Ambition Institute

THE LEARNING CURRICULUM

VERSION 3.0

Explaining the science of learning to teachers: A handbook for teacher educators

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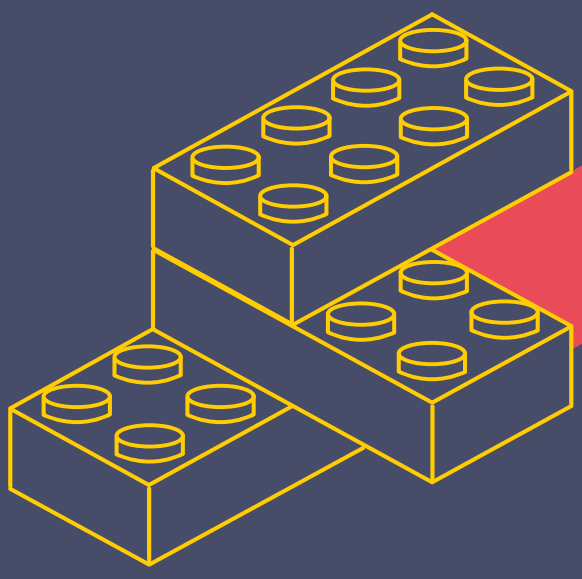

ABOUT US

At Ambition Institute, we run training programmes for teachers, school leaders and system leaders, serving children from disadvantaged backgrounds. Our courses support educators at every stage – from new teachers through to leaders of groups of schools – to keep getting better.

Our programmes are informed by the latest research and the lessons we've learned from great teachers and school leaders.

To learn more about what we do and view our full programme suite click here.

TEACHER EDUCATION FELLOWS

Teacher Education Fellows is a programme for experienced teacher educators wanting to improve their practice.

Participants develop informed and intentional approaches to the most important elements of teacher education.

Fellows also add to some of the best conversations in education, through publications including this handbook, the Deliberate Practice Handbook and the Remote Teacher Development Guide.

LEARN MORE

WELCOME

To help students learn effectively, teachers must understand and apply the science of learning.

This handbook shares guidance for teacher educators and professional development designers who wish to improve teachers' understanding and application of the science of learning in their classrooms.

It is divided into six sections, introducing and applying the evidence around:

1. Helping students attend to learning
2. Finding out what students already know
3. Helping students focus on key ideas
4. Helping students commit information to long-term memory
5. Helping students remember what they learn
6. Helping students use their knowledge flexibly

Each section focuses on one principle, and offers resources to use in training or coaching teachers:

- A visual representation of this aspect of the learning process
- A practical activity illustrating the principle
- Examples and non-examples of the principle being applied in the classroom
- Possible classroom applications for novice and experienced teachers
- A training activity for teachers to apply the principle
- Assessments to check teacher understanding before/during/after training
- Further reading for teacher educators or teachers

We are grateful for contributions from Ambition Institute's Teacher Education Fellows:

Version 1.0: Lucy Blewett.

Version 2.0: Stephen Campbell, Rosie Clark, Sarah Cottingham, Nina Dhillon, Alex Douglas, Gemma Edgcombe, Susie Fraser, Belinda Goodship, John Kirkman, John McIntosh, Lucy Newman, Clare Owen, Gary Pilkington, Rachel Sewell, Venessa Sixbery, Ashley Weatherhogg and Lesley Wright.

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All errors remain our own.

INTRODUCTION

Effective teaching depends on teachers developing and applying an accurate mental model of how students learn. Some principles are unsurprising: students struggle to learn if they are not attending to new information. It is less obvious however, that a quiz supports learning better than rereading. Two leading memory researchers have argued that, "the trials and errors of everyday living and learning do not seem to result in the development of an accurate mental model of the self as learner or an appreciation of the activities that do and do not foster learning:" instead, they suggest, teachers may have to go against their intuitions if they are to teach effectively (Bjork and Bjork, 1992, pp.56-57).

It falls to teacher educators to develop teachers' understanding of how students learn, and to support them to apply their understanding through their teaching.

As teacher educators, we have found recent syntheses of the science of learning to offer invaluable articulations of the principles of learning and their applications (for example, Deans for Impact, 2015; McCrea, 2019; Weinstein et al., 2018). We have found it more difficult to share these articulations with teachers, without a curriculum or explicit guidance. Specifically, we found ourselves asking:

- How should we sequence learning about these principles?
- How can we evidence and illustrate these principles accessibly yet defensibly?
- How can we check teachers' understanding?

We have been refining our approach and sharing our evolving answers to these questions since early 2018. Feedback on the first and second editions of this document have allowed us to make this edition more usable, by:

- Providing more examples of practice in early years and primary settings
- Offering separate guidance on possible applications and training activities for novice and experienced teachers
- Making non-examples less obvious, to help teachers think harder about them
- Providing a technical appendix offering further reading about each principle

We hope you find this third edition more useful than the second; we look forward to making the fourth edition even better, with your help.

Harry Fletcher-Wood, Ben Bignall, Jen Calvert, Josh Goodrich and Emma McCrea.

OVERVIEW

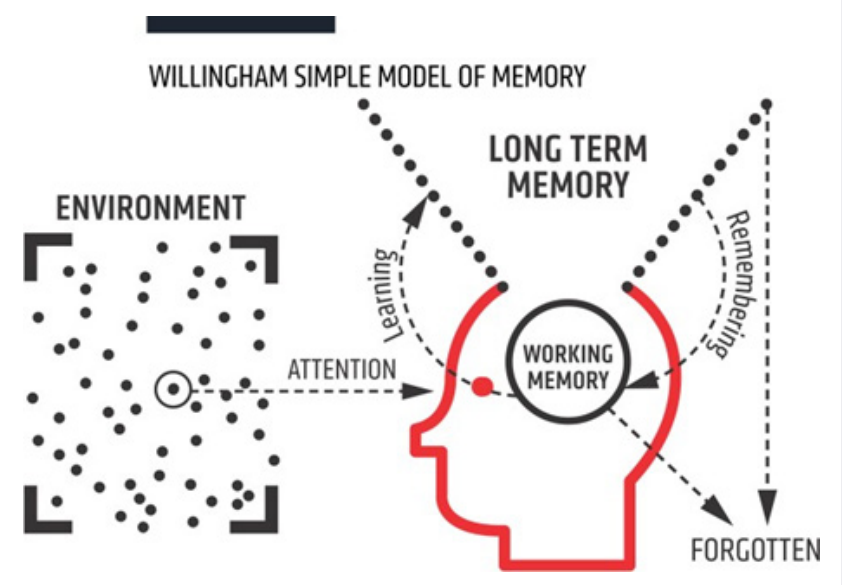
KEY IDEA:
The Working Memory - Long-Term Memory Model is a valuable explanation of the learning process.

Depending on the prior knowledge of the teachers with whom the teacher educator is working, it may be worth introducing the underlying features of the model initially, to make subsequent sections more easily comprehensible. Teacher educators could lead an introductory session, invite teachers to read the text below, or assess their existing knowledge using the questions under each principle.

