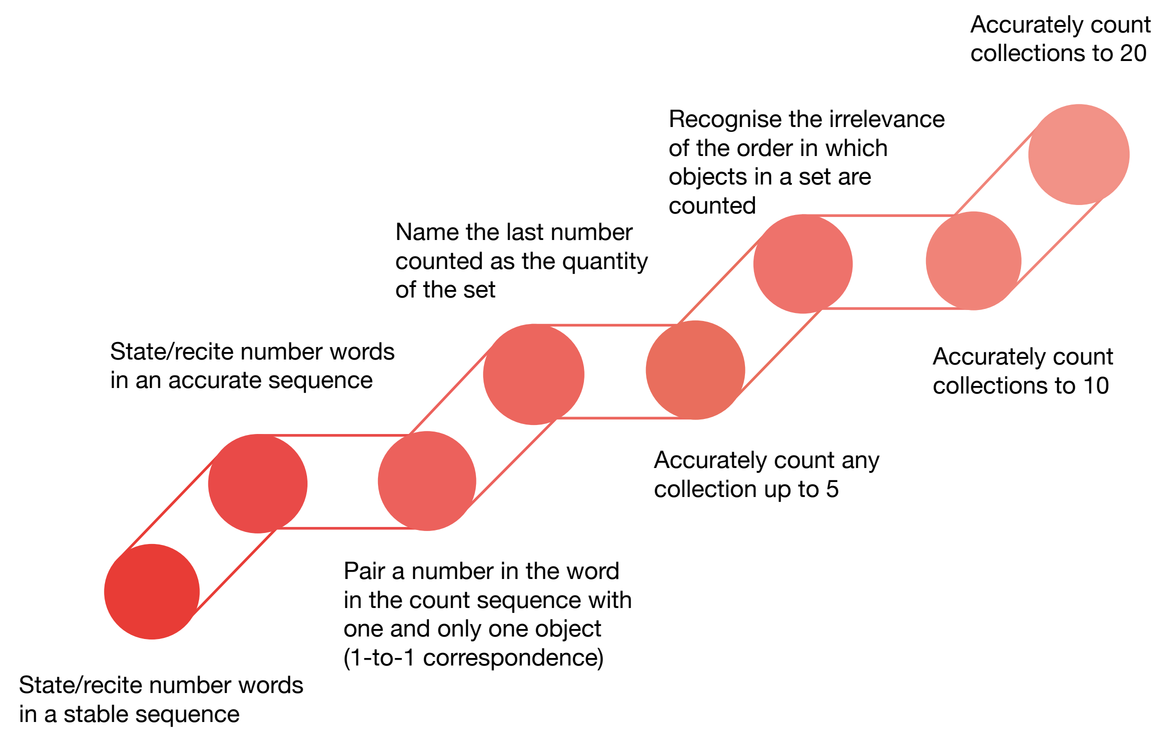
References: Boaler (2016); Foley et al. (2017); Ferguson et al. (2015); Gunderson et al. (2013); Ma (1999); Anderson et al. (2018); Nunes et al. (2009).

SYSTEMATIC MATHEMATICS INSTRUCTION IS REQUIRED USING SPECIFIC STRATEGIES

- **In each new area of learning in maths, pupils need to gain proficiency in four main areas which should be explicitly taught:** conceptual understanding, language and communication, mathematical thinking and problem solving.

- *In 'Instructional Strategies for Mathematics in the Early Grades' (the Mathematics Working Group), four strategies are identified as key to effective mathematics instruction:*

1. Respect developmental progressions	•Children's learning develops from simple to more complex understanding within each construct (e.g., number) or sub-construct (e.g. cardinality – the number of elements in a set) •Development progressions describe the key steps in children's understanding of a concept. The paper provides an example of developmental progressions for enumeration (see right) •Teaching should be sequenced and guided by where children are in their development
2. Use mathematical models to represent abstract notions	•All children benefit from mathematical models (e.g., counters, blocks, dice, number lines) to make meaning of abstract concepts •To learn, children think first in concrete ways before moving to the abstract •Teachers should select relevant models linked to content and plan how these will be used
3. Encourage children to explain and justify thinking	•Having children explain and justify their thinking deepens understanding, increases motivation, and allows teachers to adjust their instruction based on the level of children's understanding •Teachers should model how to explain and justify, and ask questions that encourage this
4. Connecting formal and informal mathematics	•Teachers must make explicit connections between informal and formal mathematics, recognising the knowledge that children bring into the classroom and how to make mathematics relevant



Recreated from 'Instructional Strategies for Mathematics in the Early Grades' (Sitabkhan et al., 2019)

References: Blausten et al. (2020); Sitabkhan et al. (2019).

MANIPULATIVES ARE POWERFUL RESOURCES THAT CAN SUPPORT YOUNG CHILDREN TO UNDERSTAND AND ENGAGE WITH KEY MATHEMATICAL IDEAS

- **Manipulatives are objects that can be handled and moved; teachers can use these to develop children's understanding of a mathematical concept, as well as the procedures needed to complete problems.**
  - They can be powerful resources that support learners to deeply understand mathematical ideas, as they allow the structure of mathematical concepts to be uncovered, named, and manipulated. However, resources are not yet consistently used across schools in a way that positively impacts pupil progress.
  - For manipulatives to be useful components to learning, it is imperative that children understand the links between the manipulatives, the mathematical ideas they represent, and how they can be physically used to solve problems.
  - Manipulatives can be used to support students of all ages, and are best used as a 'scaffold', which is removed once independence is achieved. Decisions to remove a resource should be made in response to pupil understanding rather than age.

- **A literature review by the University of Leicester (Griffiths et al. 2017) revealed the key pedagogic principles for the effective use of manipulatives, including:**
  - Careful matching of both manipulatives and activities to the mathematical focus
  - Identifying and assessing children's prerequisite understanding of concepts
  - Familiarisation of manipulatives through play
  - Teaching of protocols and vocabulary related to the manipulatives
  - Activities involving comparison, equivalence, analysis and generalisation
  - Discussion, requiring children to use manipulatives to justify reasoning
  - Requiring children to visualise using manipulatives to solve problems
  - Linking manipulatives to abstract symbols
  - Encouraging children's own recording of manipulative activity on paper
  - Creating an inclusive mathematics learning community

References: Griffiths et al. (2017); Jones & Tiller (2017); Humphreys & Parker (2015); Hoong et al. (2015).

Continues overleaf

MANIPULATIVES ARE POWERFUL RESOURCES THAT CAN SUPPORT YOUNG CHILDREN TO UNDERSTAND AND ENGAGE WITH KEY MATHEMATICAL IDEAS

No one tool will improve pupil mathematics proficiency in isolation; countless options can be used to educate pupils. A small sample of common examples include:

Dienes: Plastic blocks, in ones, rows of ten and larger arrays of 100 and 1000s – Used to develop an understanding of place value, regrouping in addition and subtraction, and model the process for long division.

Numicon: Different sized, coloured pieces, that represent each number, and can be combined in multiple ways so number relationships can be seen – Used to develop number sense, and understanding of fractions, decimals and percentages.

Place Value Arrows: Cards that can be overlapped to produce multi-digit numbers, and separated to reveal the amount of a number in relation to its place value – Used to reinforce place value and partitioning.

Bead Strings: A short string with beads on, with each alternate group of ten beads coloured differently – Used for counting on and back, exploring number bonds to 10 or 100, demonstrating fractions, decimals, percentages and the four operations (addition, subtraction, multiplication, and division).

Coloured counters and cubes: Colourful plastic discs or interlocking cubes – Used to practise counting; can also be stacked and then used to count on in certain amounts, like 2s or 5s.

Money: Plastic coins and notes that are nearly identical to real currency – Used to teach money concepts and related vocabulary.

Moveable analogue clocks: Moveable clocks that allow pupils to set the time – Used to read an analogue clock, understand the concept of time, and solve time equations.

Fraction walls and cubes: Colourful, proportional fraction blocks that fit together to form a 'whole' – Used to visualise fractions and equivalent fractions and solve fraction problems.

References: Third Space Learning (2018); Furner & Worrell (2017).

DEVELOPING A CLEAR 'NUMBER SENSE' WILL PROVIDE PUPILS WITH THE ESSENTIAL FOUNDATION OF KNOWLEDGE NEEDED FOR FUTURE LEARNING

- **Learning mathematics does not come as naturally as learning to speak, but our brains have the necessary equipment to learn mathematics.**
  - In order for a learner's brain to be able to work mathematically, it needs to first learn the language of number.
  - Conceptual understanding of number is complex, and can be enabled through developing 'number sense'. Number sense is "a well organised conceptual framework of information about numbers, that enables a person to understand numbers, number relationships and to solve mathematical problems".
- **Children who develop number sense have a range of mathematical strategies at their disposal, and know when to use them, and how to adapt them to meet different situations.**
  - It is important that principles of number sense are embedded into the long-term memories of young learners, as they are the essential foundations for all mathematics learning. A concrete sense of number also frees up pupil working memory to solve more complex problems.
- **Andrews et al. (2013) developed seven components that characterise a learner's number sense.**
  - These should be developed together, as they are all interlinked. They are summarised in Figure 1, and expanded on in the following slides.

