Improving Student Success in Senior Sciences Through Cognitive Science

Lionel Sandner

Last Year's Institute

Focus on three myths:

Knowledge is not important / content is irrelevant
Traditional testing is bad
Students are different now

Some Other System Myths

- Children are digital natives and think differently from previous generations.

- Children can multitask.

- With Google knowledge is no longer important

- Understanding a student's learning style is important to helping them learn

- Discovery Learning is the best way to learn

- School kills creativity

Why Focus on Learning Myths?

"breaking down myths is breaking down the status quo".

Gabor Mate – Myth of Normal

"Science and scientific literacy play a key role in educating citizens of today for the world of tomorrow. Critical to succeeding in this endeavour are the core competencies that provide students with the ability to think critically, solve problems, and make ethical decisions; to communicate their questions, express opinions, and challenge ideas in a scientifically literate way;…"

Check In

Where are we at?

The Problem - BCScTA Listserv

Teacher 1 (Jan 30, 2023)
I have been a teacher in BC for over 20 years. I teach Chemistry 11 and 12 almost exclusively, and have noticed a pretty serious decline in student preparedness for upper level sciences over the past 5 years. I don't think it all can be blamed on COVID.

Unfortunately, I don't have any data, only anecdotes drawn from my experience and those of my colleagues. Given how isolated we are, it is hard to get a sense if this is a local phenomenon or it is more widespread. We have been without provincial exams for a number of years, so reliable data is pretty hard to come by. I don't feel that the numeracy and literacy assessments are an accurate account of what's going on.

What is everyone else seeing?

The Problem - BCScTA Listserv

Teacher 2 (Jan 30, 2023)
I predominantly teach Physics 11/12 and some science 10 thrown in once and a while.
I see the exact same thing in my classes and it's getting worse. A slow but steady decline in processing skills, application of knowledge/skills into new situations, confidence in the process.

If they come up to ask a question it always ends with "That's what I was thinking, but just wanted to make sure," which tells me they had NO idea what they were supposed to be doing.

I'd like to see a return to at least scholarship exams for uni entrance as the course work isn't changing, but their drive to learn has.

The Problem - BCScTA Listserv

Teacher 3((Jan 31, 2023))

32 years teaching it has only been the last 5 years I have seen a huge drop. Anecdotal:

1. Covid, students were taught online, final exams were omitted, the bar was lowered to accommodate less than ideal situation.
2. The grade 8 and 9 program. No percentages just a scale. Students who have been passed on to higher grades that have completed very little. There is no incentive to work hard, and bad work habits are rewarded. This has created students that believe that they will pass, no matter how little they do. It has always worked out in the past attitude.
3. Bring back provincial exams. Without provincial exams course drift occurs, what is taught in one classroom can differ widely from another. It sets the bar high for teachers as your classroom mark was compared to the provincial mark.

The Problem - BCScTA Listserv

Teacher 4 (Jan 31, 2023)
It's not just sciences. We've noticed the same thing in mathematics.

The exceptional students are still exceptional. It seems to be that the average student is just less so.

As has been mentioned, we can't chalk it all up to Covid. I suspect (once again, anecdotal evidence) phone addiction is contributing to the problem. The average student just can't tear themselves away from their alerts and their screens.

I suspect homework suffers the same fate as class work because of phones - constant interruption and poor time management.

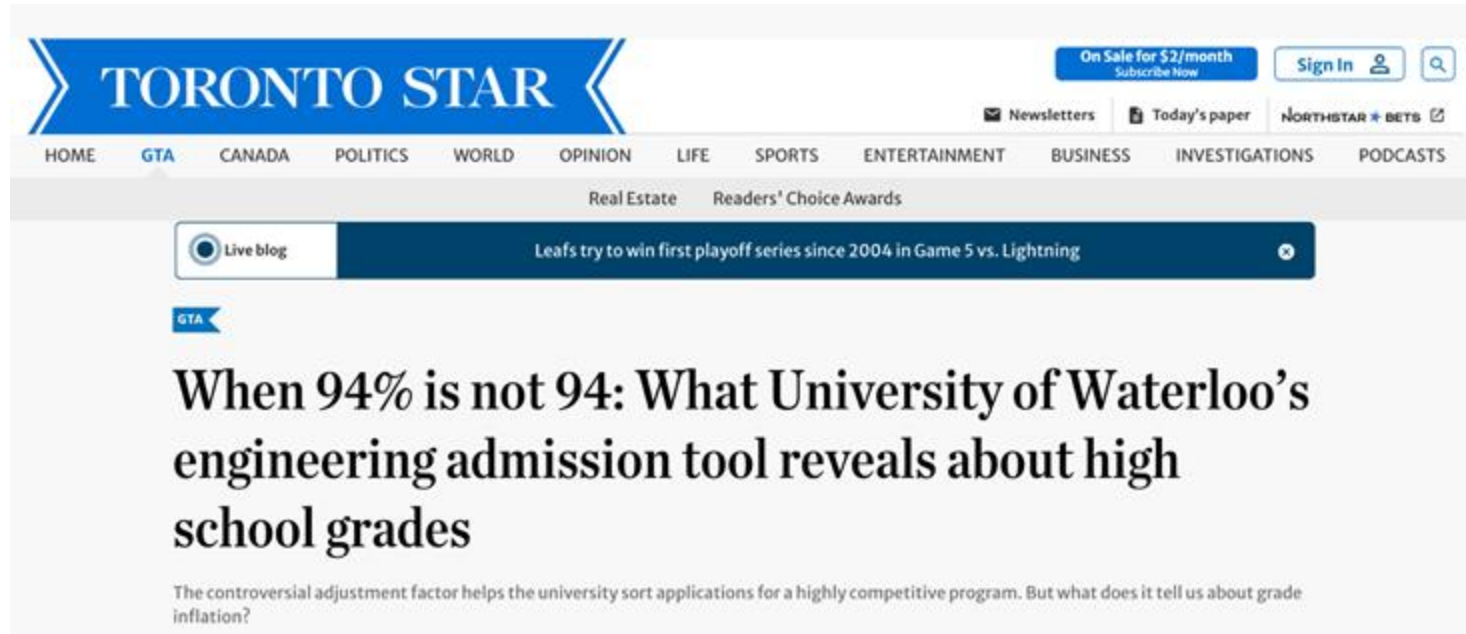# Transition from Grade 12 to First Year Post-Secondary
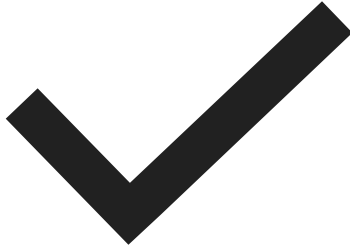
Grades