The model used here is based on the following ideas:

- Our environment – everything around us at any given moment – provides a near-infinite number of stimuli: sounds, sights and feelings people can perceive. A person can attend consciously to only a very limited number of stimuli at any given moment (Principle 1).
- What a person attends to may enter working memory – that is, they may think about it consciously. For example, if they hear a loud noise outside, they may wonder about the cause: in this case a stimulus has gained their attention and has become the focus of their working memory.
- Working memory – the temporary store for information which a person is thinking about in the moment – has a very limited capacity (around four ideas) and duration (usually measured in seconds). This means people struggle to think about multiple stimuli at once: for example, they cannot wonder about the cause of a loud noise and simultaneously read and comprehend a text (Principle 3).
- If people are to learn something, the information or procedure must move from temporary storage in the working memory to more lasting storage in the long-term memory. Long-term memory is – in practical terms – an unlimited store of ideas and procedures which people can access by recalling ideas into working memory. For an idea to move from working memory to long-term memory, it must be processed meaningfully in working memory (Principle 3).
- Items in long-term memory are forgotten quickly unless they are consolidated by being anchored to prior knowledge (Principle 2) and revisited regularly (Principle 5) in increasingly varied ways (Principle 6).

The image below shows these key ideas at work:



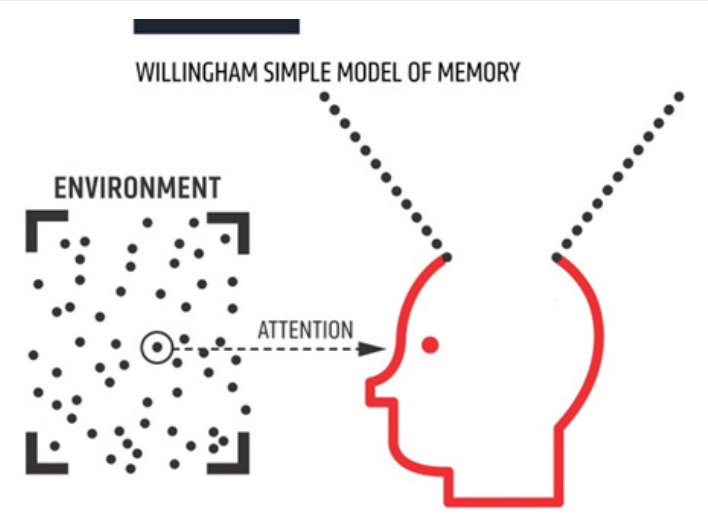
1 - ENVIRONMENT AND ATTENTION: HOW CAN TEACHERS HELP STUDENTS TO ATTEND TO LEARNING?

PRINCIPLE 1: PEOPLE CAN ONLY CONSCIOUSLY ATTEND TO A HANDFUL OF STIMULI AT A TIME.

People experience thousands of potential stimuli each moment, but they can only consciously attend to a handful.

so

Teachers must ensure that students focus on what is to be learned and overcome competing demands on their attention.



PRACTICAL DEMONSTRATION

Show this video: The Monkey Business Illusion

It demonstrates that, when the viewer's attention is drawn to one aspect of the environment (the number of passes), other aspects (such as the colour of the curtains and the departing player) are missed.

KEY LEARNING POINT:
If teachers do not explicitly draw students' attention to what it is to be learned, their attention may be drawn to less important stimuli.

EXAMPLES AND NON-EXAMPLES

Non-example: The teacher uses photos and videos to illustrate key ideas in the curriculum. Additional, non-essential details absorb students' attention, so they struggle to identify the key ideas.

Example: The teacher uses simple images – often line drawings or cartoons – to illustrate key points without introducing extraneous details. When they use photos or videos, they draw students' attention to the key aspects by pointing them out or describing them.

Non-example: The teacher is teaching students about musical notes. They use a piano keyboard image background and display the different notes alongside images of famous musicians.

Example: The teacher is teaching students about musical notes. They display the different notes on a plain slide without competing images.

POSSIBLE APPLICATIONS

NOVICE TEACHERS:

Limit distractions, both visual (such as classroom decorations) and audible (such as music, external noise or speaking by peers and teachers) to allow students to concentrate on key stimuli. Remove redundant information: limit expositional text on slides, using visuals on slides, complemented with spoken description.

Guide students' attention: use questions to guide students' attention to critical ideas: "What do we notice about the number of times Mr. Birling refers to himself as 'hard-headed'? Why do you think he does this?"

Design your resource to avoid splitting students' attention between different places, by displaying the information students need where they will need it: for example, add labels to a diagram so students can understand it without referring to a separate text.

EXPERIENCED TEACHERS:

Limit distractions: make explanations and instructions concise; use as few words as possible, and try to repeat subject specific target vocabulary multiple times when you offer an explanation.

Guide students' attention:

- Design your resources / slides to guide student attention to the correct areas. Use highlighted text / arrows and diagrams to clearly indicate where students should attend. You can also do this through clear physical gesture.
- Signal key points, for example stress key words in speaking, use arrows or pointing with images or text
- Develop your students' habits of minds in focussed attention: try to develop their ability to focus for long periods of time: "last week, you wrote silently without looking up from your books for four minutes. Today, we are going to go for six."

Design experiential activities carefully: learning songs, watching films and playing games may attract students' attention. However, their attention may be drawn to surface characteristics (for example, the rhythm of the song rather than the words, ways to win the game not what is to be learned). If teachers use such activities, they may want to check what students recall from them in a future lesson (do they recall the learning content or surface features?).

ASSESSMENT

Question: Which of these will diminish students' attention towards learning?

a. Playing music during lessons while students work

b. Allowing a small amount of off-task discussion

c. Emphasising key points in the lesson

Answer: Although (a) playing music could prove helpful if it reduces the impact of more distracting noises, both music and (b) off-task discussion will diminish students' attention towards learning, because both provide additional stimuli which students need to try to ignore. Some teachers may not recognise that these drains on students' attention are harmful to their learning. Emphasising key points in the lesson (c) should draw students' attention towards them.

ACTIVITY FOR PROFESSIONAL DEVELOPMENT SESSION

<table>
<tr><th colspan="3">PRINCIPLE 1:
PEOPLE CAN ONLY CONSCIOUSLY ATTEND TO A HANDFUL OF STIMULI AT A TIME</th></tr>
<tr><td>SUCCESS CRITERIA</td><td colspan="2">> Resources contain only essential information; redundant images, text and instructions are removed
> Instructions are clear and concise
> Information is presented where it is needed, to avoid splitting attention</td></tr>
<tr><th></th><th>NOVICE TEACHER</th><th>EXPERIENCED TEACHER</th></tr>
<tr><td>STEP 1: PREPARE</td><td>> Identify the key activity in an upcoming lesson.</td><td>> Identify the moment where teacher explanation is most important for learning in an upcoming lesson.</td></tr>
<tr><td>STEP 2: REFINE</td><td>> Use the success criteria to review and improve the resource.</td><td>> Script the teacher explanation for this section of the lesson.
> Use the success criteria to review and improve the explanation.</td></tr>
<tr><td>STEP 3: FEEDBACK</td><td colspan="2">Ask teachers to give one another feedback using the success criteria.</td></tr>
</table>

CONNECTIONS

Conscious attention helps information to enter working memory – Principle 3, and hence, long-term memory (Principle 4a).