Figure 1 – Seven components that characterise a learner's number sense (Andrews et al., 2013)

1. **An awareness of the relationship between number and quantity.** Though numbers can be used to show quantity, quantities and numbers are not the same thing.
2. **An understanding of number symbols, vocabulary and meaning.** Children need to be able to express their understanding of numbers.This requires many areas of knowledge and skill, which are sometimes used together.
3. **The ability to engage in systematic counting, including notions of cardinality and ordinality.** Counting is a complex process that has many components.
4. **An awareness of amount and comparisons between different amounts.** Awareness of amounts can be shown through classification and sorting. When learning all the different ways that amounts can be sorted, children can learn to understand the relationships between amounts.
5. **An understanding of different representations of number.** Numbers are an efficient, but abstract, way of recording mathematical understanding.
6. **Competence with simple mathematical operations.** When pupils are sorting, they make judgements about the relationships between sets.
7. **An awareness of number patterns. Children who are pattern aware can spot regularities in features of objects, or numbers.** From this, they can learn to reproduce patterns and predict how they will continue.

References: Kieran et al. (2016); Rittle-Johnson et al. (2016); Gifford (2014); Andrews et al. (2013); Geary (2011); Papic et al. (2011); Nunes & Bryant (2009); Samara & Clements (2009); Gelman & Gallistel (1978).

SEVEN COMPONENTS CHARACTERISE A LEARNER'S NUMBER SENSE

1. An awareness of the relationship between number and quantity	**Though numbers can be used to show quantity, quantities and numbers are not the same thing, as shown in their contrasting definitions below.** • Quantity – The amount you have of something, and is a mental image or idea of 'how much' E.g. 3 hats, half an hour, a cup of flour. In more advanced mathematics, quantity can be used to describe an unknown amount. • Number – This is a actual count of items (3 hats), a measure (e.g. length), or a label (e.g. the number 12 bus). Until children can understand the connections between numbers and quantities, they cannot use their knowledge of one to support the other.
2. An understanding of number symbols, vocabulary and meaning	**Children need to be able to express their understanding of numbers. This requires many areas of knowledge and skill, which are sometimes used together. There are several elements learners should know, and understand how to use, when representing numbers:** • Numeral – A written symbol for a number (e.g., 12) • Digit – A written single symbol used to make a number. There are ten that can be used: 0-9, and each of them represent a different count (e.g., The numeral 12 is made up of 2 digits: 1 and 2) • Place value – An understanding that, in multiple digit numbers, where a digit is placed in the number will affect the value of each digit (e.g., 12 is made up of 10 and 2) • Number words – The spoken or written word version of a numeral, (e.g., "twelve") • One-to-one correspondence – Saying number words out loud in exact correspondence with an object that is being counted.
3. The ability to engage in systematic counting, including notions of cardinality and ordinality	• Cardinal numbers – The number that indicates how many there are in a set, when counting. • Ordinal numbers – A number to tell us an item's position in a sequence, used to order numbers and will be counted once within a sequence (e.g., 1st, 2nd). **Counting is a complex process that has many components. There are five principles that counters must learn do to be proficient:** • Consistently use the number words in the same order. • Count every item in a set only once, using only one number word. • Understand that the last number word said when counting tells pupils how many objects have been counted. • Recognise that any collection of like or unlike items can be counted as a set. • Understand that the result is the same no matter the order in which the objects are counted.

References: Kieran et al. (2016); Rittle-Johnson et al. (2016); Gifford (2014); Andrews et al. (2013); Geary (2011); Papic et al. (2011); Nunes & Bryant (2009); Samara & Clements (2009); Gelman & Gallistel (1978).

SEVEN COMPONENTS CHARACTERISE A LEARNER'S NUMBER SENSE

4. An awareness of amount and comparisons between different amounts	**Awareness of amounts can be shown through classification and sorting. When learning all the different ways that amounts can be sorted, children can learn to understand the relationships between amounts.** Different sorting experiences include: • Developing the notion of 'a set' – classifying objects or groups by specific traits, such as colour, size or shape. • Sorting objects into a set • Partitioning sets into subsets • Comparing unequal sets 'more' and 'fewer' • Comparing both equal sets 'both the same' • Combining sets
5. An understanding of different representations of number	**Numbers are an efficient, but abstract, way of recording mathematical understanding.** When learning to use numbers, it is important that a learner understands conceptually what they mean, as rote repetition of numbers may cause cognitive overload when solving numerical problems. However, jumping from conceptual knowledge of a number to an abstract representation of it also risks cognitively overloading learners. The meaning of numbers, and relationships between them, are best learned when combining the following three representations: • Concrete – Doing: Numbers and counting represented in a 'hands-on' way, with real objects that can be moved – this is key for conceptual understanding. • Pictorial – Seeing: Numbers and counting represented by pictures, such as diagrams, or drawings of physical objects. • Abstract – Symbolic: A pupil learns to represent their understanding of number by using numerals.
6. Competence with simple mathematical operations	**When pupils are sorting, they make judgements about the relationships between sets.** • If they add or remove items from a set they are focusing on addition and subtraction informally. When they count and see that a number made up of the parts of two others, this is the basis of addition and subtraction. Exploring relationships between sets can also begin to explore mathematical language, such as more/fewer (for objects) and greater/less (for continuous numbers). Embedding mathematical language to describe process helps to free up working memory when trying to complete more complex problems.
7. An awareness of number patterns	**Children who are pattern aware can spot regularities in features of objects, or numbers. From this, they can learn to reproduce patterns and predict how they will continue.** There are three main kinds of patterns in early mathematics learning: shapes with regular features, a repeated sequence, and growing patterns. Knowing how to spot patterns is important for many mathematical processes: how to count, use number operations, and the earliest form of algebraic thinking.

References: Kieran et al. (2016); Rittle-Johnson et al. (2016); Gifford (2014); Andrews et al. (2013); Geary (2011); Papic et al. (2011); Nunes & Bryant (2009); Samara & Clements (2009); Gelman & Gallistel (1978).

KEY ORGANISATIONS

EEF

The EEF is an independent charity dedicated to breaking the link between family income and educational achievement. The EEF publish research and guidance to improve classroom practice, including in the area of mathematics.

Key publications:
Improving Mathematics in the Early Years and Key Stage 1
Improving Mathematics Key Stages 2 and 3

Website: educationendowmentfoundation.org.uk

DREME TE

A collection of free, research-based materials for early childhood teacher educators to support prospective and practicing teachers to promote young children's mathematical learning.

Key publications:
Various modules available

Website: prek-math-te.stanford.edu

Numerical Cognition Laboratory

A research laboratory in the Department of Psychology and Brain and Mind, at Western University in Canada. It studies the development of number processing and arithmetic, across the lifespan of learners, using methods of behavioural and neuroimaging research.

Key publications:
Various research publications

Website: numericalcognition.org

Early Math Collaborative

Works to improve mathematics instruction for young children in three ways: professional development, research, dissemination. Part of the Erikson Institute; an early childhood development organisation committed to ensuring that all children have equitable opportunities.

Key publications:
Various professional development modules available

Website: earlymath.erikson.edu

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LEARNING IN ADOLESCENCE

THIS SECTION EXPLORES GENERAL PRINCIPLES FOR HOW CHILDREN LEARN IN ADOLESCENCE

WHAT DOES THIS SECTION COVER?

A What do we know about **how children learn in adolescence** and what this means for **classroom practice?**

B What **references** could support further learning in this area?

Key Definitions:

- Adolescence: Many scientists agree that adolescence begins with puberty and ends when a person develops a 'stable, independent role in society'. The World Health Organisation (WHO) indicates age 10-20. Stanley Hall (the first person to coin term adolescence), says it starts with the start of puberty and ends at 25.
- Dopamine: A type of neurotransmitter made by the body and used by the nervous system to send messages between nerve cells (sometimes called a chemical messenger). It plays a role in how we feel pleasure.
- Limbic system: Part of the brain that is primarily responsible for emotions. It also has a lot to do with the formation of memories.
- Myelination: When the fatty white matter in the brain forms a sheath around neurons and allows signals to be passed faster, leading to more efficient thinking.
- Neurons: Cells within the nervous system that transmit information to other nerve cells, muscle, or gland cells.
- Prefrontal cortex: The part of the brain responsible for planning complex cognitive behaviour, personality expression, decision making, and moderating social behaviour.
- Serotonin: A chemical in the body with a wide variety of functions. One function is that it contributes to wellbeing and happiness.
- Synapses: The communication junctures between neurons.