Additional support needed

University Transition

·   When a grade/mark isn't a mark - Toronto Star (April 8, 2023)

Measuring Up: Canadian Results of the OECD PISA 2022 Study

The Performance of Canadian 15-Year-Olds in Mathematics, Reading, and Science

cmec

Canada

PISA 2022

Trends in mathematics, reading and science performance

PISA test scores, OECD average
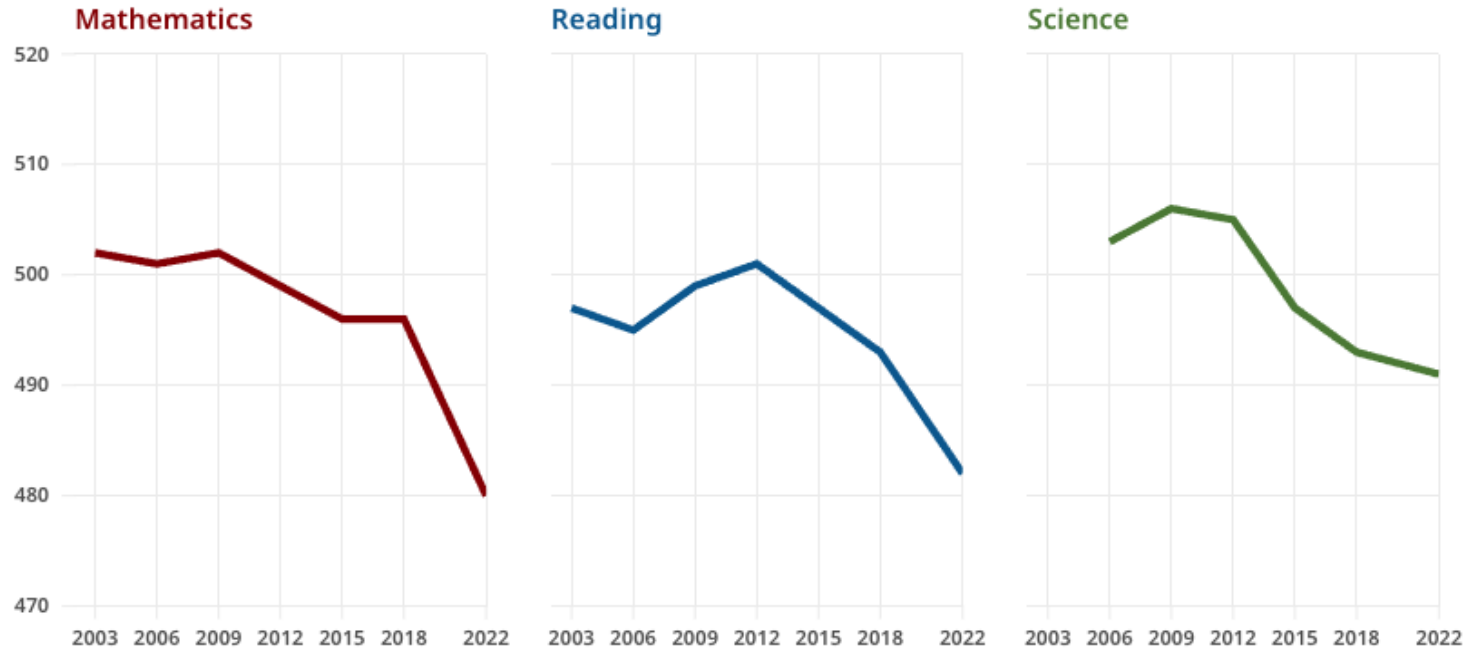
Source: OECD (2023), PISA 2022 Results (Volume I): The State of Learning and Equity in Education.

PISA 2022

"COVID probably played some role but I would not overrate it,"

OECD director of education Andreas Schleicher told a news conference.

PISA 2025

What are the implications for 2025 PISA-Science in BC?

Keynote at Walnut Grove – Oct 2019
(bit.ly/EdvantageProD2024)

The Good,
The Bad
and the Ugly

Reflections on 2018/2019
Senior Science Curriculum
Implementation.

