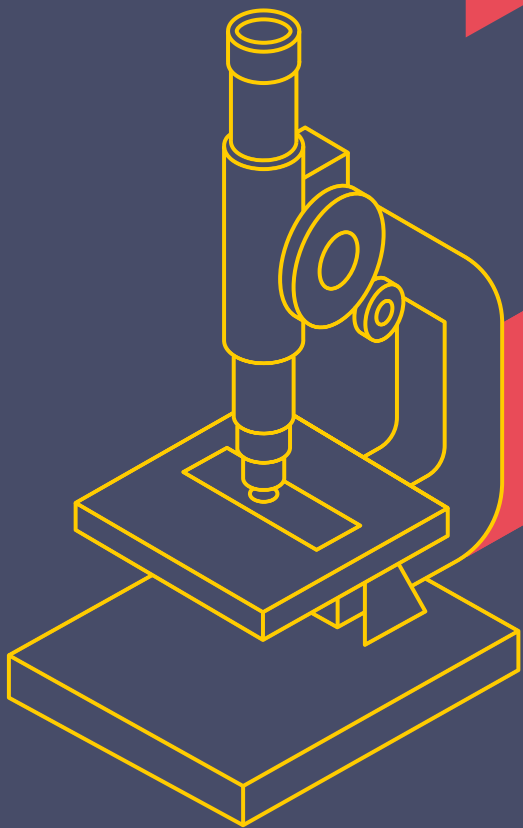
Ambition Institute

THE LEARNING CURRICULUM

VERSION 2.0

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

Harry Fletcher-Wood, Ben Bignall, Jen Calvert, Josh Goodrich and Emma McCrea with Efrat Furst



KEEP GETTING BETTER

October 2019

Welcome

The Learning Curriculum is a guide for teacher educators to support them to plan and deliver training to teachers on the science of learning. It consists of three parts.

Part A contains the content a teacher educator might wish to use when planning training. It is structured into sections that aim to help teacher educators answer key questions for teachers:

1. How can teachers help students to attend to learning?
2. How can teachers help students focus on what matters?
3. How can teachers help students encode information in long-term memory?
4. How can teachers find out what students already know?
5. How can teachers help students to remember what they learn?

Each section outlines a principle and contains the following content to use when planning and delivering training to teachers:

- Introduction - provides more details about the principle
- Model - a simple visual representation of the learning process
- Practical demonstration - a worked example to use with teachers during training
- Examples and non-examples
- Application - shares ideas on how to adapt teaching to accommodate each principle
- Assessment - to check teacher understanding during / after training
- Further reading - for teacher educators or teachers who wish to learn more

Part B offers suggestions on how to plan the training.

Part C contains a glossary of terms.

Introduction

One important task for teacher educators is helping teachers to understand how students learn and to use this knowledge in their teaching. We have found recent syntheses, such as Deans for Impact's The Science of Learning (2015) and Ambition Institute's Learning: What is it, and how can we catalyse it? (McCrea, 2018), to offer invaluable articulations of the principles of learning and possible applications. Sharing these ideas with teachers has proved more challenging; we have struggled without a curriculum or sufficient guidance on how to teach the science of learning to teachers. Specifically, we found ourselves asking:

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

We shared our initial answers to these question in 2018, but we wrote then that this was just a first draft, which we hoped to improve upon: this document is the second, refined edition. Feedback on the first edition has allowed us to make many changes which we hope make this document more useful and usable. These include:

- Offering practical demonstrations of the principles of learning alongside practical examples and non-examples, as more useful than analogies and key studies.
- Reviewing and rewording many of the assessment questions.
- Providing a glossary of key terms.
- Sharing possible activities for professional development sessions.
- Changing the title, to clarify the goal of the document: it may be useful to anyone interested in learning, but its purpose is to help teacher educators plan teacher development.

This second edition benefited from support and guidance from Amber Walraven, Nick Rose and Peps McCrea. Oliver Caviglioli's diagrams express the key ideas beautifully. It reflects suggestions made by Cohort 1 of the Fellowship in Teacher Education programme: 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. We are grateful to Lucy Blewett for her help in the first edition.

Most of all, thank you to Efrat Furst, who generously shared numerous examples of her own practice and helped us clarify our thinking and explanations throughout the document.

All errors remain our own.