Brain Functions

SECTION SUMMARY

This section explores what is known about learning in adolescence with a strong focus on changes that take place in the brain and then impact of that on teaching and learning.

The principles of learning can be applied to learners of all ages, but there are factors that can impact learning and completing tasks at certain ages.

Adolescence is a critical time in a child's schooling, as it is often the time when:

- Young people participate in high-stakes testing.
- The brain is undergoing significant development which can impact learning.
- Sexual awareness and gendered expectations are emerging. In low-income countries, gendered expectations can have a pronounced impact on learning – for example, pressures to drop out of school to participate in revenue-generating activities, early marriage, or issues around gender-based violence and discrimination.

Note: Culture plays a central role in adolescent behaviours

- The role that culture plays is often overlooked, but is central to our understanding of adolescent behaviours and to the translation of adolescent brain science to policy and public engagement.
- The social concept of adolescence differs between cultures. For example, in the UK, it is common to live with parents throughout adolescence; in other cultures, young people can be expected to have their own families as soon as they start puberty and are physically able to do so.

Key take-aways:

The brain develops substantially during adolescence
Key changes in the brain have an impact on adolescent behavior in the classroom
Statistically, teenagers are more likely to take risks than other groups
Exact differences between adolescent girls and boys are hard to confirm and linking cognitive processes to gender can be problematic
Teachers can consider specific strategies to support adolescents in the classroom

References: UNICEF (2019).

THE BRAIN DEVELOPS SUBSTANTIALLY DURING ADOLESCENCE

- **Adolescence is a time of great change in the brain.** The only other time of more significant change is from birth to age 5, as rapid growth spurts occur, and the brain quickly develops trillions of connections as a result of the experiences and relationships children are exposed to each day.
- **Changes in the adolescent brain occur in three stages,** with girls typically reaching each stage before boys. The three stages are:

1. *A major and rapid increase in number of connections in the brain around 11 years old, which coincides with rapid physical growth.*
2. *The many connections in the brain are simultaneously edited between the ages 14 and 24, as the brain attempts to become quicker and more efficient by "pruning" unwanted or unused connections between neurons, called synapses. This causes a layer of grey matter in the brain to get thinner.*
3. *At the same time, the strongest synapses in the brain are saved and upgraded, by helping them transmit signals more quickly. This process is called myelination; neural pathways are coated with a fatty substance named myelin, which helps information pass efficiently between synapses.*

- **The strongest synapses represent the knowledge and skills that are most frequently used and developed.** The last part of the brain to be myelinated is the pre-frontal cortex, which is used for rational thinking, decision making, and planning.
- **This means that environment and stimulation is vital during teenage years.** It is important that teachers guide teenagers to practise and develop key skills and knowledge, so that the synapses used to keep them in the brain are prioritised and not 'lost' in the pruning process.

The prefrontal cortex undergoes a protracted, slow and substantial change in adolescence, and doesn't finish developing until the mid-to-late 20s.

- The prefrontal cortex is responsible for activities such as:
  - Managing emotions
  - Controlling focus – e.g. when distracted or preoccupied
  - Making decisions based on predicting consequences
  - Empathy – including ability to read facial expression

As the prefrontal cortex has not yet finished developing, in the classroom, teenagers may:

- *Be less able to control behaviour as emotions take over,* and over-react to situations they deem to be unfair, embarrassing or frustrating. This can result in: aggressive or dramatic sudden behaviour; withdrawal from activities such as answering questions or performing in public; or concentration issues if they think people are looking or laughing at them.
- *Focus on immediate impact, more than long-term consequences,* leading to poor decision-making by relying on impulse rather than reason: e.g. misbehaving to gain group status.
- *Find it harder than adults to concentrate when distracted,* which can make it challenging for them to stay on task.
- *Appear to be disorganised or indecisive* as they find it difficult to do their own planning and make their own decisions.

Though these challenges may vary by context, teachers from all backgrounds can help learners to manage their behaviour by creating supportive and nurturing environments, and setting clear classroom expectations which are ambitious, empathetic and fair.

References: Morgan (2018); Manocha (2017); Altikulac et al. (2018).

KEY CHANGES IN THE BRAIN HAVE AN IMPACT ON ADOLESCENT BEHAVIOR IN THE CLASSROOM

Sleep changes during adolescence	• The release of melatonin can change during adolescence and can put most teens on a later sleep-wake clock. • As a result, there is evidence emerging to support teenagers starting their school day later to ensure they get enough quality sleep. • In the classroom, teenagers with lack of sleep may suffer from increased stress, loss of concentration, mood swings and inability to self-regulate. They may also be poorly nourished, as sleep loss can lead to increased sugar and junk food consumption, and poor immunity or illness. • Note: The EEF tried to do a study into later start times but couldn't get enough schools signed up to complete the study.
Dopamine and serotonin fluctuate	• Dopamine and serotonin – which have a role in emotional well-being – can fluctuate during adolescence. • Adolescents who experience mood swings or bad moods could find this impacts upon their readiness to learn

Social embarrassment is heightened	• Analysis of teenagers' brain activity in embarrassing social situations suggests they feel embarrassment more acutely.
	• As such, in the classroom, they may:
	  • Find it harder to answer questions or perform in public
	  • Find it harder to ignore people laughing at them
	  • Find it harder to concentrate if they think people are looking or laughing at them

Adolescents are more sensitive to reward than children and adults	• Changes in reward-related brain function means that adolescents are more sensitive to reward than children and adults. • Dopamine increases with uncertain reward as an element of chance in the anticipation of a reward can be highly engaging and could improve attention and learning. Rewards are uncertain when their details and value are hidden before being awarded. • The Education Endowment Foundation (EEF) conducted a study to explore how uncertain rewards can enhance learning and pupil outcomes in secondary school. However, the results were not conclusive as only 54% of teachers met the minimum requirements of fulfilling the intervention. Further research is needed in this area.

References: Blakemore (2018); Foulkes & Blakemore (2018); Morgan (2018); Pendey et al. (2018); Heerde & Hemphill (2018); Manocha (2017); Henderson (2019); Knoll et al. (2016); Fuhrmann, Knoll & Blakemore (2015); Crone & Dahl (2012); Howard-Jones & Jay (2016); EEF (2019).

STATISTICALLY, TEENAGERS ARE MORE LIKELY TO TAKE RISKS THAN OTHER GROUPS

- Statistically, teenagers are more likely to take risks than adults and brain imaging shows greater brain activity in teenagers when risks are being contemplated (especially when peer pressure is factored in).
  - In adolescence, the limbic system, which gives the rewarding feeling of taking risks, is structurally more developed than the prefrontal cortex, which reduces the tendency to take risks.
  - Teenagers have less control of their prefrontal cortex and, as a result, often make poor decisions, relying on impulse rather than reason. They engage in more sensation-seeking and impulsive behavior.
- This may have implications on behavior in the classroom and they may be more tempted to misbehave to gain group status.
  - However, because social embarrassment is heightened, they may be inhibited from taking the risks teachers would like, e.g. answering questions, volunteering to present to the class or audition.
- Additionally, studies suggest that risk-taking behaviours may be more common when adolescents are in front of their peers:
  - In a study conducted in 2005, neuroscientist Laurence Steinberg asked teenagers and adults to play a virtual driving game that tested their willingness to take risks as traffic lights turned from green to yellow to red. Participants were penalised when accidents occurred. Adolescents responded to the risks as well as adults did and performed about equally when playing alone.
  - However, in the presence of peers, risk-taking surged among the teenagers and young adults—risky driving increased threefold for 13- to 16-year-olds, and the number of crashes spiked—while remaining flat among adults.
  - Using real crash data from 2007–10, a study published in 2012 found that the risk of death for teenagers driving alone increased by 44 percent per mile when traveling with one peer, and quadrupled with three peers in the car.

References: Davidow et al. (2016); Blakemore (2018); Morgan (2018); Gardener & Steinberg (2005); Tefft et al. (2012).

Note: There is a risk that negative beliefs about adolescent development can create self-fulfilling prophecies

Beliefs about adolescent brain development have the potential to reinforce negative behaviours – such as risk-taking behaviours.

- Research shows that adolescents and adult perspectives of the teenage brain are in line with often unbalanced overviews displayed in the media, and adolescents are more likely to behave in line with their ideas about adolescent neurocognitive development.

To prevent negative perceptions of the teenage brain from becoming self-fulfilling prophecies, it is important that all adult communication about adolescent neurocognitive development is framed in a more balanced way.

- Teachers must therefore ensure that they do not communicate negative, generalised perceptions of the adolescent brain in class.
- In addition, by using metacognitive strategies to guide learning, teachers can support pupils to understand the way they learn in an objective way and reinforce behaviours that have a more positive impact on learning.