FURTHER READING

Mayer, R. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. American Psychologist, 63(8), pp.760-769.

2 - LINKING NEW LEARNING TO PRIOR KNOWLEDGE: HOW CAN TEACHERS FIND OUT WHAT STUDENTS ALREADY KNOW?

PRINCIPLE 2: PRIOR KNOWLEDGE DETERMINES WHAT STUDENTS CAN LEARN.

Students make sense of new information by reference to what they already know. → so → Teachers can help students to commit new information to long-term memory by connecting it to existing knowledge.

PRACTICAL DEMONSTRATION

Ask teachers what students need to know to make sense of this sentence from a Key Stage 3 history textbook:

"Some say that Henry only made the Break with Rome because the Pope would not let him have a divorce (Byrom et al., 1997, p.49)."

The list might include that:

- "Henry" is Henry VIII, King of England.
- "the Break with Rome" is the separation of the church in England from the Roman Catholic church.
- "the Pope" governed the Catholic church and lived in Rome.
- "would not let him have a divorce" a divorce required church permission; for a monarch this had to come from the Pope; Henry was a Catholic.
- "Some say" – historians interpret the past differently.

KEY LEARNING POINT:
Students can only make sense of new information, appreciate its meaning and commit it to memory by connecting it with what they already know.

EXAMPLES AND NON-EXAMPLES

Non-example: The teacher begins a new unit of work on pronouns by defining them and identifying them in sentences.

Example: The teacher begins a new unit of work on pronouns by revisiting their knowledge of nouns. She then checks how much students recall about nouns using a short, low-stakes quiz. She uses this to check whether students' prior knowledge is secure, revisiting any knowledge gaps she identifies.

Non-example: The Year 7 teacher is planning to teach a unit of work on mountains. Before they plan the first lesson, they check the national curriculum to find out what students have learned in Year 6.

Example: The Year 7 teacher is planning to teach a unit of work on mountains. Before they plan the first lesson, they design a short quiz based on what students should have learned in Year 6. They use what they learn to plan the unit.

POSSIBLE APPLICATIONS

NOVICE TEACHER:

- Before teaching a topic, make a list of all the things students need to know to understand it. For example, before learning about a character's motivations to act in certain ways, students will need to know the plot of the story.
- Check that students have the foundational knowledge needed for the subject or topic (for example, times tables in maths, an understanding of the plot in order to analyse characters in literature). If students are missing foundational knowledge, prioritise reteaching this before moving on to new material.
- Make a list of all the important vocabulary students will need to make sense of a new topic. Teach this vocabulary first, so that students can understand subsequent explanations.

EXPERIENCED TEACHERS:

- When planning a unit, design a check for students' prior knowledge at the start of the unit. Ensure that each lesson builds on preceding lessons.
- Use quizzing at the start of the lesson to remind students of key material they will need to understand the current lesson. A good method is to ask three questions on the previous lesson, two questions on important content from the current unit, and one question on important content from a previous unit. This will help students access the knowledge they will need.
- Make connections between new information and existing knowledge explicit: "In this unit, we will learn about Macbeth, a tragic hero. Previously, we've learned about another tragic hero, Othello."

ASSESSMENT

Question: Planning should disregard students' prior knowledge…

a. If the topic is completely new to students

b. Students' prior knowledge is likely to contain many errors

c. Never

Answer: Some teachers may believe that students' prior knowledge is sometimes irrelevant to their planning, but this is never the case (c is correct). Even when a topic is completely new to students (a) they will have some relevant prior knowledge from previous topics, other subjects or their own experience, which should help them to make sense of new information. If student's prior knowledge is likely to contain many errors (b) this is particularly important for teachers.

CONNECTIONS

Ensuring students have the necessary prior knowledge reduces the burden on working memory which new information imposes (Principle 3) and is essential to meaningful processing of new ideas (Principle 4a). Checking prior knowledge is an opportunity to identify students' existing misconceptions (Principle 4b) and a chance for students to retrieve past knowledge, improving retention (Principle 5).

ACTIVITY FOR PROFESSIONAL DEVELOPMENT SESSION

PRINCIPLE 2: PRIOR KNOWLEDGE DETERMINES WHAT STUDENTS CAN LEARN		
SUCCESS CRITERIA	> Check students' prior knowledge before introducing new learning > Help students activate and retrieve key ideas they have covered previously early in the lesson > Introduce key ideas before getting into details with students > Help students connect new learning to existing knowledge	
	NOVICE TEACHER	**EXPERIENCED TEACHER**
STEP 1: PREPARE	> For an upcoming lesson, list everything you want students to learn. > List everything students need to know to make sense of what you want them to learn.	> Pick an explanation of a new idea in an upcoming lesson.
STEP 2: REFINE	> Prepare a quiz to check whether students have foundational knowledge. > Prepare explanations or reminders for ideas you may have to reteach.	> Review your explanation: refine it to highlight and clarify the links between prior knowledge and new learning.
STEP 3: FEEDBACK	Ask teachers to give one another feedback using the success criteria.	

FURTHER READING

Willingham, D. (2006). How Knowledge Helps. American Educator. Spring.

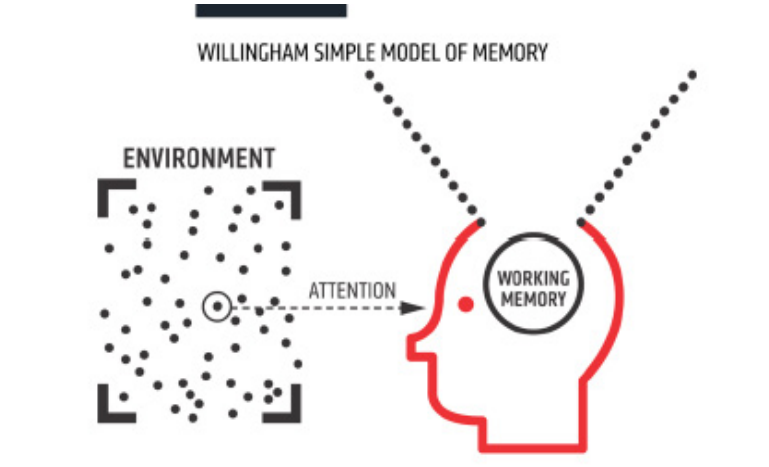
3 - WORKING MEMORY, LOAD AND THOUGHT: HOW CAN TEACHERS HELP STUDENTS FOCUS ON WHAT MATTERS?