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

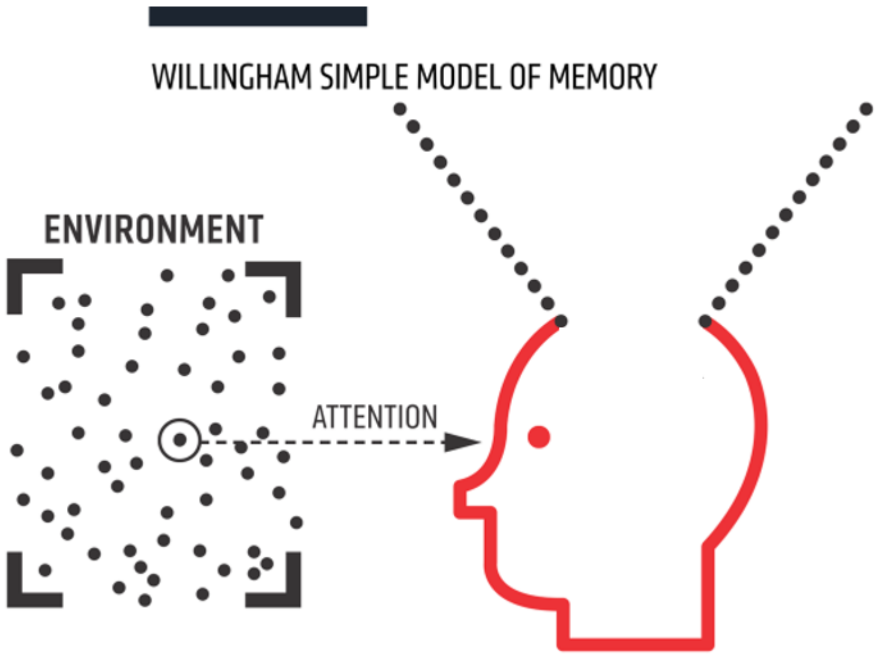
Harry Fletcher-Wood, Ben Bignall, Jen Calvert, Josh Goodrich and Emma McCrea.

Part A: Principles of learning and ways to share them with teachers

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 stimuli each moment, but they can only consciously attend to a handful. 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, there is a risk they will be distracted by something else.

Examples and non-examples

Non-example: Mr Gilbert plays students' favourite songs in the background while they are working, has decorated the walls and uses colourful slides with animations and a lot of words on them. His students often struggle to concentrate on their work.

Example: Mr Gilbert helps students to focus by removing potential distractions from the environment. When students need to concentrate, he asks them to work silently, removes music and shuts the door to avoid noise distracting them.

Non-example: Mr Gilbert shows his students a variety of images to illustrate key ideas in the curriculum. He draws most of these images from real life, so they are often full of details and students struggle to identify the key ideas from them.

Example: Mr Gilbert uses simple images – often cartoons – in order to illustrate key points without introducing extraneous details. When he uses real-life images, he draws students' attention to the key aspects by pointing them out or describing them.

Possible applications

Limit distractions

- Limit distractions, both visual (such as classroom decorations) and audible (such as music, external noise or speaking by peers and teachers) to allow student to concentrate on the key stimuli
- Make explanations and instructions concise: use as few words as possible
- Limit expositional text on slides: use visuals on slides, complementing them with spoken description

Guide students' attention

- Signal key points, for example stress key words in speaking, use arrows or pointing with images or text
- Use questions to guide students' attention to critical ideas

Design experiential activities carefully:

- Experiential activities like 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 the surface features?)

Assessment

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

a) Playing music while students work
b) Allowing a small amount of off-task discussion
c) Emphasising key points in the lesson verbally or visually

Answer: Both a and b 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.

Connections

Conscious attention is necessary for information to enter working memory – Principle 2, and hence, long-term memory (Principle 3a).

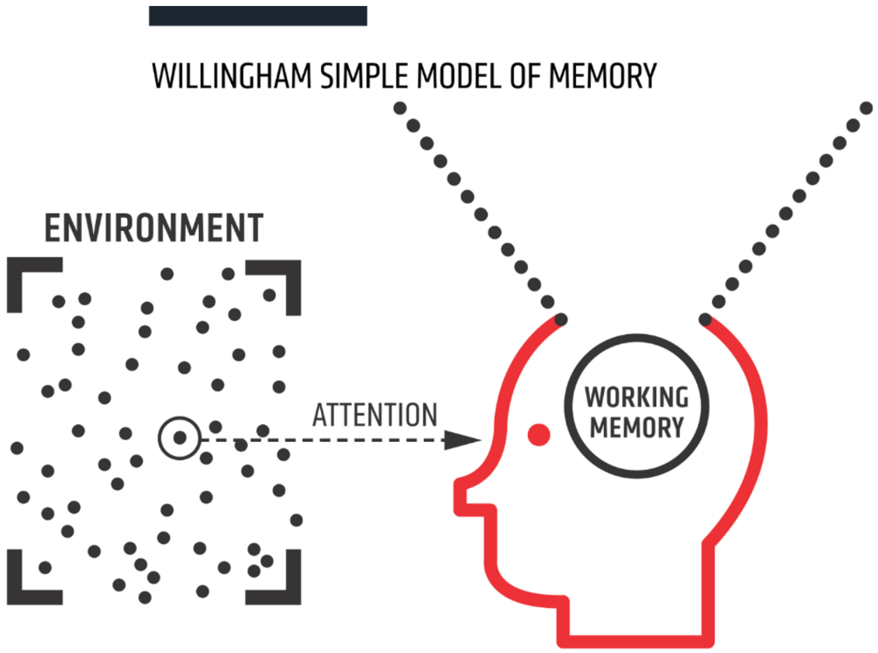
Further reading

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) Working memory, load and thought: how can teachers help students focus on what matters?