References: Altikulac et al. (2018).

EXACT DIFFERENCES BETWEEN ADOLESCENT GIRLS AND BOYS ARE HARD TO CONFIRM AND LINKING COGNITIVE PROCESSES TO GENDER CAN BE PROBLEMATIC

- **Both biology and environment can influence brain development in both males and females. It is not universally understood how, and the extent to which both factors can influence brain development between the sexes.**
  - When evidence is considered as a whole, the features of both sexes' brains are mostly the same. There are, however, some structural and functional differences in brain development (see right).
  - There are also a number of strong societal and environmental factors that can impact girls and boys differently during adolescence (see Appendix 7).
- **Regardless of the cause of observed gender differences in the brain, human brains cannot be categorised into two distinct classes of male or female brain.**
  - In an analysis of over 1,400 MRI scans of human brains, substantial overlaps between the structure and function of female and male brains were found, and features that were consistently in only 'male' or 'female' brains were rare.
  - It was concluded that brains are made up of a "mosaic" of "male" or "female" features. Some features may be more common in females compared with males, vice versa.
  - In addition, the features that are evident in most females, are also the ones evident in most males.
- **Though not all scientists agree that gender diversity between brain processes exists, it is possible that differences could have implications when different genders complete classroom tasks.**

References: Joel et al. (2015); Tomaszek & Muchaka-Cymerman (2019); Global Partnership for Education (2020, 2018); UNESCO (2020, 2015).

Observed differences between genders in four key areas of the brain could impact task completion:

- *Chemistry:* Female and male brains are made of the same chemicals. Both genders have testosterone but males have it in a bigger proportion, which can lead to more physically impulsive or aggressive behaviour. The function of female sex hormones on brain development is not well understood.
- *Processing:* Though female infants can be more advanced in vision, hearing, memory, smell, touch, and responding to human voices or faces, boys eventually catch up in many of these areas in early childhood. Males of all ages can perform better than females on mental rotation tasks (e.g., mentally re-orientating representations of two-dimensional and three-dimensional objects) while females of all ages tend to perform better than males at certain verbal tasks such as word fluency (e.g., naming as many examples as they can of words in a certain category, such as animals, within a given time) and identifying emotional expression in another person's face.
- *Structure:* Males, on average, have a larger total brain volume than women. The female brain reaches its biggest size around 11 years old, and the male brain reaches its biggest size around age 14. Females can have more connections to the hippocampus, responsible for memory, which can enable them to process more sensory and emotional information.
- *Activity:* Some research shows men can have almost 7 times more grey matter, and women can have 10 times more white matter. Grey matter is found in areas of the brain where information and action processing takes place, and can help with focus on tasks. White matter connects all the processing centres to each other, which can help when switching between tasks and multi-tasking.

References: Wierenga et al. (2018)Nasser (2016); Joel et al, (2013); Koolschijn & Crone (2013); Weiss et al. (2006).

TEACHERS CAN CONSIDER SPECIFIC STRATEGIES TO SUPPORT ADOLESCENTS IN THE CLASSROOM

Show the value	• Teachers can show students, or their parents, why what they are learning is of value, and provide time for them to generate their own summaries of these ideas. • This can increase student motivation and achievement.
Take the direct approach	• Teachers can talk to teenagers frankly about their brain development to provide useful context for their emotional changes and reset their expectations about their potential for continued intellectual growth. • Explaining the role of the limbic system, the influence of peers, and the malleability of the teenage brain establishes a basis for students to better understand themselves and exert control over their emotional and academic lives.
Make good use of peer pressure	• Peer pressure and social influence can be used for good. • For example, research shows that teenagers are more likely to ignore warnings about the long-term health consequences of cigarettes but respond to the social effects. It can be effective to remind teenagers that smoking "gives you bad breath or puts younger children in danger". • Schools are aware of many of these social dynamics, and have successfully used teenage leaders, social influencers, and appeals to fairness and justice to change behaviours around vaping, bullying, and academic cheating.
Teach self-regulation	• Explicitly teaching self-regulation, long-term planning, and empathy might have particular benefits for teenagers. • Though the principles of the science of learning are mostly the same for learners of all ages, the prefrontal cortex, which governs executive functions (see Appendix 2), is still developing in adolescence and remains highly responsive to the environment and to training. • According to Steinberg, efforts to improve the self-regulation of teenagers "are far more likely to be effective in reducing risky behavior than are those that are limited to providing them with information about risky activities." • Social and emotional learning programs that show adolescents "how to regulate their emotions, manage stress, and consider other people's feelings" can have positive effects on executive functions more generally, improving focus and self-discipline, and setting teenagers up for academic and professional success well beyond high school.

References: Blakemore (2018); Fletcher-Wood (2019); Steinberg (2014).

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LEARNING REMOTELY USING TECHNOLOGY

THIS SECTION EXPLORES GENERAL PRINCIPLES FOR HOW CHILDREN LEARN REMOTELY USING TECHNOLOGY

WHAT DOES THIS SECTION COVER?

A — What do we know about **how children learn remotely using technology** and what this means for the **design of remote solutions?**

B — Which **organisations** are doing interesting work relating to remote learning using technology?

C — What **references** could support further learning in this area?

Key Definitions:

- Adaptive Learning Platforms / Personalised Learning Platforms: Platforms that tailor learning in line with learners' progress, needs, and attainment.
- Artificial Intelligence: Intelligence demonstrated by machines.
- Bitesize Learning / Chunking: Breakdown of learning concepts into smaller, more manageable learning experiences to support engagement, motivation, attention, memory, and cognitive load.
- Blended Learning: Typically refers to approaches that blend offline learning and online learning in a variety of modes or using a variety of solutions
- Collaborative Learning: Students working together through learning or problem-solving exercises. Can be done in the classroom (online or offline) or in remote settings.
- Ed Tech: Education Technology; technology used for learning
- Flipped Learning: Learning scenarios where learners typically consume a learning resource (e.g,. watching a video) before the lesson, to deepen their understanding during the lesson.
- Gamification: Use of games to promote student engagement and motivation (often includes elements of competition and opportunities to earn 'rewards')
- Learning Management Systems: Systems used by education institutions to deliver teaching and learning, assign resources and tasks, conduct assessment and track student and teacher progress.
- Machine Learning: An application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed
- MOOC: Massive Open Online Course.
- Open Educational Resources (OER): Freely accessible, openly licensed text, media, and other digital assets that are useful for teaching, learning, and assessing as well as for research purposes.
- Synchronous Learning: Online learning where learners engage in 'live' activities
- Asynchronous Learning: Pre-recorded content or asynchronous social learning experiences – e.g., online discussion groups happening over an elapsed time
- Virtual Reality: Simulated experiences outside of the real world
- Augmented Reality: Enhancement of real-world objects by computer-generated perceptual information

SECTION SUMMARY

This section explores what is known about learning remotely using technology.

- Remote learning via technology is common in the higher education sector, where MOOCs (Massive Open Online Courses) are commonly available. Increasingly, virtual learning solutions are also available for K-12, often to complement formal education through out-of-school tuition or clubs.
- Given the COVID-19 crisis which has led to mass school closures across the world, there has been a significant re-focusing on how learning can best happen in a virtual or remote context.
  - Many schools were unprepared for the task of shifting to online delivery and focused on retrofitting existing teaching practices using online communications tools such as Zoom, Teams, Skype and Google G-Suite, with a lesser focus on the pedagogical implications of online delivery.
  - School closures have also exposed massive digital divides between students, with many disadvantaged students not getting access to education at all during school closures.
- Development of new pedagogies and remote or hybrid teaching and learning scenarios offer great opportunities to redefine learning and make learning more accessible, but should take the science of learning into account.

Key take-aways:

- Multiple types of EdTech exist to support remote or blended forms of learning; therefore, trying to define categories is complex
- EdTech is seeing rapid evolution and innovation across many different thematic areas
- Technology can be used to support learning in a changing world but should be rooted in principles from the science of learning
- Machine learning is a growing trend in Ed Tech, although there is more to be done to connect evidence about how children learn
- Research into the effectiveness of remote or online learning is relatively new and largely inconclusive
- Remote learning and EdTech introduce challenges which should be considered when designing and delivering solutions
- General principles of effective pedagogy apply in the context of remote learning, but there are additional challenges facing the remote teacher

MULTIPLE TYPES OF EDTECH EXIST TO SUPPORT REMOTE OR BLENDED FORMS OF LEARNING; THEREFORE, TRYING TO DEFINE CATEGORIES IS COMPLEX

- **Remote learning is often supported by online learning technologies** which could be used alone or in combination with offline learning scenarios (blended learning).
- **'EdTech' is a very broad term, and includes all types of learning technologies.**
  - Developing a comprehensive list of EdTech categories or an EdTech Glossary or Taxonomy is proving highly complex and has not been fully achieved.
  - Navitas have attempted to map the EdTech landscape (see next slide) which reveals the breadth of the EdTech sector.
  - The spectrum of EdTech tools and solutions increases on a continuing basis, with considerable variety in terms of delivery channels, infrastructure, tools and technologies and the contexts that are being served. This makes the development of implementable and impactful frameworks complex and it is difficult to agree a framework which works across all contexts.
- **To design effective online learning solutions, key findings from the learning sciences need to be combined with appropriate digital pedagogies** (still an area that requires considerable development).
- **This then needs to be underpinned by strong digital design and usability principles,** supporting UX (user experience) and UI (user interface design) good practices.