PRINCIPLE 3 – WORKING MEMORY CAPACITY IS LIMITED

The site of conscious thinking – working memory – is limited in both capacity and duration. When students' working memory is overloaded, they are unable to retain or process some of the information they have been presented with. Individual students' working memory capacity differs, but there is no known way to increase working memory capacity. However, the more relevant prior knowledge students have, the less working memory will be required for a new idea, and the more easily they can process new information (Principle 2).

so

Teachers must ensure students focus on a few ideas, processes or pieces of information at a time.



PRACTICAL DEMONSTRATION

This demonstration gives an indication of a person's digit span: their verbal short-term memory capacity.

Provide teachers with the list of numbers below. Taking each line of digits in turn, ask teachers to read the digits and then cover the line and repeat them back. They continue moving through the lines until they fail to correctly recall BOTH lines with the same number of digits. Their digit span is one less than the number of digits in the lines that were both failed.

For example, if they fail to correctly recall the 5th line but successfully recall the 6th line they can continue to line 7 because lines 5 and 6 both contain 6 digits. If they then failed to recall both lines 7 and 8 they would stop because they have failed to recall two lines with the same number of digits. Their digit span would be 6 (one less than 7, the number of digits in lines 7 and 8).

9754

3825

94318

68259

913825

648371

7958423

5316842

86951372

51739826

719384261

163874952

9152438162

7154856193

KEY LEARNING POINT:
If teachers ask their students to work with too many new ideas at once, their working memory will be overloaded. Processing in working memory is necessary (although not sufficient) for long-term storage: so overloading their working memory will restrict students' ability to comprehend the ideas or to learn from the experience.

The effect of prior knowledge on working memory could be emphasised by repeating this task using unfamiliar numerals (for example, Mandarin numerals). Teachers process familiar numerals automatically, but processing unfamiliar numerals will overload their working memory far more quickly.

EXAMPLES AND NON-EXAMPLES

Non-example: The teacher explains the equipment needed for the practical. This requires unfamiliar equipment, so the teacher explains how to set it up and how to conduct the experiment. Then they ask students to do the practical.

Example: The teacher provides students with the required equipment for the practical. They demonstrate how to set the equipment up in stages, asking students to complete each stage after the demonstration. Once all students have the equipment set up, the teacher explains how to conduct the experiment.

Non-example: After modelling how to add one more to a given number whilst on the carpet, the teacher asks the students to go to their tables. They then ask two children to give out the maths books and tell all students to rule the margin, write the date and title. Students then begin to practise adding one more.

Example: Before modelling how to add one more to a given number at the carpet, the teacher ensures that the students already have their maths book, have ruled the margin, written the date and title. Once the teacher has modelled the process at the carpet, the students begin practising at their tables immediately.

Non-example: The teacher models how to write a descriptive paragraph with a focus on using similes effectively, then asks students to write their own paragraph.

Non-example: To model how to add two fractions, the teacher talks through three worked examples of increasing difficulty, while asking students questions. Then the teacher checks for understanding before students complete independent practice.

Example: The teacher models how to add two fractions together using one worked example, then asks students to finish a partially-completed example, then asks them to complete a very similar question on mini whiteboards, before proceeding to the next worked example. The teacher continues this sequence before asking the students to complete independent practice.

Non-example: Students are learning to write using expanded noun phrases. The teacher models one example and asks students to write their own.

Example: Students are learning to write using expanded noun phrases. The teacher models one example and displays a second sentence with omitted adjectives and asks students to fill in the gaps, then asks them to write their own.

POSSIBLE APPLICATIONS

NOVICE TEACHER

Help students to process new information:

- As you plan lessons, think about what students will be required to think about at each stage.
- Design tasks which challenge students to think about one key idea at any one time. Break tasks down and/or help students to focus on one step at a time. Provide worked examples demonstrating how to complete novel tasks.

Record information students will need but cannot retain in working memory:

- Note important information that students might need to think about for a task (but that they have not yet committed to memory) on a "working wall," allowing students to access it without having to rely on working memory.
- Encourage students to note key ideas themselves when tasks become more cognitively challenging, especially when students are novices.

EXPERIENCED TEACHER

Help students to process new information:

- Offer worked examples and completion problems (partial worked examples for students to complete) to allow students to focus on how problems can be solved and focus on one step at a time.
- Phrase questions simply, so that students need not use working memory capacity decoding them.
- When asking questions, provide students with wait time to think about the answer before responding: "What reasons might Mr Birling have to want his daughter to marry Gerald [wait five seconds] what do you think John?
- Remove support gradually to help students complete problems increasingly independently. If students appear to be managing the existing problems, considering making practice harder by varying it (this is discussed in Principle 5).

Help students store information they need which goes beyond working memory capacity

- Encourage students to develop effective note-taking practices, helping them to minimise the burden on their working memory.

ASSESSMENT

Question: Which of these is most likely to help students learn without overloading their working memory?

a. Focus on topics in which students are interested.

b. Prioritise two or three ideas for students to think about at any one time.

c. Ensure the lesson is engaging for students.

Answer: Some teachers may believe that engaging students (c) is crucial to learning but this does not diminish the load on students' working memories. Students may have more existing knowledge about topics which interest them (a), but teachers can still overload their working memories, and focusing on topics which interest students will impede teachers from educating students beyond their existing experience. Only (b) helps keep learning within the limits of working memory.

Question: An explanation is most likely to remain within students' working memory capacity if it is…

a. Detailed.

b. Concise.

c. Stimulating.

Answer: Detailed (a) and stimulating (c) explanations provide additional chunks of information which strain the capacity of students' working memory. A concise explanation (b) which offers the minimum required information is most likely to remain within students' working memory.

CONNECTIONS

Processing in working memory supports transfer of information to long-term memory; practice increases students' automaticity in processing, reducing the burden on working memory (Principle 4a).

ACTIVITY FOR PROFESSIONAL DEVELOPMENT SESSION

PRINCIPLE 3: WORKING MEMORY CAPACITY IS LIMITED		
SUCCESS CRITERIA	> Keep tasks, resources and explanations clear and simple > Break activities down to reduce the number of steps or "moving parts" students must think about at once > Provide supports such as worked examples to limit the load on students' working memory	
	NOVICE TEACHER	**EXPERIENCED TEACHER**
STEP 1: PREPARE	> Identify a model of new learning you will share with students in an upcoming lesson.	> Pick a point at which students will begin independent practice in an upcoming lesson.
STEP 2: REFINE	> Use the success criteria to simplify and clarify the model.	> Decide when to remove working memory supports to increase the demand on students gradually.
STEP 3: FEEDBACK	Ask teachers to give one another feedback using the success criteria.	

FURTHER READING

Centre for Education Statistics and Evaluation. (2017). Cognitive load theory in practice: Examples for the classroom. New South Wales Department of Education.