Principle 2 – Working memory is limited

Working memory – the focus of conscious thinking – has limited capacity. Teachers must ensure students focus on a few chunks (ideas, processes or pieces of information) at a time. While individual students' working memory capacity differs, there is no known way to increase working memory capacity; however, gaining knowledge and practising helps students commit learning to long-term memory (Principle 3a): this reduces the need for students to rely on their working memory.



Practical demonstration

This demonstration gives an indication of a person's digit span – which is their working memory's number storage 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).

9 7 5 4
3 8 2 5
9 4 3 1 8
6 8 2 5 9
9 1 3 8 2 5
6 4 8 3 7 1
7 9 5 8 4 2 3
5 3 1 6 8 4 2
8 6 9 5 1 3 7 2
5 1 7 3 9 8 2 6
7 1 9 3 8 4 2 6 1
1 6 3 8 7 4 9 5 2
9 1 5 2 4 3 8 1 6 2
7 1 5 4 8 5 6 1 9 3

Key learning point: If teachers ask their students to work with too many ideas at once, their working memory will be overloaded as processing in working memory is necessary, but not sufficient, for long-term storage. This severely restricts students' ability to comprehend these ideas or to learn from the experience.

Examples and non-examples

Non-example: Mrs Forbes explains how to obtain all the equipment needed for the practical and how to set it up. She is frustrated to find that students collect the wrong equipment and set it up incorrectly: students were unable to retain all the equipment needed and how to set it up.

Non-example: Mrs Forbes asks students to read a text individually and identify the key points. While they are reading, she tells them about the meaning of key words and how the text links to previous lessons. At the end of the activity, she finds that students have struggled to identify the key points, because they were distracted.

Example: Mrs Forbes reads the text with the class before analysing it. She pauses when she reaches tricky words to explain them and gives students time to record their meaning on the text before moving on. After reading the text, she asks students to turn it over and listen to her describe how the text links to previous lessons. Then, she asks them to identify the key points: she finds students have identified them more easily than before.

Example: In a Year 5 class, Mrs Forbes reminds pupils the three steps needed in order to convert a mixed number to an improper fraction before setting them off to work individually and ask them to recite them back.

Example: Solving simultaneous equations requires a process that has many steps. To reduce the cognitive load, Mrs Forbes explains each step individually, allowing students to practice each step before moving to the next. Finally, the teacher models and the students practice the whole process.

Example: Mrs Forbes wants students to read a complex scientific text independently. Before she asks them to begin, she reviews key vocabulary students will encounter in the text and offers them a glossary. This reduces the load on working memory as students are reading.

Example: Having modelled how to add two fractions together using a worked example, Mrs Forbes asks students to complete a minimally different question on mini whiteboards before proceeding to the next worked example.

Possible applications

Help students to process new information:

> Design tasks which challenge students to think about one key idea at any one time. Limit the number of ‘moving parts’ you ask them to think about.
> Reduce the cognitive load of challenging tasks by breaking them down and asking students to focus on one step at a time.
> Offer worked examples and completion problems (partial worked examples which students can complete) to allow students to focus on how problems can be solved and focus on one step at a time.
> Provide the information students will need where they will need it, for example, labels on a diagram.
> When asking questions, provide students with wait time to think about the answer before responding.

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

> Use working walls to record information students will need but have not yet committed to long-term memory.
> Encourage students to note key ideas where necessary.

Remove support gradually to help students complete problems increasingly independently. If students appear to be managing under the current cognitive load, considering increasing that load through mixing practice (See Principle 5a).

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) Identifying and prioritising the two or three ideas you want students to be thinking 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 limits the information used to the minimum necessary is most likely to remain within students' working memory.

Connections

Processing in long-term memory supports transfer of information to long-term memory (Principle 3a).