Note: Not all remote learning necessarily happens online

In many resource-poor contexts, other media – including TV and radio – are used for remote and blended learning.

Interactive Radio Instruction (IRI) is used as a tool to improve education quality in parts of Africa, Latin America, Asia and the Caribbean with high radio penetration levels

- Studies of the IRI experience in more than two dozen countries during the past 25 years have shown that the use of IRI has led to significant and consistent improvements in school achievement and has helped overcome equity gaps between urban and rural children and between boys and girls (Anzalone and Bosch, 2006).

Television has long been used to deliver education content to young people.

- Sesame Street (150 countries) and Ubongo (33 African countries) are two notable examples education-focused TV content.
- In the context of COVID-19, many countries have leveraged national television to deliver learning remotely (World Bank, 2020).

References: Holon IQ (2019); Lichtman (2013); Anzalone & Bosch (2006); World Bank (2020).

EDTECH IS SEEING RAPID EVOLUTION AND INNOVATION ACROSS MANY DIFFERENT THEMATIC AREAS

CREATE	MANAGE	DISCOVER	CONNECT	EXPERIENCE	LEARN	CREDENTIAL	ADVANCE
Knowledge	Institutional management	Enrolment and admissions	Learning management	Maths, science and literacy	Open online	Tutoring and test prep	Career planning
Publishing	Online programme management	Study abroad	Social platforms	Classroom tech	Proptrietary	Testing and assessment	Hiring
Courseware	Student management	Student financing		K12 STEM	Bootcamps	Badging and credentialing	
Curriculum	Teacher management			AR/VR	Language		

Reacreated from Navitas' 'Global EdTech Landscape 3.0'

- **Navitas' 'Global EdTech Landscape 3.0' maps 26 clusters of EdTech innovation across 15,000 EdTech companies around the world.**
- The full report is available *here*

TECHNOLOGY CAN BE USED TO SUPPORT LEARNING IN A CHANGING WORLD BUT SHOULD BE ROOTED IN PRINCIPLES FROM THE SCIENCE OF LEARNING

Higher numbers of pupils are now engaging with online content, in addition to learning in face-to-face classrooms.

- This is likely to increase further, in the post-COVID world, with growth in blended / hybrid learning approaches, especially in resource-rich contexts. As such approaches become more ubiquitous, it is critical that remote learning solutions take into account the science of learning.

Many of the same cognitive principles that apply in offline learning context also apply in an online learning environment:

- *During remote and digital learning, the role of memory needs to be carefully considered.*
  - Many EdTech solutions are focused on practise and recall, relying heavily on quizzes. These have some value but methods that support long-term memory retention, such as spaced learning and active retrieval, should be prioritised and must be adapted to suit the functions of online platforms.
  - Meaningful knowledge acquisition cannot be substituted by online search functions.
- *Remote learning design must take into account principles relating to attention and cognitive load.*
  - Keeping learners engaged in non-interactive activities (e.g. videos longer than 8 minutes) can be difficult. Remote learning should prioritise 'bitesize' learning, where content and concepts are broken down into smaller, more digestible learning experiences. Avoiding switching between tasks is also advised to retain learner attention.
- *Online learning should consider, address and recognise the importance of learners' emotions.*
  - This is hard to achieve in a remote context, where it is more difficult for teachers teaching remotely (or machines) to detect a learner's emotional state. Many new EdTech and Machine Learning solutions make claims about supporting emotional development but these are rarely backed up by research into their efficacy.
  - Teachers need to understand the emotional needs and state of their learners, as it can impact their wellbeing, ability to focus their attention and learn new information. In addition, though online peer interactions can provide motivation and improve learning outcomes, social interaction is likely to be limited in remote learning solutions.
- *Consideration should also be given to the role of metacognition in learning.*
  - Metacognitive function is the orchestrator of learning and is often ignored in online learning solutions.
  - Metacognitive skills are often 'assumed' rather than explicitly taught. Metacognitive processes, including self-reflection are highly complex and are therefore not easily supported in digital and Machine Learning technologies (yet!).

References: Education Endowment Fund (2020); Clinton (2019); Foulkes & Blakemore (2018); Pane et al. (2017); Palmer (2012); McPhee & Söderström (2012); Clark & Mayer (2008); Lodge, Kennedy & Lockyer (2016); Jack & Higgins (2019); Vaughan & Beers (2017); Higgins, Xiao & Katsipataki (2012).

MACHINE LEARNING IS A GROWING TREND IN ED TECH, ALTHOUGH THERE IS MORE TO BE DONE TO CONNECT EVIDENCE ABOUT HOW CHILDREN LEARN

- **Machine Learning (ML) applies artificial intelligence to enable systems to automatically learn and improve from experience without being explicitly programmed.**
- **In education, this presents an opportunity for adaptive, personalised learning experiences.**
  - The onset of ML technologies in the learning landscape is gaining significant momentum but ML algorithms still lack the sophistication to recognise the complexities of the cognitive, neurocognitive and developmental processes involved in learning.
- **ML enabled learning platforms are starting to gain more traction.**
  - In particular, platforms that support remedial learning for test preparation in the tutoring and post-school private tuition markets are gaining traction in China and India. Such platforms have enjoyed considerable investment and are becoming more mainstream (particularly in the context of COVID-19 and the need for remote learning solutions).
  - Leading ML tutoring and learning platforms globally: 17zuoye (China) – provides intelligent education resources to students, parents, teachers; VIPKid (China) – teaches English to Chinese children; Byju's (India) – offers offline extra-curricular maths tutoring; Embibe (India) – provides tutoring and assessment services; Century (UK) – supports home learning; Seneca Learning (UK) – a homework and revision programme; Khan Academy (US) – a major player in scaled adaptive learning.
- **There is a growing number of ML start-ups providing support to EdTech providers to incorporate ML more broadly (Cerego, SANALabs, Bibbio). Other applications of ML in EdTech include:**
  - Speech-to-text, text-to-speech technologies to support students with specific learning difficulties and in language learning (e.g., Babbel, Gweek, VoiceRecognition).
  - EdTech markets in low and middle-income countries, where mobile technologies provide the main means to access, increasingly rely on machine learning to support mobile adaptive learning (e.g., M-Schule, Mtabe).
  - Chatbots are increasingly being used in education settings, particularly by African EdTech start-ups as they are well suited to mobile-device use. (e.g., Fineazy for finance awareness, LangBot for language learning).
  - VR and AR platforms use ML to recognise movement, integrate speech recognition, etc.

Benefits of integrating ML in education:

- Ability to provide adaptive, personalised learning experiences.
- Educators have access to formative student assessment data immediately, which can be used to support learning.
- It can help learning to be more relevant and engaging.

Challenges with integrating ML in education:

- As yet, ML isn't deeply grounded in the complexities of learning and tend to be based on algorithmic approaches that address knowledge acquisition shortcomings (through memorisation and recall), rather than the complexities of cognitive and learning processes.
- ML algorithms can also reinforce human biases.

Reference: Aerts (interview)

RESEARCH INTO THE EFFECTIVENESS OF REMOTE OR ONLINE LEARNING IS RELATIVELY NEW AND LARGELY INCONCLUSIVE

Research looking at whether online learning could generate equivalent outcomes to in-person learning is relatively new and so far inconclusive, necessitating more collaboration between EdTech providers and researchers.

- Some research shows learners are less likely to retain knowledge accessed through a screen; other evidence suggests it is possible to maintain similar levels of student academic outcomes and satisfaction through online and offline teaching.

Multiple challenges exist relating to the effectiveness of remote learning:

- Research often relies on self-reported impact data, through questionnaires and surveys.
  - These methods are often the only means that researchers have available to them (due to cost, time, access constraints) but are limited and not always robust.
- There is a disconnect between technology designers/developers, researchers and educators.
  - This means that EdTech solutions are not always grounded in the reality of educational delivery or underpinned by evidence of what works. As a result, much work in this space happens in silos and there is a lack of a holistic view of effectiveness.
- The rapid response to COVID-19 school closures has resulted in a significant scale-up or remote learning but the impact of this is not yet seen.
  - The COVID-19 context was unprecedented and has forced institutions, teachers, parents and learners into new learning scenarios that have been deployed without adequate consideration of the science of learning or teacher development needs.
- Governments are largely absent from debates about remote learning, yet are responsible for setting education policy.
  - Due to the absence of research in this area, policy is often ill-informed.
- A lot of research (market and academic) stems from the US and US-centric products, which may not be applicable to different contexts
- There is a lack of qualitative studies on the efficacy of remote learning solutions.