The Good

Over the last 20 years, science education
in BC has been better than good.

✓ Sometimes a good curriculum
✓ Good resources
✓ Clear goals
✓ Great teachers

How Canada became an education superpower

Moving Forward

Some Learning Ah Ah's

The Brain is a Prediction Machine

Theory of Constructed Emotion

"Your brain is always predicting"

Lisa Feldman Barrett in *How Emotions are Made*

The Brain is a Prediction Machine

When you are thirsty and you have a drink of water, it takes 20 minutes for the water to get into your bloodstream.

Information Processing Model
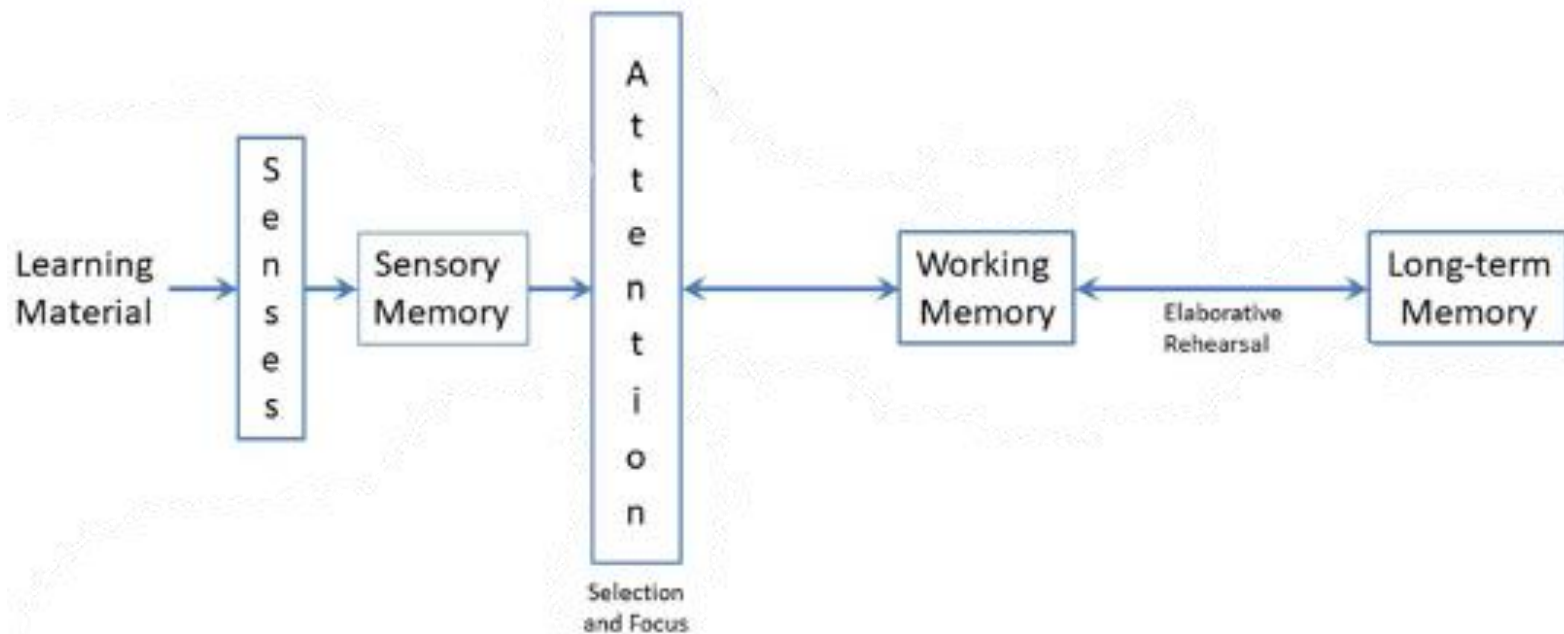
Cognitive Theory of Multimedia Learning (Mayer and Moreno)
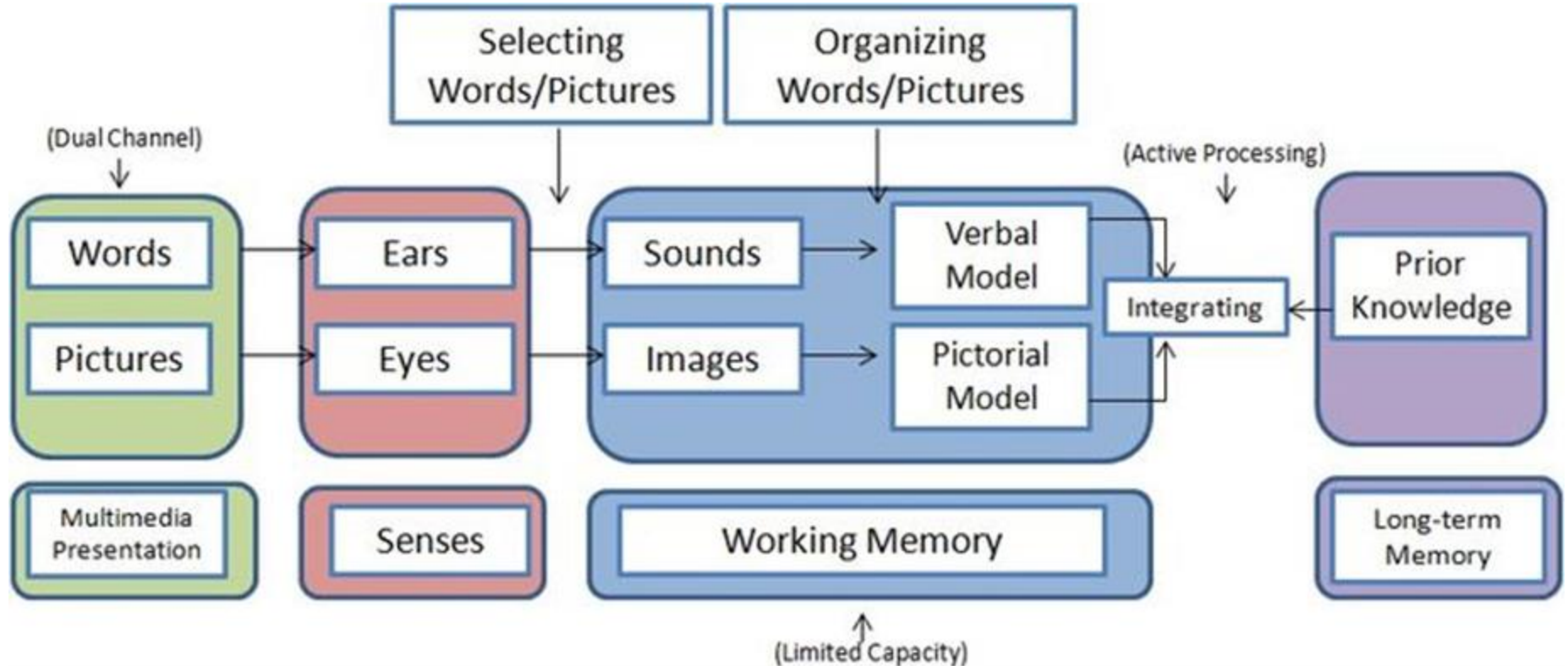
Three Assumptions in CTML