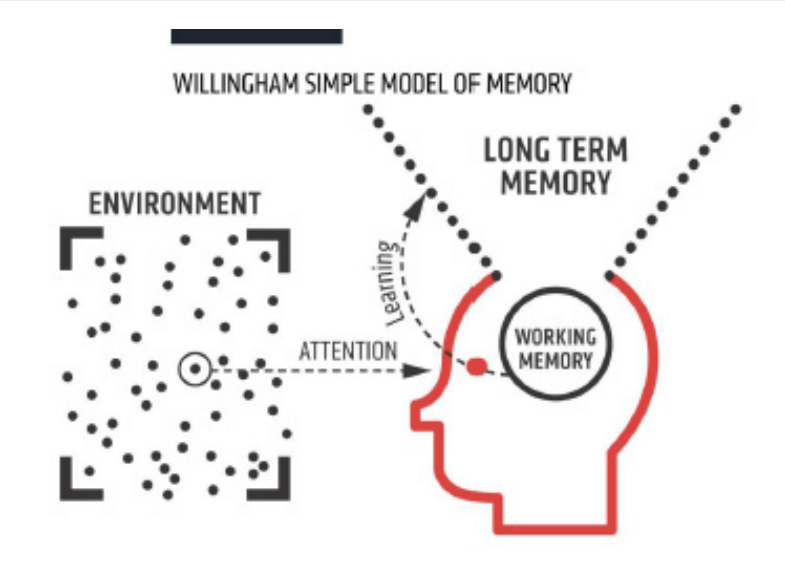
4 - LONG-TERM MEMORY: HOW CAN TEACHERS HELP STUDENTS COMMIT INFORMATION TO LONG-TERM MEMORY?

PRINCIPLE 4A: MEMORY IS THE RESIDUE OF THOUGHT.

Students transfer information into their long-term memories when they think hard about its meaning.

so

Teachers must plan to ensure students think hard about the meaning of what is to be learned.



PRACTICAL DEMONSTRATION

Read the following instructions:

"We're now going to try an experiment to see what helps learners remember new information. I'm going to read thirty words aloud. For each word, I'll ask one of three questions:

- Does it have an A or U in it?
- Does it rhyme with the word 'train'?
- Is it pleasant?

I'll tell you the question, then the word: please just write 'Yes' or 'No': you don't need to record the words. For example, if I said, "A or U. Cheese." you would record no (since cheese does not have an A or U in it). If I said "Is it pleasant? Sewer.", it's highly likely you'd record no. Any questions?"

Now read the following list, pausing briefly for teachers to record their response.

1. Rhymes with train? Hundred
2. Is it pleasant? Corn
3. A or U? Cool
4. Rhymes with train? Rate
5. A or U? Jump
6. Rhymes with train? Pain
7. Is it pleasant? Urge
8. A or U? Country
9. Rhymes with train? Main
10. A or U? About
11. Is it pleasant? Diamond
12. Rhymes with train? Into
13. Is it pleasant? Welcome
14. A or U? Window
15. Rhymes with train? Maintain
16. Is it pleasant? Airplane
17. Rhymes with train? Thread
18. A or U? Match
19. Rhymes with train? Cane
20. Is it pleasant? Fruit
21. A or U? Melt
22. Rhymes with train? Rain
23. Is it pleasant? Rage
24. A or U? Only
25. Is it pleasant? Winter
26. A or U? Single
27. Is it pleasant? Disease
28. A or U? Yourself
29. Rhymes with train? Else
30. Is it pleasant? Camp

Ask teachers to turn over their sheet and write as many of the 30 words as they can remember. Once they are finished, display the 30 words, grouped by the question asked:

A OR U?	RHYMES WITH TRAIN?	IS IT PLEASANT?
Cool	Hundred	Corn
Jump	Rate	Urge
Country	Pain	Diamond
About	Main	Welcome
Window	Into	Fruit
Melt	Thread	Rage
Only	Cane	Winter
Single	Rain	Disease
Yourself	Else	Camp

Ask teachers which column they remembered the most words from. Teachers are likely to remember the most words from the pleasant column because they were forced to think about what the words meant. Teachers could respond to A or U just by thinking of the spelling and rhyming just by listening to the sound of the words. To respond to the question "Is it pleasant?" teachers had to think of meaning, and that's what really helps memory (Craik and Tulving, 1975).

EXAMPLES AND NON-EXAMPLES

Non-example: The teacher gives students a map showing the extent of Viking voyages to help students understand why Viking raids were so successful. They ask them to list the different places to which Vikings travelled.

Example: The teacher gives students a map showing the extent of Viking voyages and a historian's description of the different ways their boats could be used (for example, pulling them ashore for roads, carrying them across rapids, sailing up rivers). The teacher asks students to use the historian's description to explain why the Vikings were able to travel and raid so successfully.

POSSIBLE APPLICATIONS

NOVICE TEACHERS

Design activities so that all students must think about the key ideas, for example:

- If students are reading a text, provide questions for them to think about while reading, helping them process the key ideas.
- If students are learning about multiple factors (such as causes/reasons/explanations), ask them to rank the factors or explain their importance, not just summarise them.
- When teaching new vocabulary to students, design activities ensuring they think about the meaning of the word in context: "Why might someone feel anguished on their birthday?" is a better question than "What does anguished mean?"
- If you want students to think at length about something, ask them to write something, rather than to think about it: this encourages them to process the ideas more fully.
- Avoid activities which encourage students to think about the mechanics of the task, not the meaning of the information. For example, thinking about craft skills is crucial in art lessons, but may limit learning in science.

EXPERIENCED TEACHERS

Keep all students accountable for thinking:

- Don't give the names of students before you ask a question to the class. This means that every student will expect to be asked and will therefore think about the answer. Ask a question, pause (or ask students to write an answer), then nominate the student to answer, so all students have time to think about the answer.
- Where meaningful structures exist, use them: for example, use stories, which have recognisable common plot points and are more memorable for students, and share organising frameworks with students (see Principle 6).
- Where there is no obvious meaningful structure but an idea is important (times tables, a scientific formula) use mnemonics, songs or repetition to help students commit it to memory.

ASSESSMENT

Question: Students are most likely to commit information to long-term memory if they are…

a. Emotionally engaged in an activity.

b. Interested in what they are studying.

c. Making sense of a new idea using what they already know

Answer: Students are more likely to remember events and experiences during which they are emotionally engaged. However, this is a problematic strategy for ensuring students' memory of key ideas: not all teaching can be emotionally engaging, and there is no guarantee what students recall about the event. So although teachers may believe this is important, (a) is incorrect. Students may be more motivated if they are interested in what they are studying – and motivation supports effective learning – but unless they are processing it meaningfully, it will not be committed to long-term memory, so (b) is also incorrect. (c), making sense of a new concept with what they already know, is most likely to help them commit new information to long-term memory.

Question: Students are most likely to commit information to long-term memory if we ask them to…

a. Complete a fun activity about it.

b. Use several pieces of information at once.

c. Think about the meaning of the information.

Answer: Teachers may believe that a fun activity stimulates learning (a) or that they should challenge students with a lot of information (b) but the biggest support for learning is ensuring students think about the meaning of the information (c).

CONNECTIONS

This kind of meaningful thinking exemplifies the burden new information places on working memory (Principle 3). Learning depends on students making connections between their existing knowledge and new information (Principle 2). Students may hold or develop misconceptions while thinking about new information, which should be checked (Principle 4b). New information is forgotten and must be reinforced (Principle 5) and organised (Principle 6) if students are to retain and apply it.