Reference: Aerts (interview)

Remote Learning in the Australian Outback

Remote learning has been a mode of learning for many children in the Australian outback and has yielded considerable success.

- A number of different programmes offer remote learning across Australia and combine different synchronous and asynchronous learning experiences.
- For example, in Western Australia, the School of Isolated and Distance Education (SIDE) supports students who are geographically isolated or unable to attend a local school. The approach uses distance technology in the form of:
  - Synchronous, real-time communication via a WebEx web-conferencing platform (‘live’ instruction).
  - Asynchronous, 24/7 access to curricula materials and students and staff collaboration through Moodle.
- In 2014 the Australian Government announced significant funding for the 'Flexible Literacy for Remote Primary Schools Programme' which was designed to improve the literacy outcomes of students in 34 remote schools.
- An evaluation report covering the first two years of the program argued that there is 'little doubt that the program is having an impact on literacy levels’.

Reference: www.education.wa.edu.au; www.education.gov.au

REMOTE LEARNING AND EDTECH INTRODUCE CHALLENGES WHICH SHOULD BE CONSIDERED WHEN DESIGNING AND DELIVERING SOLUTIONS

Increasing use of Ed Tech can add to the digital divide	• Variability in student (and teacher) access to technology and connectivity can exacerbate gaps in achievement between socio-economic groups. The most disadvantaged students often need more support but may not have sufficient access to technology, setting them back in the development and learning attainment. This should be considered when designing remote learning solutions.
Some technological developments have complex ethical implications	• Eye tracking, facial expression and neural electricity monitoring are emerging neurocognitive applications that technology companies are increasingly adopting. For example, several Chinese schools are using headbands that monitor concentration by reading brain signals. • Despite uptake, there are strong concerns from neuroscientists about the devices' effectiveness, as well as concerns about privacy. Machine Learning algorithms can also reinforce biases.
Online learning relies more on pupil interaction	• As online learning is self-accessible by pupils, they will be able to control their interaction with the content, instructor and other learners. • Educators should consider how they can communicate clear task expectations, deadlines and requirements, to maintain pupil engagement and retention and make learning outcomes clear.
Online learning can make it more challenging to support pupil wellbeing	• Pupil wellbeing is vital to academic progress. Educators must be mindful that pupils may be less able to access support for their wellbeing, compared to in face-to-face classrooms. They should consider how to support pupil wellbeing, as well as the other 'four pillars' of online student success: community, academic support, technology support, and health.
Increased screen time may negatively impact young people	• Some evidence suggests that 'screen time' promotes sedentary behaviours among children. This can negatively impact their weight, fitness, quality of life, self esteem, academic achievement and mental health. Though there is need for further research in this area, educators should consider how they might address pupils increased exposure to 'screen time'.
Social learning interactions may be limited	• Collaborative learning tasks, and opportunities for social development, could be challenging to structure and maintain in online learning. Communication, however, does not need to occur at the same time. Online teachers should consider how they can most effectively use their online platform to facilitate meaningful and purposeful interactive opportunities.

References: Christodoulou (2020); Schleicher (2020); Kamenetz (2019); Paulus et al. (2019); Roddy et al. (2017); Thistoll & Yates (2016); Volery & Lord (2016).

GENERAL PRINCIPLES OF EFFECTIVE PEDAGOGY APPLY IN THE CONTEXT OF REMOTE LEARNING, BUT THERE ARE ADDITIONAL CHALLENGES FACING THE REMOTE TEACHER

In a remote learning context, the role of the teacher should be carefully considered, as should the importance of teacher development to fulfil this role:

- Though the online learning environment is different to a traditional classroom, teachers should consider how to use technology in ways that still consider cognitive and other learning processes, such as executive function, metacognition and cognitive load. High-end technical equipment or programming does not guarantee positive learning outcomes without high quality instruction.

The effective remote teacher is a subject matter expert, who is skilled in different aspects of 'direct instruction', including clear explanation and frequent diagnostic feedback (see right).

- Remote learning activities can be designed in ways that maximise cognitive engagement and minimise the risk of passivity on the part of the learner.
- Students should be frequently encouraged to evaluate their own work and to understand 'what good looks like' and how they can take responsibility for improvement.

Findings following the Chinese government approach to pedagogy during school closures has provided some interesting findings.

- When moving to remote pedagogy, teachers can be overwhelmed by the challenge of organising online resources, and may need specific training. In addition, some learners may lack adequate skills in self-regulation and independent study.

Creating entirely new learning resources can take up a disproportionate amount of a remote teacher's time.

- Governments can help by providing centralised guidance on suitable learning resources.
- Open Education Resources (OER) are particularly useful because they allow teachers to modify materials to suit the particular needs of their students.

References: McAleavy et al. (2020); Anderson et al. (2001); Huang et al. (2020).

Supporting students to learn remotely – Education Endowment Foundation

In response to the increase of remote learning solutions during school closures due to COVID-19, the Education Endowment Foundation have produced a rapid evidence assessment examining existing research that focuses on impactful practice in digital learning.

The report is intended to support the development of digital learning solutions that are rooted in principles of the science of learning. It states that when implementing strategies to support pupils' remote learning, or supporting parents to do this, key things to consider include:

- *Teaching quality is more important than how lessons are delivered*
- *Ensuring access to technology is key, especially for disadvantaged pupils*
- *Peer interactions can provide motivation and improve learning outcomes*
- *Supporting pupils to work independently can improve learning outcomes*
- *Different approaches to remote learning suit different types of content and pupils*

The Foundation also released a framework to support the design of remote learning, and ensure it is informed by metacognitive strategies, and principles of the science of learning. See Appendix 8 for more information.

References: Education Endowment Foundation (2020).

KEY ORGANISATIONS

EdTechHub

A consortium of key organisations in education and development, who are committed to ensuring inclusive and equitable quality education for all, by maximising research, innovation, and engagement related to the appropriate and effective use of education technology.

Key publications:

Overview of emerging country level response to providing educational continuity under COVID-19: Best practice in pedagogy for remote teaching.

Continue or reboot? Overarching options for education responses to coronavirus (COVID-19) in low and middle-income countries.

Website: edtechhub.org

Center for Education Innovations

Designed and managed by Results for Development, this is a network of more than 750 engaged education innovators, and the largest of its kind. It serves as a platform to advocate cutting-edge research, practical tools and emerging best practices and programmes, directly to practitioners.

Key publications:

A number of organisations focused. On education technology profiled through the site

Website: education innovations.org

International Society for Technology in Education (ISTE)

A global, online community of educators who believe in the power of technology to transform teaching and learning, accelerate innovation, and solve tough in education. The platform delivers: practical guidance, evidence-based CPD, virtual networks, publications and thought-provoking events.

Key publications:

The Perfect Blend – A Practical Guide to Designing Student-Centered Learning Experiences

Website: iste.org

Res Blog on Learning and Development (BOLD)

An interdisciplinary online blogging platform, contributions from researchers, science journalists, policymakers, and educators. Powered by the Jacobs Foundation. Dedicated to sharing how young people develop and learn, 'Learning Technologies' is one of four key areas of focus.

Key publications:

Blogs:
Teaching hard-to-reach students/
Ready or not, online teaching is here
Teaching from a distance: How teachers can support their students during the COVID-19 outbreak

Website: bold.expert

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Note: This section was developed in consultation with Carla Aerts

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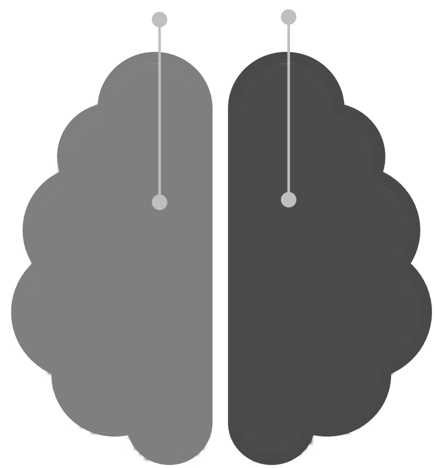
APPENDICES

APPENDIX 1: THE STRUCTURE OF THE BRAIN

- The brain is divided into two cerebral hemispheres (sometimes referred to as the left and right brain). Each hemisphere is then divided into four different lobes.
- A healthy brain uses both hemispheres, and evidence suggests there is not a “dominant” side. Both sides are connected by a great number of nerve fibers, and communicate with one another. However, a person’s brain activity does differ depending on what task they are doing.
- Brain activity is not symmetrical, and it does vary from person to person. However, there are no observable differences between males and females in terms of specialisation of brain activity. The functions of each area of the brain are:

Left Brain
More active in verbal and visual language understanding and production than the right. More involved with attention to factors relative to one’s body, such as thoughts, movement etc. Responsible for the dominant hand and manual tasks in a right-handed person.