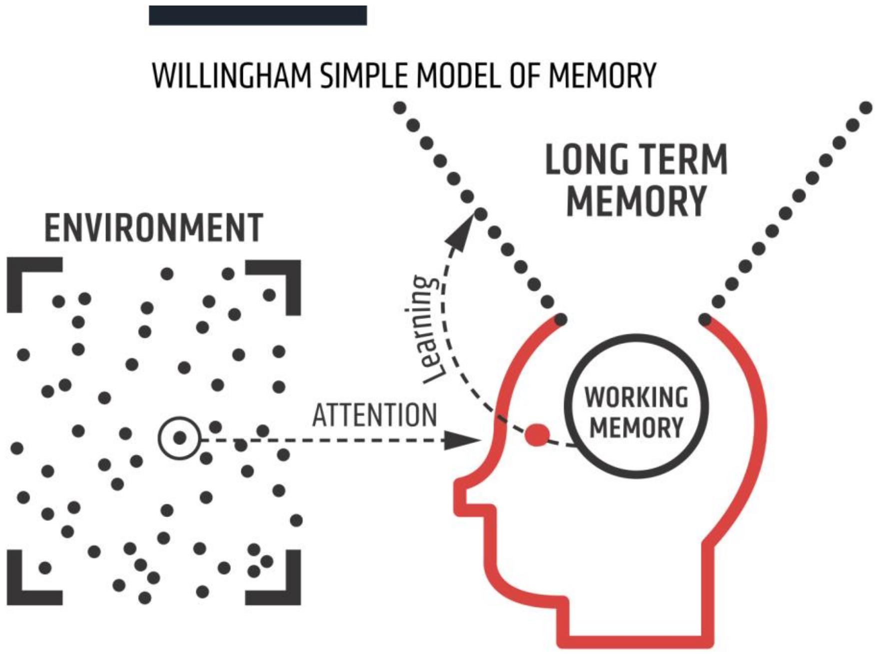
Further reading

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

3) Long-term memory: how can teachers help students encode information in long-term memory?

Principle 3a – Memory is the residue of thought

Students transfer information into their long-term memories when they think hard about its meaning. Teachers must encourage students to think hard about the meaning of what is to be learned.



Practical demonstration

Read the following instructions:

"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? Race*
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	Aeroplane
Match	Maintain	Fruit
Melt	Thread	Race
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.

Key learning point: While processing in working memory is essential for remembering (Principle 2), the kind of processing – deep and meaningful – is equally important. Thinking about meaning and connecting new concepts to existing information helps get material into memory better than thinking about other aspects of the content.

Examples and non-examples

Non-example: Mr Mohammed asks students to construct a Viking longship in a Year 4 history lesson. Mostly, students think about the cutting, sticking and colouring needed to complete the ship.

Example: Mr Mohammed asks students to examine a picture of a longship and guess what went where, how many people it carried, and the dangers they faced. He then reads students a story about a Viking raid, and asks pupils to identify the features of a longboat which allowed the Vikings to conduct the raid successfully.

Non-example: Mr Mohammed gives students a map showing the extent of Viking voyages: he asks them to list the different places to which Vikings travelled. Students make the list, but they are not thinking about the distances and difficulties the journeys have. They therefore struggle to understand the significance of the Vikings' journeys and the role their ships played in making them possible.

Example: Mr Mohammed gives students a map showing the extent of Viking voyages and a historian's description of the different ways their ships could be used (for example, pulling them ashore for roads, carrying them across rapids, sailing up rivers). Mr Mohammed asks students to use the historian's description to explain why the Vikings were able to travel and raid so successfully. Students recognise that Vikings were able to travel unusually far and fast for the time because their ships could be used in many ways.

Possible applications

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

> If students are learning causes for an event, ask them to explain the importance of each factor, rather than just summarising it.
> If students are reading a text, give them a question to consider while reading.

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.

Ensure all students are thinking about key ideas: ask a question, pause, then nominate the student to answer, so all students think about the answer.

Where meaningful structures exist, offer those to students: for example, use stories, which have recognisable common plot points and are more memorable for students, and share organising frameworks with students (see Principle 5b).

Where there is no obvious meaningful to an important idea (times tables, a scientific formula) use mnemonics, songs or repetition to help students commit it to memory.

Assessment

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

a) Emotionally engaged in an activity.
b) Motivated to remember what they are studying.
c) Making sense of a new concept with information they already know

Answer: Teachers may believe that enjoyable engagement and activity ensure learning, but the crucial factor is students' *cognitive* activity: what they are thinking about; so (a) is incorrect. If students are reading information and writing about it (b) they may not be actively processing it is, that is, thinking about it and encoding it to long-term memory. (c), making sense of a new concept with what they already know, is most likely to help them encode new information to long-term memory.

Question: Students are most likely to encode 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

The kind of thinking reflects the cognitive load which teachers' planning imposes (Principle 2). Learning depends on connections between students' existing knowledge and new information (Principle 4). Students may hold or develop misconceptions while thinking about new information, which should be checked (Principle 3b). New information is forgotten and must be reinforced (Principle 5a) and organised (Principle 5b) if students are to retain and apply it.

Further reading

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

Principle 3b – Identify and address student misconceptions

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

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: Ms Williams concludes her explanation of a new idea, shows students how they can answer the next set of questions, then asks them to begin. She circulates around the classroom: after a few minutes, she notices several that students have misunderstood the key idea, are struggling and writing incorrect answers.