ACTIVITY FOR PROFESSIONAL DEVELOPMENT SESSION

PRINCIPLE 4A: MEMORY IS THE RESIDUE OF THOUGHT	
SUCCESS CRITERIA	> Activities and questions guide students to think meaningfully about each new idea > Written activities prompt students to think > There is enough time planned for meaningful thinking > All students are accountable for their thinking

	NOVICE TEACHER	EXPERIENCED TEACHER
STEP 1: PREPARE	> Pick a point in an upcoming lesson when students will be practising new learning. > List what you want students to think about and specific thoughts you want them to have (for example, 'I want students to recognise the link between these two ideas.')	> Pick a point at which you will be questioning students in an upcoming lesson. > List the questions you will use.
STEP 2: REFINE	> Use the success criteria to refine questions and activities to guide students explicitly to think meaningfully about key ideas.	> Practise lesson questioning, including techniques to hold all students accountable for their thinking.
STEP 3: FEEDBACK	Ask teachers to give one another feedback using the success criteria.	

FURTHER READING

Willingham, D. (2008). What Will Improve a Student's Memory? American Educator. Winter.

PRINCIPLE 4B: STUDENTS MAY COMMIT INCOMPLETE OR INCORRECT IDEAS TO THEIR LONG-TERM MEMORIES

IDENTIFY AND ADDRESS GAPS AND MISCONCEPTIONS IN STUDENTS' UNDERSTANDING

Students may hold misconceptions already or form new ones as they learn: if they maintain these misconceptions, these are what they are likely to recall.

so

Teachers need to identify what students are thinking and have understood during the lesson, without waiting for students to articulate their misconceptions.

PRACTICAL DEMONSTRATION

Ask teachers to identify all the things students will struggle to understand if they believe that:

- You multiply by 10 by adding 0 to the end of the number – Answer: they will be unable to multiply numbers with a decimal point correctly
- You use a comma every time you pause to take a breath – Answer: they will place commas incorrectly
- Objects sink because they are heavy – Answer: they will not understand density
- The Church is (only) a building – Answer: they will not understand the Church as a universal institution

KEY LEARNING POINT:
If students maintain or develop misconceptions of which teachers are unaware, they will struggle with key aspects of future topics.

EXAMPLES AND NON-EXAMPLES

Non-example: The teacher explains the concepts of tone and colour and asks students to create different tones of blue. The teacher checks their work at the end of the lesson.

Example: The teacher explains the concepts of tone and colour. They check students' understanding using a hinge question (a multiple-choice question designed to elicit students' misconceptions), and respond, before asking students to create different tones of blue. The teacher checks student progress during the task.

Non-example: Students are exploring shapes. The teacher observes that a student correctly names a circle and square. The teacher notes this as secure on her assessment sheet.

Example: Students are exploring shapes. The teacher observes that a student correctly names a circle and square. The teacher notes this as secure on her assessment sheet. Later that day, the student is asked by a teaching assistant to name a shape – she incorrectly names a square. The teacher amends their assessment sheet, in order to revisit it later.

POSSIBLE APPLICATIONS

NOVICE TEACHER

- Ask a colleague or mentor about likely misconceptions in an upcoming unit or lesson.
- Avoid using subjective measures to check students' understanding, such as "Give me a thumbs up if you get it." or "On a scale of 1-5, tell me how much you now understand." This indicates students' confidence, but may provide misleading information about their understanding.

- Use targeted questions or activities to check students' understanding: "We've been learning about Lady Macbeth's manipulation of Macbeth. Tell me then, what is Lady Macbeth's main strategy to manipulate her husband?"
- Design an exit ticket that students fill out at the end of lessons: a task which encapsulates the lesson's learning, which students can complete quickly before they leave the classroom. Review students' answers to the exit ticket question to guide the planning of your next lesson.

EXPERIENCED TEACHER

- Identify likely misconceptions before teaching and plan ways to address them which build on students' existing (correct) knowledge to demonstrate why the misconception is untrue.
- Assess whether students have developed misconceptions and address them accordingly: for example, use hinge questions, multiple-choice questions designed around misconceptions, which show rapidly what students have understood during the lesson.
- Use students' exit tickets to design activities to correct misconceptions. Sensitively use specific examples of incorrect student work to highlight and address misconceptions.

ASSESMENT

Question: The most valuable information which a check for understanding can provide during a lesson is whether:

a. Students will remember what they have been taught

b. Students have made progress

c. Students have gaps in their understanding

Answer: Teachers may believe (a), that a check for understanding demonstrates what students will recall, but current performance does not guarantee learning. They may also be accustomed to using checks for understanding to demonstrate students are making 'rapid' progress (b), but checks for understanding are much more useful if they give teachers a genuine appreciation of students' understanding and misconceptions (c), so they can adapt the lesson.

Question: Teachers can be assured students do not hold major misconceptions if:

a. Students are confident they have understood the key ideas

b. Targeted students answer questions well

c. Students respond correctly to a hinge question

Answer: Teachers may be satisfied by students' confidence (a), but this is not a valid measure of what students know; teachers may feel content that the correct answers of some students reflect the whole class (b), but the response of some students may mask the misconceptions of others. Of these options, only a hinge question (c) demonstrates that students do not hold major misconceptions.

CONNECTIONS

Misconceptions may develop if the burden on working memory is excessive (Principle 3); they may re-emerge, even after students appear to have overcome them, so should be checked again when encouraging students to retrieve knowledge (Principle 5).

ACTIVITY FOR PROFESSIONAL DEVELOPMENT SESSION

PRINCIPLE 4B: STUDENTS MAY COMMIT INCOMPLETE OR INCORRECT IDEAS TO THEIR LONG-TERM MEMORIES		
SUCCESS CRITERIA	> Identify the most likely misconceptions around the key learning point > Select the best moments in the lesson to address them > Design activities explicitly to expose likely misconceptions > Pre-plan ways to address misconceptions	
	NOVICE TEACHER	**EXPERIENCED TEACHER**
STEP 1: PREPARE	> Identify the best moment in the lesson to check students' misconceptions. > List potential misconceptions with a more experienced colleague.	> Identify the best moment in the lesson to check students' misconceptions. > List potential misconceptions
STEP 2: REFINE	> Refine the lesson activity to expose likely misconceptions. > Script how you will respond to each misconception.	> Identify a response for each misconception. > Plan ways to highlight the misconception and correct answer for students.
STEP 3: FEEDBACK	Ask teachers to give one another feedback using the success criteria.	

FURTHER READING

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5 - FORGETTING: HOW CAN TEACHERS HELP STUDENTS TO REMEMBER WHAT THEY LEARN?