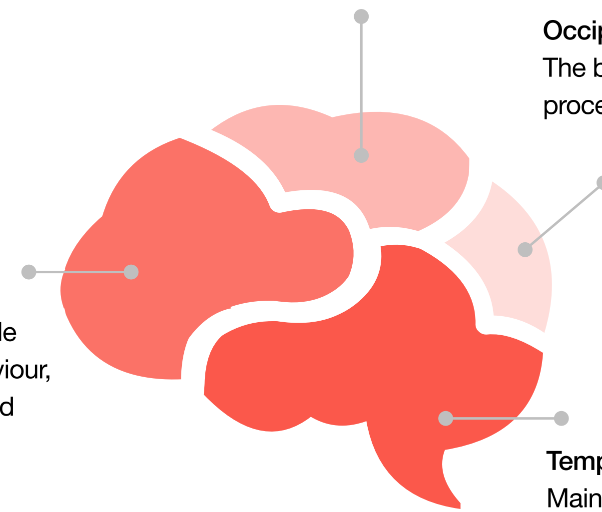
Top view

Right Brain
More specialised for expression of, and perception of, emotion. More involved with attention to factors outside of the body, such as surfaces, objects, directions, speeds etc. Responsible for the dominant hand and manual tasks in a left-handed person.

Parietal Lobe
Involved in the reception and processing of sensory information.

Occipital Lobe
The brain’s visual processing centre.

Frontal Lobe
The frontal lobes include areas involved in behaviour, personality, learning and voluntary movement.



Side view

Temporal Lobe
Mainly involved in hearing and selective listening but also has a role in other functions such as memory

Recreated from 'The developmental relations between spatial cognition and mathematics in primary school children. Developmental science' (Gilligan, 2018)

References: Churches et al. (2017); Corballis (2014).

APPENDIX 2: CHILDREN RELY ON EXECUTIVE FUNCTIONING SKILLS TO FOCUS ON AND PROCESS LEARNING

- **The executive functions allow for purposeful, deliberate, and intentional interactions with the world and concern attention and focus, impulse control, decision making, and working memory.**
  - They enable humans to deliberately self-regulate their behaviour and emotions, understand different points of view, plan and prioritise, focus attention, remember instructions, and handle multiple tasks successfully.
- **Executive function (EF) skills depend on three types of brain function.** These three areas are highly interrelated, and the successful application of executive function skills requires them to operate in coordination with each other:
  - *Working memory:* governs our ability to retain and manipulate distinct pieces of information over short periods of time.
  - *Mental flexibility:* helps us to sustain or shift attention in response to different demands or to apply different rules in different settings.
  - *Self-control:* enables us to set priorities and resist impulsive actions or responses.
- **EF skills are crucial for learning and development. They also enable ongoing, positive behaviour choices, and allow people to make healthy decisions for themselves and others.**
  - They have also been correlated with academic outcomes and quality of life.
  - Children aren't born with EF skills, but are born with the potential to develop them. EF skills are not affected by someone's sex or gender.
  - A number of studies with children and adults have shown that executive function skills, particularly working memory, can be improved. However, more research is needed to show the best methods for strengthening specific executive functioning in schools.

References: Grissom & Reyes (2019); Blair (2017); Centre on the Developing Child (2007).

Executive functioning problems in learners

Some children may need more support than others to develop EF skills.

- Adverse environments resulting from neglect, abuse, and/or violence may expose children to toxic stress, which can disrupt brain architecture and impair the development of EF. Mental health and learning difficulties, such as depression and ADHD, can also affect pupil EF.
- Pupils with EF issues may have the following symptoms: trouble controlling emotions or impulses; problems with starting, organising, planning, or completing tasks; trouble listening or paying attention; short-term memory issues; inability to multitask or balance tasks; socially inappropriate behaviour; inability to learn from past consequences; difficulty solving problems or tasks accurately; difficulty learning or processing new information.
- In addition to poor performance at school, pupils with EF problems are likely to have: problems forming or maintaining relationships; mood issues; low self-esteem; avoidance of difficult tasks; and low motivation or loss of interest in activities.

As EF take time to develop, many of the challenges listed above are normal in young children.

- Persistent behaviours may indicate a child has EF issues. It is important not to penalise pupils who are less able to perform EF skills.
- Children with EF problems may need support from teachers to: sustain attention, initiate tasks, plan their work, organise their work, process information in their working memory, shift attention onto new tasks, and self monitor completing tasks.

References: Cooley (2020); Centre on the Developing Child (2007).

APPENDIX 3: THE MATTHEW EFFECT

- **The Matthew Effect describes a pattern of self-reinforcing inequality related to economic wealth, political power, prestige, and stardom.**
  - The principle suggests that the rich are more likely get richer and the influential even more powerful. In contrast, being born into poverty greatly increases the probability of remaining poor, and each further disadvantage makes it increasingly difficult to escape the economic undertow.
- **The concept of The Matthew Effect is much debated (and can be highly contentious) and is believed to affect many areas of scientific research.**
  - Principles of The Matthew Effect have gained traction in educational dialogue and research, as developments in cognitive science have highlighted the importance of knowledge acquisition, as a form of 'capital', in future pupil success.
  - Principles of the Effect support the scientific theory that those who know more (have more knowledge stored within their long-term memory) can think more effectively (have more processing power/medium term memory capacity). Broadly: the more we know, the better we can 'think', and the better we think, the more we know.
- **Those who believe in the impact of the Effect believe that it is something that educators should attend to in the classroom.**
  - They believe that it is the role of great teachers to manage what learners think and compensate for any discrepancies in learning caused by the Matthew Effect.

References: McCrea (2017); Barabási (2012); Petersen et al. (2011); Morgan (2008).

Evidence base in support of the Matthew Effect

Some research has shown the Matthew Effect to impact overall life outcomes; for example, the more successful an individual, the longer their career is likely to last (Petersen et al.2011).

- Tests by Stanovich (2009) suggest that falling behind in literacy during formative primary school years creates disadvantages that may be difficult to compensate all the way to adulthood .
- Research by Rigney (2010) reveal while good readers gain new skills very rapidly, and quickly move from learning to read to reading to learn, poor readers are likely to become increasingly frustrated with the act of reading, and try to avoid reading where possible. It has been proposed that the Matthew Effect is key to this, as students who begin with high verbal aptitudes are likely to be advantaged by verbally enriched social environments, and the more learners interact with others who are 'word rich', the deeper their own pool of words will be.

The degree to which the Matthew effect holds true in reading development is a topic of much debate.

- Research by Asbury and Plomin (2013) has shown that when environmental factors are broadly similar, genetic make-up accounts for 60-80% of reading ability , and that shared environment (growing up in the same household with the same parental influences) practically vanishes as a source of influence in reading ability. This suggests that as children's environmental influences become more similar, genetic differences become more noticeable.
- However, though the main factor in determining reading ability is genetic inheritance, such genetic differences were only revealed after all children had received similar reading instruction, which suggests the important role of quality instruction in overall reading ability.
- Studies by Raizada and Kishiyama (2010) on the effects of socioeconomic status on brain development also draw on the Matthew Effect, as a potential triggering mechanism for long-term executive function ability in young children. It is proposed that status can impact pupil self-control, which can enable attentiveness and learning.
- Studies by Cohen et al. (2006; 2009) over a two-year period have shown that brief self-affirmation writing assignments aimed at reducing feelings of academic threat in ethnic minority high-school students produced significant improvements in overall academic outcomes.

APPENDIX 4: EVIDENCE INFORMED STRATEGIES TO SUPPORT THE MOST COMMON SPECIFIC LEARNING DIFFICULTIES ARE ROOTED IN THE SAME PRINCIPLES

- **Though learning difficulties are not associated with lower intelligence, they can result in low-confidence, poor self-image, and impact learning outcomes.**
- **Most children with learning difficulties can succeed in school with a specialised education program and emotional support.**
  - When designing learning interventions, teachers should be knowledgeable of any pupil neurological challenges, so that activities meaningfully target pupil needs.
- **A number of empirically-validated teaching practices are available to address numeracy and literacy difficulties. Witzel and Mize (2018) outline four of the key strategies as:**
  - *Task analysis:* Breaking a task down into small steps, and sequentially prompt each step for students to practise each step at a time. For reading, this may include: previewing the text before reading, identifying unknown word meanings during reading, or reviewing reading. For mathematics, this may involve breaking down long division into a series of steps.
  - *Explicit instruction:* Gradual release from teacher knowledge to student knowledge: beginning with an introduction to set the purpose of the lesson, followed by teacher modelling and 'think alouds', high interactivity through guided practice, and an abundance of independent practice.
  - *Multisensory instruction:* Task analysis and explicit instruction will include auditory, visual, and/or tactile sensory input to increase engagement and aid memory. In literacy, this may include sounding from letter identification to phonological memory and processing. In mathematics, this may include using a concrete, pictorial and abstract instruction activities.
  - *Field-dependent scaffolding:* Progressive scaffolding of fully worked examples guide pupils through understanding, and enable incremental learning to support limited working memory capacity. This relies on a teacher's task analysis, and using graphic or visual organisers to show pupils how to incrementally complete a problem.