Example: Ms Williams concludes her explanation of a new idea, then asks a hinge question which elicits student misconceptions. She clarifies the key points students have misunderstood. She shows students how they can answer the next set of questions, then asks them to begin. She circulates around the classroom: she prioritises students who answered the hinge question incorrectly, ensuring that she has corrected their misconceptions and they are able to answer correctly.

Possible applications

Check what students have actually understood, rather than whether they believe they have understood, as assessments of confidence (for example, 'Thumbs up if you think you understand, thumbs down if not') often provide misleading information.

Check what students have understood and the misconceptions they may hold:

> Use tasks such as exit tickets which encapsulate what students have understood at the end of the lesson.
> Use tasks such as hinge questions, multiple-choice questions designed around misconceptions which show rapidly what students have understood during the lesson.

Assessment

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 then 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 with students' self-reported confidence (a), but this is an unreliable 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) provides assurance that students do not hold major misconceptions.

Connections

Misconceptions may develop if students struggle with excessive cognitive load (Principle 2); they may re-emerge, even after students appear to have overcome them, so should be checked again when encouraging students to retrieve knowledge (Principle 5a).

Further reading

Millar, R. (2016). Using assessment to drive the development of teaching-learning sequences. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto & K. Hahl (Eds.), Electronic Proceedings of the ESERA 2015 Conference. Science education research: Engaging learners for a sustainable future, Part 11 (co-ed. J. Dolin & P. Kind) (pp. 1631-1642). Helsinki, Finland: University of Helsinki.

4) Linking new learning to prior knowledge: How can teachers find out what students already know?

Principle 4 – Prior knowledge determines what students can learn.

Students make sense of new information by reference to what they already know: new information enters long-term memory by connecting to existing knowledge.

Practical demonstration

Ask teachers what students need to know already 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” – 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” – that that Pope governed the Catholic church; that he lived in Rome.
> “would not let him have a divorce” – that 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, on the basis of, and by connecting it with, what they already know.

Examples and non-examples

Non-example: Ms Clarke begins a new topic with an activity to elicit students’ interest, by showing students how it can be used. She then begins to present new information and ask students to use it.

Example: Ms Clarke begins a new topic with an activity to elicit students’ interest, by showing how it can be used. She then checks how much students recall of the prerequisite knowledge to understand the new information using a short, low-stakes quiz. This allows her to fill any knowledge gaps before she presents new information, avoiding confusion.

Possible applications

Plan teaching sequences which provide students with the knowledge they need to understand key ideas; ensuring 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).
> Students learn critical vocabulary or ideas at the start of each unit, so that they understand subsequent explanations.
> Each lesson builds on preceding lessons.

Check students' prior knowledge at the start of a unit or lesson through a quiz or questions and adapt teaching to address gaps.

Help students to activate and retrieve relevant knowledge early in the teaching sequence and make the connections between new information and existing knowledge explicit.

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 not always relevant 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 students' 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 cognitive load which new information imposes upon them (Principle 2); checking prior knowledge is also an opportunity to check for pre-existing misconceptions (Principle 3b).

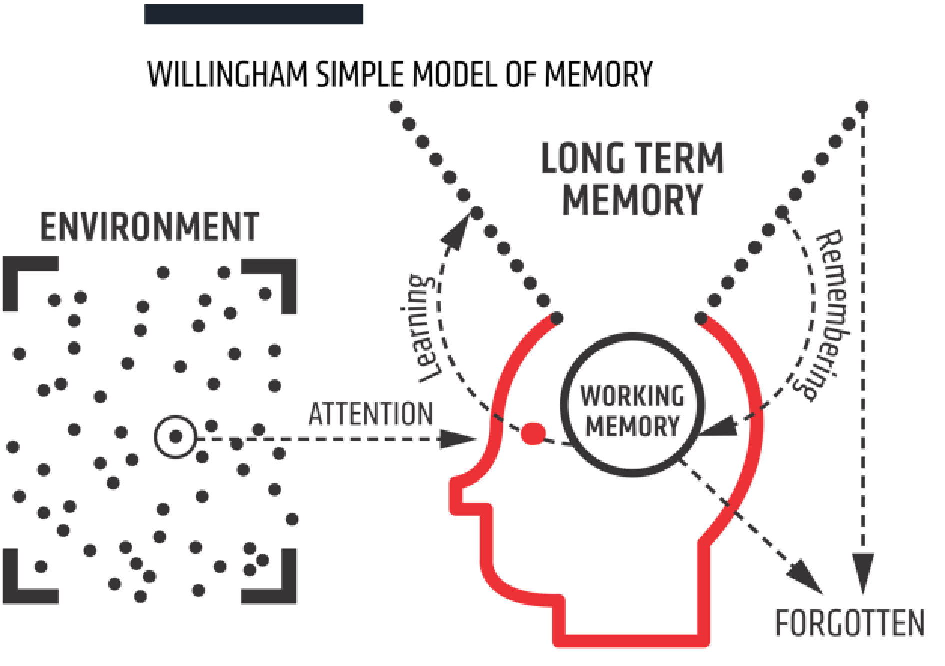
Further reading

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

5) Forgetting: how can teachers help students to remember what they learn?