Mayer describes three assumptions in CTML that underlie how people learn:

Dual Channels - Humans possess separate channels for processing visual and auditory information.

Limited Capacity - Humans are limited in the amount of information that can be processed in each channel at one time.

Active Process - Humans engage in active learning by attending to relevant incoming information, organizing selected information into coherent mental representations and integrating mental representations with other knowledge.

Sensory Memory - Attention

Myth of multitasking or why mobile devices don't belong in the classroom

Stroop Effect

- the delay in reaction time between congruent and incongruent stimuli.

Stroop Effect - Step 1

STROOP EFFECT GAME
Part 1 - card A

Duration: 45 seconds
Purpose: Read aloud the words by following the lines, and this as quickly as possible. When you reach the end of the page, start again from the beginning.

GREEN	YELLOW	RED	BLUE	YELLOW
GREEN	RED	BLUE	GREEN	BLUE
RED	YELLOW	BLUE	GREEN	RED
YELLOW	YELLOW	GREEN	BLUE	RED
GREEN	YELLOW	BLUE	RED	RED
BLUE	YELLOW	GREEN	YELLOW	RED
GREEN	BLUE	RED	GREEN	BLUE
YELLOW	YELLOW	BLUE	RED	GREEN
BLUE	YELLOW	GREEN	RED	BLUE
GREEN	RED	YELLOW	GREEN	YELLOW

www.memozor.com

Stroop Effect - Step 2
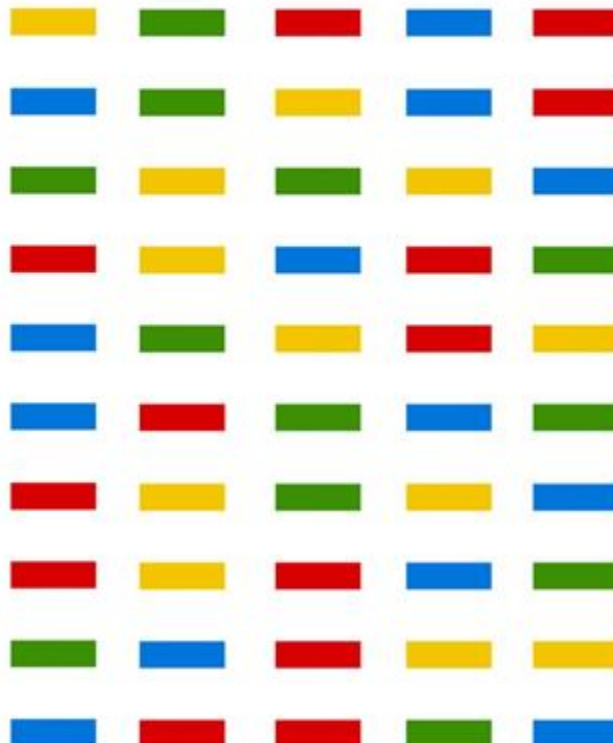
Stroop Effect - Step 3

STROOP EFFECT GAME
Part 3 - card B

Duration: 45 seconds
Purpose: By following the lines and as quickly as possible, name out loud the color of each word (not what the word says). When you reach the end of the page, start again from the beginning.