References: Cooley (2020), Gilligan et al. (2018); Butterworth et al. (2011).

Common learning difficulties:

Dyslexia: A specific reading disorder, and a pattern of reading difficulties affecting phonetic decoding (sounding out words), automatic word recognition and spelling. It is the most common learning difficulty (affects up to 17% of people).

- Pupils may have poor ability to hear sounds that make up words, have difficulty naming letters and numbers quickly, guess the pronunciation of words that look similar to others (such as 'between' or 'because'), have difficulty decoding words accurately and fluently, have poor spelling skills, or read aloud inaccurately or in a disjointed way.
- In later school years, pupils may show additional difficulties such as: reading silently at a very slow pace, weakness in comprehension and written tasks, transposing letters or words (such as b for d, or bog for dog), disliking reading, and struggling with other academic subjects.

Developmental Dyscalculia (DD): A common brain related condition that could impact a child's maths learning (affects around 5-7% of pupils). It is a specific and persistent difficulty understanding numbers, which can lead to a diverse range of difficulties, such as learning number facts or performing calculations.

- It is thought that there is a genetic factor that affects learner's ability to process numbers, known as numerosity; low levels of which may be the root cause of DD.
- Magnetic imaging technology have shown that learners are likely to have underactive activity in their frontal lobes when engaging with arithmetic activities. This area of the brain regulates attention and processes the working memory.
- Although research is inconclusive, it indicates that developing number sense may be the most helpful intervention, instead of a more traditional focus of teaching number facts.

APPENDIX 5: KNOWLEDGE ORGANISERS

Overview:

- **A knowledge organiser is a short document (usually no more than two sides of A4) that contains key facts and information that children need to have a basic knowledge and understanding of a topic.**
  - Knowledge for a unit of learning is made explicit and the expectation for what should be learnt is transparent to pupils, teachers, leaders and parents.
- **The purposes of a knowledge organiser are threefold:**
  - It acts as a planning tool, setting out all of the core, foundational facts that must be learnt to understand and master a particular topic.
  - It is useful as an assessment tool, allowing teachers to quickly check that pupils are learning exactly what they need to, throughout a unit of learning.
  - It functions as a quizzing tool, helping pupils to quickly recall the key information needed to make sense of the topic.
- **Most knowledge organisers will include:**
  - The essential facts about the topic, usually laid out in easily digestible chunks.
  - Key vocabulary or technical terms and their meanings.
  - Images such as maps or diagrams.
  - Famous quotations, if relevant.
- **What a knowledge organiser includes will depend on the subject.**
  - For example, a ‘Second World War’ knowledge organiser and a ‘Rivers’ knowledge organiser would both include maps, but the former would also include a timeline, and the latter could include labelled diagrams.

References: Hutchinson (2019)

APPENDIX 6: GROWTH MINDSET OVERVIEW

Overview:

- **Popularised by Carol Dweck, growth mindset is the belief that intelligence is malleable and can be nurtured through learning and effort.**
- **Individuals with a growth mindset believe that motivation is something that can be cultivated.**
  - This is likely to have a positive impact on their academic performance, and develop a passion for learning.
  - The term is often used in opposition to a 'fixed mindset'; the belief that people are born with innate talents, abilities and intelligence, which can not be changed.
- **Pupils with a growth mindset are likely to learn by a mastery approach and embrace challenge, lifelong learning, and incremental personal growth**
  - Growth minded learners are said to perceive task setbacks as a necessary part of the learning process and are likely to be more resilient learners.
- **The evidence for growth mindset strategies improving attainment is inconclusive and subject to popular debate.**
  - In response to criticism, Dweck posits that teachers should be cautious about using the approach as a sole method of improving pupil attainment, as the theory is a work in progress.
  - Dweck has also expressed that her work has been misunderstood and misapplied in a range of ways, and the theory has been misappropriated by being conflated with the self-esteem movement.
- **Empirical studies reveal that growth mindset has positive effects on student intrinsic motivation.**
  - However, more research must be done to understand the neural mechanisms of mindset-motivation interaction.

References: Dweck (2018, 2015, 2008); Ng (2018); Churches et al. (2017).

APPENDIX 7: STRONG SOCIETAL FACTORS CAN IMPACT ON GIRLS AND BOYS DIFFERENTLY DURING ADOLESCENCE

- Access to education is critical for the development of boys and girls alike, but there are strong societal factors that can impact on girls and boys differently during adolescence.
- For example, girls are more often denied access than their male counterparts. An estimated 130 million girls worldwide remain out of school and face multiple barriers to education.
- The Global Partnership for Educations' 2019 Results Report revealed that while school completion rates are rising for both girls and boys, the gender gap has not changed over the past year.

Risks for boys in adolescence

The role of adolescence of boys' engagement in schooling has been explored less. UNESCO is currently developing the 'Leave No Boy Behind' to explore this further. The Leave No Boy Behind initiative will develop national case studies across four regional contexts (Asia-Pacific, Latin America and the Caribbean, the Arab States, and Sub-Saharan Africa) to explore the nature and root causes of boys' disengagement from education, which groups are particularly at risk, and what policies and programs are effective to ensure that boys thrive in education and are able to achieve their full potential.

- *Boys can be at risk of becoming disengaged with education in adolescence.* This is informed by economic, social, and cultural factors.
- *Push factors include the perceived irrelevancy of education and costs of schooling.* Pull factors include parental pressure, expectation and boys' own desire to work, which all steer them away from school.
- *Gender stereotypes and negative notions of masculinities can further cause boys to disengage and engage in risky behaviour.*

Risks for girls in adolescence

Much has been written around the contextual factors that can affect schooling of girls in adolescence. Teenage girls can face multiple disadvantages which can lead to high levels of absenteeism, poor performance and dropout. These can include:

- *Gender based violence at school or on the way to school.* Up to 10% of adolescent girls in low and middle-income countries, experience forced sexual acts in school (Global Partnership for Education, 2018).
- *The significant opportunity costs of sending girls to school.* The high costs of tuition, uniform, transport etc. balanced with generally poor learning outcomes have caused many families in low and middle income countries, to prioritise girls working in the home, or marriage, over schooling.
- *Social and cultural factors,* including prioritising a girl's role as a wife, not wanting girls to be taught by men, and gendered stereotypes that are encouraged by older generations in communities.
- *Poor sanitation conditions and the lack of appropriate facilities to deal with menstrual hygiene,* which can affect attendance and lower chances of school completion.
- *Gender-insensitive environments, and gender bias in school materials and teacher expectations.* In some contexts, girls may not be represented in textbooks, and teachers may compound this by asking girls to take on gendered roles such as making tea, washing cups and sweeping floors.

References: Global Partnership for Education (2020, 2018); UNESCO (2020, 2015).

APPENDIX 8: FRAMEWORK FOR PLANNING REMOTE LEARNING

- The most effective learners can self-regulate and organise their approach to learning. Metacognitive strategies can be taught, and are particularly powerful when they are subject specific. It is therefore important that they are also included in digital learning experiences. The Education Endowment Foundation (2020) released a framework to inform the design of remote learning sequence which is guided by metacognitive strategies, and principles of the science of learning:

Approach	What is it?	Why include it?
Activate	Promoting pupils to think about what they have learnt previously, that will help them with their next steps.	An important aspect of metacognition is planning how you'll approach a task, using what you already know.
Explain	Explicitly teaching strategies to pupils and helping them decide when to use them.	Metacognitive stategies are most effective when they are context- specific, especially if pupils understand when and why to use them.
Practise	Pupils practicing stategies and skills repeatedly, to develop independence.	Pupils need to practise new strategies, to develop independence. Scaffolds and support are needed at first, but should decrease over time.
Reflect	Pupils reflecting on what they have learnt after they have completed a piece of work.	Self-regulated learners use tasks they have completed to evaluate what went well, and what they will do differently next time.
Review	Revisiting previous learning after a gap.	Retrieving things from memory, particularly after you've started to forget them, aids long-term retention.

- This framework is for a learning sequence, and is unlikely to take place within a single session.
- The framework can be adapted to allow for learning in a variety of contexts, age rages, and asynchronous/synchronous needs.

Recreated from The Education Endowment Foundation website (2020)

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