Principle 5a – Ensure that learning sticks through practice and retrieval

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. Teachers can make students' knowledge more secure by giving them practice in using and retrieving this information once students' memories are beginning to fade. Practice increases recall, particularly if it is spaced (there is a delay between practice episodes) and mixed (students practise different tasks, rather than one task at a time). The gaps between practice should be allowed to increase – especially if students remember items correctly – and practice should be varied to increase the number of stimuli which help students remember the item and the usefulness of the information. The more students' knowledge develops, the more this frees their working memory to process new ideas.



Practical demonstration

Returning to the practical demonstration given in Section 3, ask teachers to remember as many of the thirty words 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 of 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: Mrs Opoku introduces her students to writing paragraphs with evidence, then asks them to write one paragraph with evidence. Satisfied, she moves on.

Example: Mrs Opoku introduces her students to writing paragraphs with evidence. She asks them to write several paragraphs offering evidence for different propositions.

Non-example: Mrs Opoku offers students practice in identifying parts of the flower and continues practising until all students can do this well. She ticks the topic off and does not return to it for the rest of the year.

Example: Mrs Opoku offers students practice in identifying parts of the flower and continues practising until all students can do this well. She gives students a brief test two weeks later, checking what students remember before moving on. She returns to parts of the flower when discussing pollination in another unit.

Possible applications

Offer practice when learning new material:

> Offer students guided practice initially, practising together (for example, choral repetition in languages, checking the answers after each question in maths).
> When students are completing guided practice effectively, offer them independent practice.
> Ensure a high level of student success.

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:

> Use low-stakes quizzing to return to key ideas repeatedly.
> Give cumulative tests or quizzes which draw on all previously-studied topics.
> Retrieve knowledge which will be relevant to a new topic (supporting Principle 4, above)
> Increase the length of time between practice sessions, 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 practice 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, and so (c) is correct.

Question: 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 3a); it is an opportunity to revisit past misconceptions, which may have re-emerged (Principle 3b). Practice reduces the cognitive load imposed on students by what they have encountered previously, allowing them to learn new material more easily (Principle 2).

Further reading

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

Brame, C. and Biel, R. (2015). Test-enhanced learning: The potential for testing to promote greater learning in undergraduate science courses. CBE—Life Sciences Education 14, pp.1-12.

Principle 5b – Help students organise their knowledge

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 knowledge is organised; highlighting the underlying principles and links between key ideas. Students' knowledge of a concept extends and deepens when they practise it in new situations and contexts. Organisation and practice build a mental model, or 'schema', which makes the concept useful to students. This also supports students to transfer learning to new contexts and to think critically about what they know.

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

Examples and non-examples

Non-example: Mr Kennedy focuses on covering the content specified in each topic, and rarely finds time to make links between topics.

Example: Mr Kennedy sets aside time in each topic to ask students how it is connected to previous topics.

Possible applications

Highlight the links between topics and ideas students have understood

Give students time and opportunities to identify how new learning can be connected to what they already know

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 3a) and reduce the cognitive load they undergo in thinking about it (Principle 2).

Further reading

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

Part B: Possible structures for teacher development sessions

All the session plans shared below follow this general structure:

Preparation: *Participants should come to session with a pre-planned lesson to refine.*	
Success Criteria	> *Insert a bullet pointed success criteria for given principle.*
Activity 1: Clarify	> *Teacher educator clarifies the purpose of the session and the principles on which it is based. They use the practical demonstration to show teachers the validity of these principles.*
Activity 2: Analyse	> *Teacher educator highlights what these principles look like in practice, by showing examples and non-examples of the principles. This should guide teachers to recognise aspects of their plans which they can refine.*
Activity 3: Refine	> *Teachers refine their lesson based on the success criteria and guidance.*
Activity 4: Feedback	> *Teachers share their refinements and gain feedback based on the success criteria. They may make further refinements based on this.*
Follow-up	> *Teacher educator signals to participants that they should take this principle forward into their future planning.*