BLUE	YELLOW	BLUE	RED	BLUE
GREEN	YELLOW	RED	GREEN	YELLOW
GREEN	RED	GREEN	YELLOW	YELLOW
YELLOW	RED	YELLOW	GREEN	BLUE
BLUE	RED	YELLOW	YELLOW	GREEN
RED	BLUE	GREEN	YELLOW	GREEN
RED	YELLOW	BLUE	RED	GREEN
BLUE	GREEN	YELLOW	YELLOW	YELLOW
BLUE	RED	RED	YELLOW	RED
GREEN	BLUE	RED	GREEN	BLUE
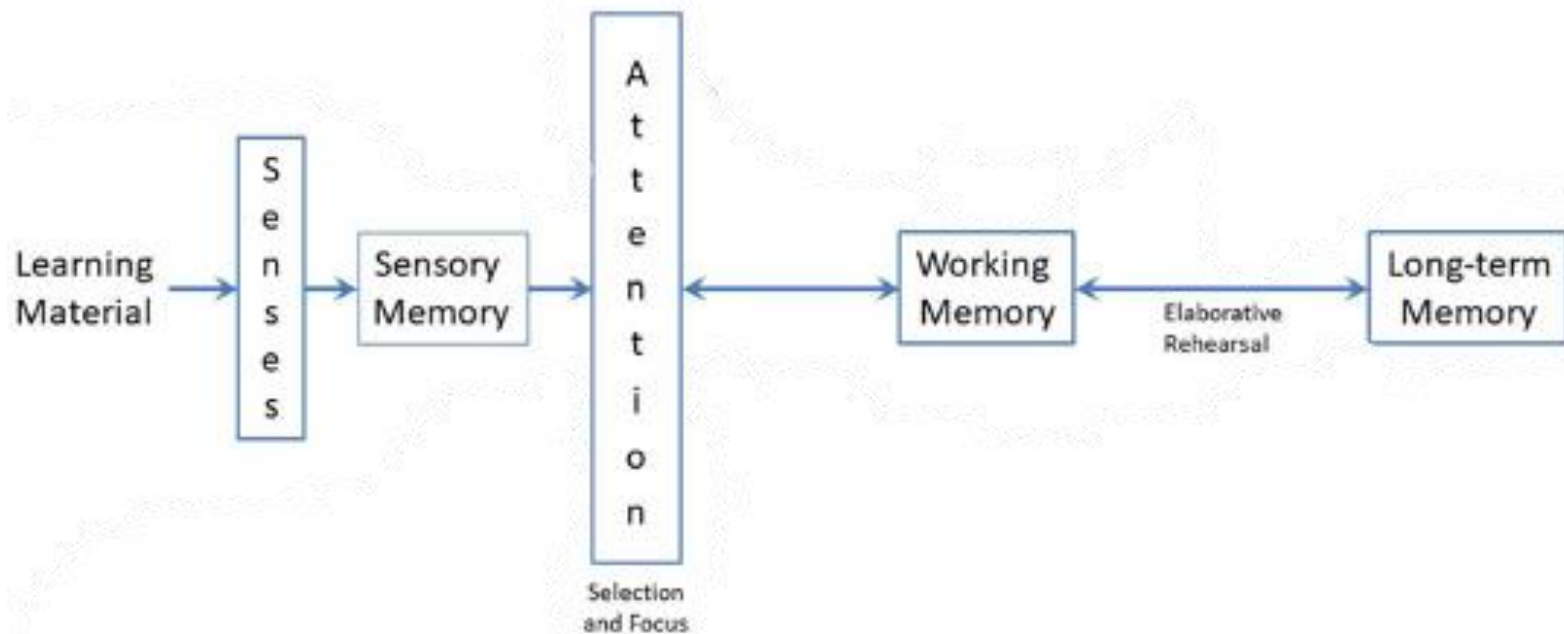
Working Memory

- 4 – 6 slots that can hold a chunk of information
- Holds information temporarily - 15 - 30 seconds
- Can hold unlimited amounts of information from long term memory for active processing

Example of how the brain chunks

Remember these letters

MoaStsmreohT.