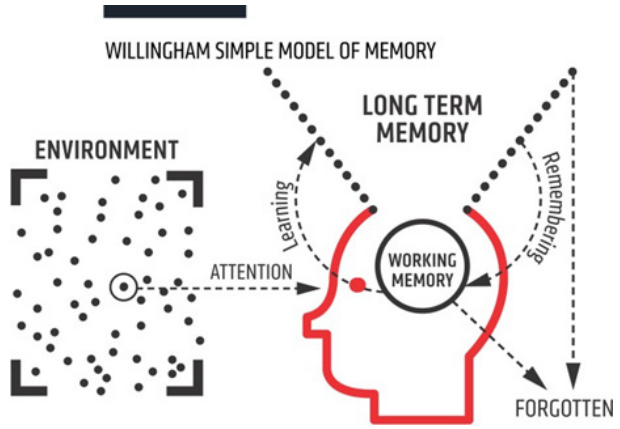
PRINCIPLE 5: FORGETTING IS INEVITABLE

Learning is a persistent change in long-term memory, not just a temporary increase in student performance. Introducing students to an idea once is very unlikely to be enough for them to recall it after a month, a year, or beyond.

so

Teachers can make students' knowledge more secure by giving them practice in using and retrieving this information once their memories of an idea are beginning to fade. Retrieval practice increases recall more than restudying material, particularly if it is:

- Varied: students practise different tasks, rather than one task at a time, increasing the number of cues helping students recall the idea, and increasing its usefulness.
- Spaced (for verbal materials): increasing delays between practice episodes, especially if students answer correctly.



PRACTICAL DEMONSTRATION

Ask teachers to list the Teacher Standards.

KEY LEARNING POINT:
Despite being very familiar with the Teacher Standards during their training teachers are likely to have forgotten many of them through lack of use. That said, those who trained more recently or are mentors to trainees are likely to remember more. If we show teachers the correct answers, ask them to make meaning of them perhaps by asking them which they are most successful at now and test them again in our next professional development session, they are likely to remember more of them.

OR

Ask teachers to remember as many of the thirty words from the practical demonstration in Principle 4a as they can. Ask them whether this is more or fewer than they remembered at the time.

KEY LEARNING POINT:
Teachers are likely to have forgotten almost all the words they learned. However, if we now show them the correct answers, and test them again in our next professional development session, they are likely to remember more of them.

EXAMPLES AND NON-EXAMPLES

Non-example: The teacher has taught students to add fractions over a carefully planned sequence of lessons. Towards the end of the sequence, the teacher finds that students are correctly able to add fractions of varying difficulty during independent practice. They infer that students have learned how to add fractions and move on.

Example: While the teacher knows that their students can add fractions having just been taught it, she is cautious that this could be a temporary increase in performance. Consequently, they create opportunities for their students to practise adding fractions at increasing intervals, to assess whether they can recall how to do it.

Non-example: Having taught students about the parts of a flower, the teacher asks students to list the parts in a mini quiz at the start of the next lesson, the next week and in a month's time.

Example: Having taught students about the parts of a flower, the teacher asks students to match the parts to the diagram in a mini quiz at the start of the next lesson, annotate the diagram the next week and list the parts in a month's time.

POSSIBLE APPLICATIONS

NOVICE TEACHER

During a lesson, ensure that students have a chance to practise new material before moving on:

- Offer students guided practice initially, practising together (for example, choral repetition in languages, checking the answers after each question in maths).
- When students can complete guided practice successfully, ask them to practise independently.
- Make practice tasks easy initially, then gradually increase their difficulty as students succeed.

Across a term or year, plan when and how to return to key concepts. Revisit questions sooner if students answer incorrectly and delay revisiting them if students answer correctly:

- Use low-stakes quizzing to return to key ideas repeatedly. Whenever you introduce a new idea, plan questions to test the idea, and pick a future lesson in which to use them.

EXPERIENCED TEACHER

Ensure that students have a chance to practise new material before moving on:

- Develop practice activities where questions move slowly from less to more challenging, where the style of question gradually shifts from simple to complex, or where the conditions of practice (such as the cue for an answer) are changed.
- As students move through practice material, check their learning at different stages. A simple way to do this is to circulate around the classroom reading their work.

Plan when and how to return to key concepts; revisit questions sooner if they are answered incorrectly and delay revisiting them if they are answered correctly:

- Give cumulative tests or quizzes which draw on all previously-studied topics.
- Write quizzes where students retrieve knowledge which will be relevant to a new topic (supporting Principle 2, above)
- Increase the length of time between quizzes on a certain topic, provided students continue to answer successfully.

Make practice increasingly challenging when students are successful: mix the kind of practice students are doing, for example, vary the questions or content, such as setting questions about addition, subtraction, multiplication and division, to promote greater thought about the appropriate technique to use.

Create time for retrieval by offering students less practice initially and allocating the time saved to revisit the same topic or skill in a future lesson.

ASSESSMENT

Question: Students benefit from practice if…

a. They are not yet good at what they are practising.

b. They are already good at what they are practising.

c. Both of the above.

Answer: Teachers may underestimate students' capacity to practise if they are not yet good at something (a) or may believe that some success renders further practice unhelpful (b). However, practice increases students' automaticity and fluency in using any new knowledge or skill, so (c) is correct.

Question: When revising new vocabulary, students are likely to benefit more from:

a. Half an hour of practice today

b. Fifteen minutes practice today, and fifteen minutes next week

Answer: Half an hour of practice today (a) will allow students to perform well today, however they will soon forget what they have learned; splitting the practice between two lessons (b) will be harder for students, but this will mean they are thinking harder about the learning, and it will therefore last longer.

Question: If students have been introduced to new information today, retention quizzing will be most useful…

a. Every lesson for the next fortnight

b. In one week, one month and six months

c. In one month and six months

Answer: Quizzing every lesson for a fortnight (a) will lead to gains in performance, but this may be more practice than students need, and they will subsequently forget. An initial gap of one month (c) may be too long, and students may have forgotten most of what they knew by then. So one week, one month and six months (b) is likely to be the most effective interval.

CONNECTIONS

Effective retrieval requires students to think about the meaning of key ideas again (Principle 4a); it is an opportunity to revisit past misconceptions, which may have re-emerged (Principle 4b). Practice reduces the burden imposed on students' working memory by what they have encountered previously, allowing them to learn new material more easily (Principle 3).

PRINCIPLE 5: FORGETTING IS INEVITABLE		
SUCCESS CRITERIA	> Select the most important knowledge to practise > Plan when to revisit key ideas (spacing this over time) > Vary practise to encourage transfer and retention > Scaffold and guide practice, to ensure it starts easy and gets harder > Provide feedback to ensure students are succeeding and improving more than they are struggling	
	NOVICE TEACHER	**EXPERIENCED TEACHER**
STEP 1: PREPARE	> For an upcoming lesson, list everything you want students to learn (and retain). > List everything students already need to know to make sense of what you want them to learn.	> For an upcoming unit, list everything you want students to learn (and retain).
STEP 2: REFINE	> Prepare a quiz which will allow students to retrieve this knowledge in future. > Include questions from older lessons as well.	> Plan questions to revisit key ideas > Plan when you will use them, so that students are exposed to key ideas many times, and the gap between exposures gradually increases
STEP 3: FEEDBACK	Ask teachers to give one another feedback using the success criteria.	