Principle 1 - Environment and attention: People can only consciously attend to a handful of stimuli at a time	
Success Criteria	> Resources contain only information essential to learning. > Remove redundant information from resources: are images essential for learning? > Remove redundant information from resources: is all text essential for key learning point? > Remove redundant information from resources: are your instructions complex and procedural? If so, include them on the resource. > Remove redundant information from resources: are your instructions simple? If so, remove from resource. > Is all related information organised logically?
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measureable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to think about. Are they all necessary? > Of these, which is the central learning point for the lesson?
Activity 2: Analyse	> Share examples and non-examples from Principle 1. Use the success criteria to evaluate. > Looking at your key activity, use the success criteria to analyse your planning.
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Principle 2 - Working memory, cognitive load and thinking: Working memory is limited	
Success Criteria	> Have you strictly limited the amount of new "moving parts" you require students to process at one time. > Have you carefully considered whether students will be able to deal with all the new learning in this lesson? > Have you carefully considered whether there is enough new learning this lesson? > Have you considered splitting your lesson into more than one, or including more new learning, depending on the answers to the above questions? > If the material is novel or complex, have you thought about providing students with "external working memory" (scaffolds, supports, thinking tools like calculators) to limit load on working memory?
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measurable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to think about. Are they all necessary? > Of these, which is the central learning point for the lesson?
Activity 2: Analyse	Display example and non-example of cognitive load friendly activity. (See Principle 2). Use the success criteria to evaluate. Use the list of all the things students will need to think about: > Circle items that are likely to be new for students > Underline those that are likely to exist already within their long-term memory Re-write your circled pieces of knowledge in a logical teaching sequence (first this, then…)
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Principle 3a - Long Term Memory and Encoding – Memory is the residue of thought	
Success Criteria	> Have you created an opportunity to transform the knowledge you have shared? > When asking students to 'think' have you given them an opportunity to write? > Have you modelled an example of how you have thought about the key area of learning? > Is there adequate time planned into the lesson to allow for thinking > Carefully consider your activity and or questions, do they guide the student to think about the right learning point
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measurable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to think about. Are they all necessary? > Of these, which is the central learning point for the lesson?
Activity 2: Analyse	Display example and non-example of cognitive load friendly activity. (See section A, Principle 2). Use the success criteria to evaluate. Focus on the main learning activity. > Write down what you want students to think about for that task. > Look at your task instructions /questions / design. How good are they at directing thinking?
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Principle 3b - Long Term Memory and Encoding - Identify and address student misconceptions	
Success Criteria	> Do you know where in your lesson it is worth stopping to identify and address misconceptions? (What is the key learning point?) > Have you considered the areas where students are likely to have misconceptions around your key learning point? > Is the activity designed in a way to allow for easy exposure of the misconceptions? > Have you included an activity that allows you to do this? > Have you considered how you will address any misconceptions that might arise?
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measurable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to think about. Are they all necessary? > Of these, which is the central learning point for the lesson?
Activity 2: Analyse	Display example and non-example of checking for misconceptions in encoding. (See section A, Principle 3). Use the success criteria to evaluate. Focus on the main learning activity. > List 2-3 possible misconceptions. > For each, decide how to solve if identified. > For each, create an activity that allows you to easily identify the misconception. > Work out the right place for this in your lesson.
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Principle 4 – Linking new knowledge to prior learning **-** Prior knowledge determines what students can learn	
Success Criteria	> Are you pre-teaching key ideas before exposing students to new content? > Are you checking student knowledge early in the lesson? > Are you helping students to activate and retrieve key ideas early in the lesson?
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measurable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to know to complete the lesson successfully. Are they all necessary? > Of these, which is the central learning point for the lesson?
Activity 2: Analyse	> Of the list of knowledge, mark everything which students are not being taught explicitly in the lesson (i.e. what they should already know). > Turn the items you hope students already know into brief questions which will show you whether or not they do know this.
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Principle 5a - Remembering - Ensure that learning sticks through practice and retrieval	
Success Criteria	> What is your method for choosing the most important knowledge to practise? > Have you completed a whole-class check for understanding before beginning practise? > How is practice scaffolded and guided to ensure to ensure a high degree of success (80%)? > Will students have multiple opportunities to practise (spaced over time)? > How are you varying practice to encourage transfer and retention? > What feedback will students receive to ensure increasing accuracy?
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measurable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to think about. Are they all necessary? > Of these, which is the central learning point for the lesson? > What is the single skill in the lesson which students should practise to automaticity (knowledge which students will use frequently)?
Activity 2: Analyse	Display examples and non-examples of building fluency. (See Principle 5a). Use the success criteria to evaluate them. Design a practice activity for this lesson. Plan when and how the skill should be revisited in a future lesson.
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Principle 5b - Helping students to reorganise and recategorise their knowledge.	
Success Criteria	> Have students' gained fluency in the knowledge you want them to organise and categorise? (How do you know?) > How will organising the knowledge help deepen students' understanding of the topic/subject? > Have you identified/planned the links/categories and why they are meaningful? > Does the activity help students think about the links/identify the links for themselves/understand what they are and why they matter?
Activity 1: Clarify	> Use the practical demonstration and explain the key learning point. > What is the objective? Is it **manageable**, **measurable**, and **important**? > Leaving nothing out, write down all the different pieces of knowledge students will need to think about. Are they all necessary? > Write and label the critical links between these items of information. > Of these, which is the central learning point for the lesson?
Activity 2: Analyse	Display example and non-example of organisation and categorisation. (See Section 5b). Use the success criteria to evaluate them. Design a practice activity for this lesson.
Activity 3: Refine	> Refine your planning based on the success criteria.
Activity 4: Feedback	> Look at a partner's refined activity. Use the success criteria to give them feedback. **Success:** It was effective when… **Further improvement:** Next time, try…
Follow-up	> In your planning for this week, focus and act on this week's principle.