Or

St. Thomas More

Information Processing Model
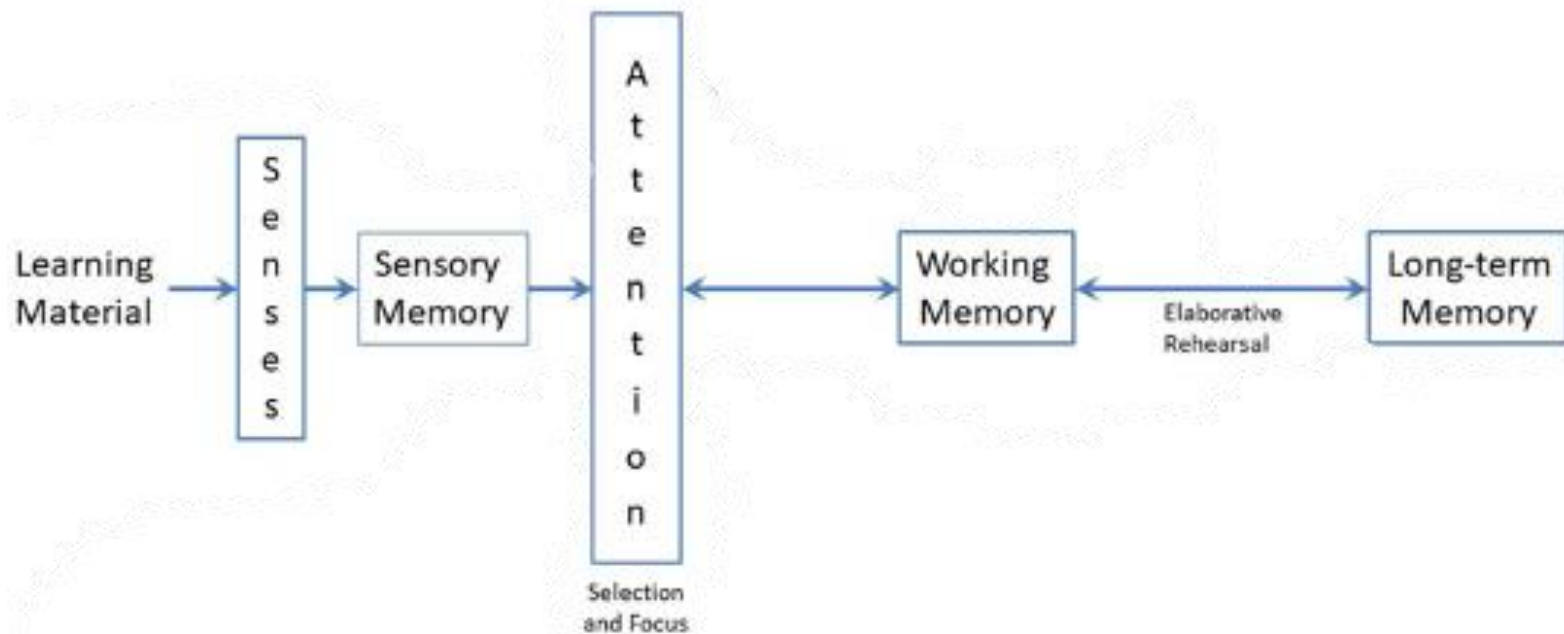
Long Term Memory - Efrat Furst

Working Memory

Long-term memory

KNOW
- ✓ Reduce distractions
- ✓ Focus attention
- ✓ Introduce separately

UNDERSTAND
- ✓ Explanations, Examples
- ✓ Models, Analogies
- ✓ Images and illustrations

USE
- ✓ Questioning
- ✓ Retrieval Practice
- ✓ Generative Learning

Practice to MASTER
- ✓ Spacing
- ✓ Variation
- ✓ Integration

@EfratFurst

https://sites.google.com/view/efratfurst/home
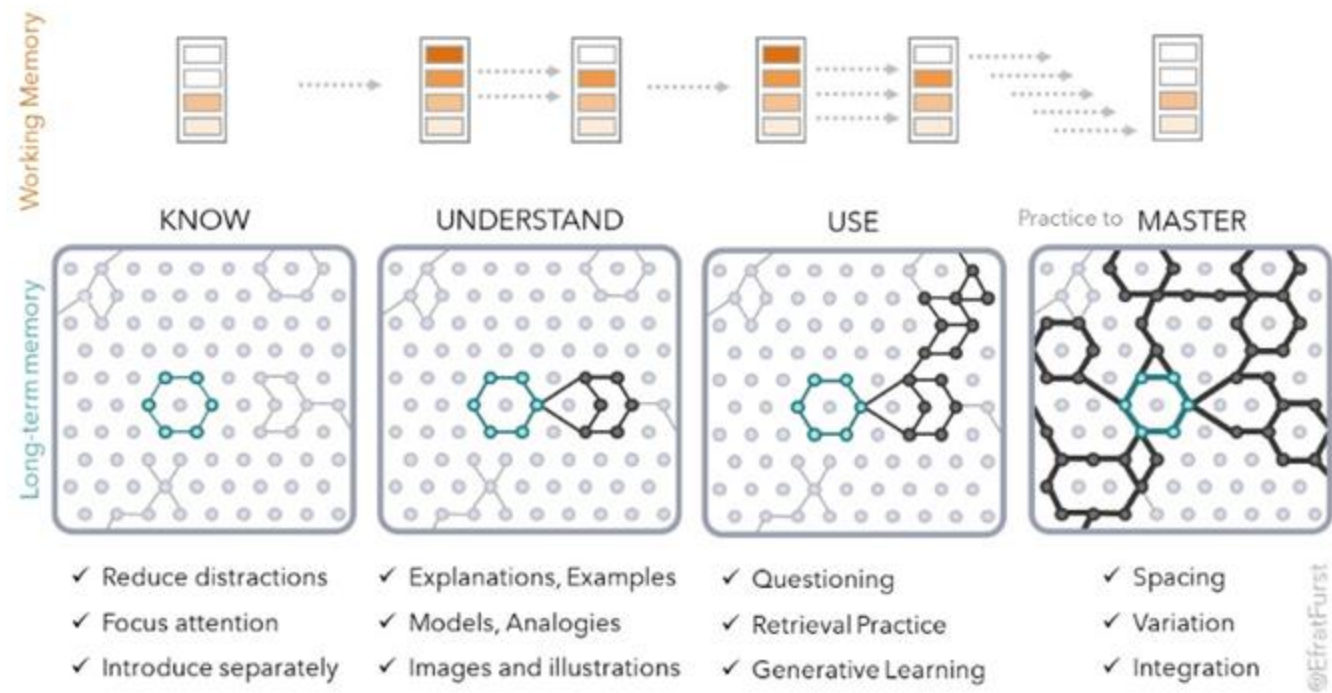
Choke Points and Pitfalls in Learning