FURTHER READING

Willingham, D. (2004). Practice Makes Perfect—but Only If You Practice Beyond the Point of Perfection. American Educator. Spring.

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6 - ORGANISATION: HOW CAN TEACHERS HELP STUDENTS TO USE THEIR KNOWLEDGE FLEXIBLY?

PRINCIPLE 6 – INFORMATION CAN BE ORGANISED IN INCREASINGLY SOPHISTICATED MENTAL MODELS

Students' knowledge of a concept extends and deepens when they practise it in new situations and contexts. Organisation and practice build a mental model, a framework which organises knowledge and makes it usable to students. This helps students transfer learning to new contexts and think critically about what they know.

Teachers can help students apply their knowledge by encouraging them to make links between ideas and to apply them in a variety of situations. Teachers can also help them by showing them how.

PRACTICAL DEMONSTRATION

Ask teachers what comes next in each sequence:

- James I, Charles, I, Charles II, James II, _____ (Answer: William and Mary - monarchs)
- Vingt, trente, quarante, cinquante, _____ (Answer: soixante – numbers in French)
- 2, 3, 5, 7, ___ (Answer: 11 – prime numbers)
- Mercutio, Tybalt, Paris, _____ (Answer: Romeo – deaths in Romeo and Juliet)

KEY LEARNING POINT:
Teachers' knowledge is not isolated, but organised. This organisation makes that knowledge usable. Teachers need to offer students structures to organise their knowledge if they are going to recall and apply what they know.

Non-example: The teacher follows the scheme of work and teaches a lesson on pyramids, Ancient Egyptian Gods and mummifying a body.

Example: The teacher sets aside time during each lesson to ask students how it is connected to previous lessons and uses the theme of ancient Egyptian belief systems to make these links explicit.

Non-example: The teacher helps students to understand how to calculate 3 x 40 by saying "I know 3 x 4 is 12, so 3 x 40 is 120".

Example: The teacher helps students to understand how to calculate 3 x 40 by saying "I know 3 x 4 is 12. 3 x 40 is the same as 3 x 4 x 10, which is ten times bigger so 3 x 40 is 120".

POSSIBLE APPLICATIONS

NOVICE TEACHER

- Before teaching a topic, review what students have learned previously and identify possible links.
- In explanations, highlight the links between topics and ideas students have previously learned. "Macbeth is a tragic hero, with a flawed personality. In this way, he is like Romeo. Remember that we learnt that Romeo's flaw is..."

EXPERT TEACHER

> Plan opportunities and activities for students to identify how new learning connects to what they already know.

> Design quizzes and practice tasks that manage the links you want students to make. If a useful link is possible, design a quiz question that guides students towards it.

ASSESSMENT

Question: Students are most likely to apply knowledge in new contexts if they…

a. Receive training in problem solving and critical thinking

b. Try to solve complex problems with limited guidance

c. Are prompted to use existing knowledge in new contexts

Answer: Some teachers may believe that training in problem solving and critical thinking (a) will help students, but this tends not to substitute for a lack of knowledge in the domain. Asking students to solve complex problems (b) is likely to leave them completely out of their depth as they lack the knowledge and skill to approach them. Prompts may remind students to use their existing knowledge (c).

CONNECTIONS

Offering students an organising structure for knowledge helps to make it meaningful for them (Principle 4a) and reduces the burden on their working memory (Principle 3).

ACTIVITY FOR PROFESSIONAL DEVELOPMENT SESSION

PRINCIPLE 6: INFORMATION CAN BE ORGANISED IN INCREASINGLY SOPHISTICATED MENTAL MODELS		
SUCCESS CRITERIA	> Check students' recall and fluency in any knowledge you want them to link or organise > Identify how organising knowledge will deepen students' understanding > Identify the links you want students to make > Design activities to focus students' thinking on those links	
	NOVICE TEACHER	**EXPERIENCED TEACHER**
STEP 1: PREPARE	> Pick a point when you will be explaining new learning in an upcoming lesson. > List possible relevant connections to other topics.	> For an upcoming unit, identify the most important organising structure for the ideas students will encounter.

	NOVICE TEACHER	EXPERIENCED TEACHER
STEP 2: REFINE	> Script your explanation, drawing students' attention to these connections. > Plan an activity which leads students to think meaningfully about these connections.	> Plan an explanation to introduce the organising structure to students. > Plan an activity which causes students to apply the organising structure to their learning.
STEP 3: FEEDBACK	Ask teachers to give one another feedback using the success criteria.	

FURTHER READING

Pan, S., Agarwal, P. (2018). Retrieval practice and transfer of learning: fostering students' application of knowledge. Retrieval Practice.

TECHNICAL APPENDIX

For readers interested in learning more about the evidence underlying each principle and going beyond the further reading suggested in each section above, we recommend the following technical and non-technical papers. Full bibliographic details are available in the reference section below.

Principle 1 People can only consciously attend to a handful of stimuli at a time For the specific distracting effects of background noise and music	Cowan (1999) Vasilev, Kirkby and Angele (2018)
Principle 2 Students make sense of new information by reference to what they already know: teachers can help students to commit new information to long-term memory by connecting it to existing knowledge.	Deans for Impact (2015); Recht and Leslie (1988); Willingham (2009), Ch.4
Principle 3 Working memory – the focus of conscious thinking – is limited in both capacity and longevity.	Cowan (1999); Deans for Impact (2015); Gathercole and Alloway (2007); Mayer (2008); Oberauer et al. (2016
Principle 4a Students transfer information into their long-term memories when they think hard about its meaning.	Agarwal (2019); Barclay et al. (1974); Bjork and Bjork, (1992, 2011); Brown, Roediger and McDaniel (2014); Craik and Lockhart (1972); Deans for Impact (2015); Dunlosky et al. (2013); Morris, Bransford and Franks (1977); Pan and Rickard (2018); Pashler et al. (2007); Rohrer and Taylor, (2007); Willingham (2009), Ch.3
Principle 4b Students may hold misconceptions already or form new ones as they learn: if they maintain these misconceptions, this is what they are likely to recall.	Feltovich, Spiro and Coulson (1994); Lucariello and Naff (n.d.); Potvin, Sauriol and Riopel (2015); Spiro et al. (1988)
Principle 5 Learning is a persistent change in long-term memory, not just a temporary increase in student performance. Introducing students to an idea once is very unlikely to be enough for them to recall it after a month, a year, or beyond.	Feltovich, Spiro and Coulson (1994); Lucariello and Naff (n.d.); Potvin, Sauriol and Riopel (2015); Spiro et al. (1988)
Principle 6 Students' knowledge of a concept extends and deepens when they practise it in new situations and contexts.	Agarwal (2019); Barnett and Ceci (2002); Chi, Glaser and Rees (1982); Pan and Rickard (2018); Pashler et al. (2007); Morris, Bransford and Franks (1977); Willingham (2009), Ch,4

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