Part C: Glossary of key terms

Dual coding: Visual and verbal information are processed separately: this provides greater working memory capacity for students.

Elaborative interrogation: This method involves prompting the learner to read a fact-to-be-remembered and generate an explanation for it. The learner uses questions like 'Why?' and 'How?' to understand the meaning of the information, for example.

Expert: Someone with highly developed schemas representing large amounts of background knowledge and experience within a particular domain or topic within a domain. It may be better to consider the degree to which someone has expertise rather than whether they classify as an 'expert'.

Expertise reversal effect: The 'expertise reversal effect' is an important exception to the worked example effect. According to the expertise reversal effect, the heavy use of worked examples becomes less and less effective as learners' expertise increases, eventually becoming redundant or even counter-productive to learning outcomes.

Extraneous load: From Cognitive Load Theory. A proposed type of cognitive load arising from the method used to teach the subject matter. Examples of extraneous load are where materials split the attention of the learner, or where verbal and written materials are provided simultaneously. Extraneous load can be considered undesirable because it adds to the load upon working memory, but isn't related to helping to pupil learn.

Germane load: From Cognitive Load Theory. A proposed type of cognitive load arising from the effort required to process the learning material and directed towards schema development. Germane load can be considered desirable (some authors relate this to Bjork's concept of 'desirable difficulties).

Interleaving: Mixing practice to promote deeper processing, for example including questions involving the adding of fractions when practising the procedure for multiplying them.

Intrinsic load: From Cognitive Load Theory. A proposed type of cognitive load arising from the inherent complexity of the material to be learnt. Background knowledge influences how much intrinsic load arises when tackling material. For a very young child, for example, learning to write the letters of the alphabet is likely to have a high intrinsic load, but this would be much lower for a most children in the second or third year of school.

Mnemonics: A system such as a pattern of letters, ideas, or associations which assists in remembering something, A classic example is using an acronym 'ROY G BIV' to recall the order of colours in the visible part of the electromagnetic spectrum. Visual mnemonics (e.g. keyword method) exploit the fact that visual images and verbal information are encoded differently, increasing the cues available for retrieval.

Modality effect: Evidence suggests that working memory can be subdivided into verbal and visual streams, so presenting information using both verbal and visual working memory can increase working memory capacity. For example, when a diagram and text might be used to explain a concept, the written text may be better communicated in spoken form.

Novice: Someone who has little background knowledge or experience within a particular domain or topic within a domain.

Redundancy effect: The ‘redundancy effect’ occurs when learners are presented with additional information that is not directly relevant to learning, or with the same information in multiple forms. An example is a PowerPoint presentation in which the presenter reads the text presented on the screen.

Retrieval practice: (also sometimes referred to as practice testing, or test-enhanced learning). The finding that it is useful for people to test their knowledge of the to-be-remembered material during the studying process, instead of solely studying or reading the material.

Retrieval strength: A measure of how easily recalled something is currently, given what is relevant to the present situation (does it come to mind now?).

Cognitive Load Theory: A theory arising from cognitive science and educational psychology, closely associated with the researcher John Sweller. Cognitive load theory is built upon two commonly accepted ideas. The first is that there is a limit to how much new information the human brain can process at one time. The second is that there are no known limits to how much stored information can be processed at one time. The aim of cognitive load research is to develop instructional techniques and recommendations that fit within the characteristics of working memory, in order to maximise learning.

Schema: A framework or mental plan that helps organise and interpret information and deal with new experiences. Schemas help working memory by organising larger amounts of information into chunks.

Self-explanation: This technique encourages pupils to explain to themselves (aloud) facts and concepts they encounter during studying. (see also elaborative interrogation)

Spaced practice (also known as spaced repetition or distributed practice): is a learning strategy, where practice is broken up into a number of short sessions – over a longer period of time.

Split-attention effect: The ‘split attention effect’ occurs when learners are required to process two or more sources of information simultaneously in order to understand the material. This might occur, for example, when a diagram is used to explain a concept, but it cannot be understood without referring to a separate piece of explanatory text.

Storage strength: A measure of whether information is deeply embedded or well learned (is it likely to be recalled later?).

Worked example effect: A ‘worked example’ is a problem that has already been solved for the learner, with every step fully explained and clearly shown. The ‘worked example effect’ is the widely replicated finding that novice learners who are given worked examples to study perform better on subsequent tests than learners who are required to solve the equivalent problems themselves.

Working memory: The currently active part of long-term memory. Working memory has a very limited capacity (around 4 chunks) and duration (usually measured in seconds, a few minutes at most).

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