From our Summer book club article:

Improving student success in chemistry through cognitive science, Hartman (2022)

Choke Points and Pitfalls in Learning

Choke Point
Mental effort or concentration is a limited resource
Solution
Overlearning and practice to make knowledge automatic

Choke Point
WM has a limited capacity of about 4 chunks of information
Solution
Chunking: Organize information into large chunks

Pitfall
Students often prefer the least effective study strategies for long-term learning
Solution
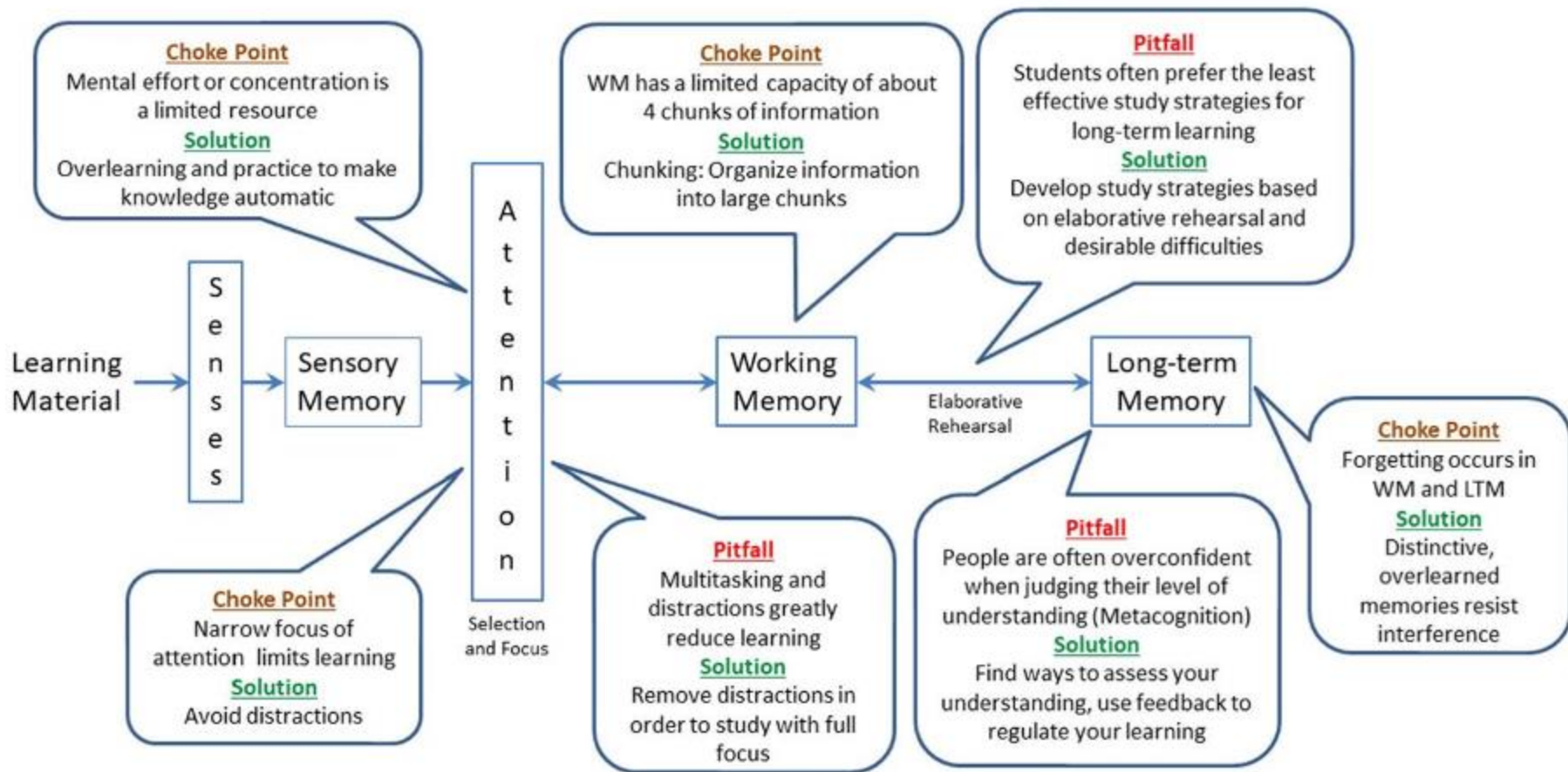Develop study strategies based on elaborative rehearsal and desirable difficulties

Learning Material → Senses → Sensory Memory → Attention ↔ Working Memory ↔ Long-term Memory

Attention: Selection and Focus

Elaborative Rehearsal

Choke Point
Narrow focus of attention limits learning
Solution
Avoid distractions

Pitfall
Multitasking and distractions greatly reduce learning
Solution
Remove distractions in order to study with full focus

Pitfall
People are often overconfident when judging their level of understanding (Metacognition)
Solution
Find ways to assess your understanding, use feedback to regulate your learning

Choke Point
Forgetting occurs in WM and LTM
Solution
Distinctive, overlearned memories resist interference

One More Consideration - Biological Knowledge

Folk
Knowledge

Domain
Specific
Content
Knowledge

Biologically primary	Biologically seconday
Knowledge is acquired "easily and unconsciously"	Conscious effort
Intrinsic motivation	Extrinsic motivation
Limited instruction required	Explicit instruction required
Long term memory important in knowledge acquisition	Long term memory important in knowledge acquisition
Working memory limitations are limited	Strong working memory limitations
Problem solving does not seem to apply	Problem solving/generate and test model essential

David Geary

Definition for Learning - Leanne

Learning is a structural and functional change in the brain.

Definition for Learning

Acquiring knowledge and skills and having them readily available from memory so you can make sense of future problems and opportunities.

Brown et al. (2104)

A Curricular Dilemma

Curriculum goal is to teach 21st Century Skills

But knowledge and skills are domain specific. A person needs deep knowledge to automate skills

Therefore, can't teach transferable 21st Century Skills

Curriculum Problems

· Curriculum provides only general guidance in competencies. And there is an assumption that the skills learned are transferable.

· Novices are not Experts – Prior Knowledge determines the quality of our problem solving. For example Chess Grand Masters (Chi et al. (1979)

·

NOVICE	EXPERT
No access to relevant schema	Possess schema for encoding elements into a single entity
Attempt to remember and process individual elements	Skills acquisition without needing to recall the rule
Need to apply cognitive capacity to inefficient problem-solving	Automation important for complex problem-solving transfer
Work backwards (means-end)	Work forwards

"Science and scientific literacy play a key role in educating citizens of today for the world of tomorrow. Critical to succeeding in this endeavour are the core competencies that provide students with the ability to think critically, solve problems, and make ethical decisions; to communicate their questions, express opinions, and challenge ideas in a scientifically literate way;…"

Strategies to Support Students

The Challenge

We have a curriculum that does not support current research in how we learn. We teach content heavy courses. How do we support our students be successful in our classes and in the future when teaching content is seen as undesirable to teaching skills?

Context	Strategy	Description
Planning When to Study	Spaced Practice	Creating a study schedule that spreads study activities out over time
	Interleaving	Switching between topics while studying
Developing Understanding	Elaboration	Asking and explaining why and how things works
	Concrete Examples	When studying abstract concepts, illustrating them with specific examples
	Dual Coding	Combining words with visuals
Reinforcing Knowledge	Retrieval Practice	Bringing learned information to mind from long-term memory

# Planning Learning – Spaced Practice

Ebbinghaus Effect
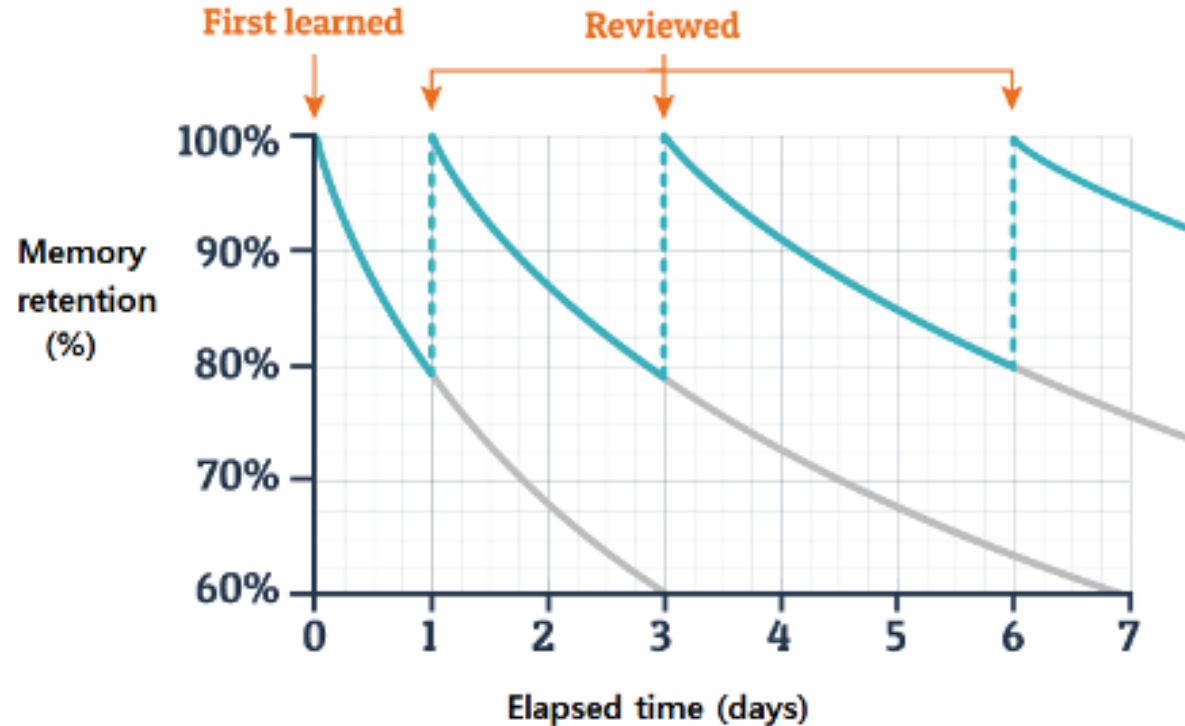
The Research

Effect of massed and spaced reading on immediate vs. delayed test

Six Learning Condition Groups in Rawson and Kintsch (2005)

| STUDY			TEST	
Single				
Group 1		Read	Immediate	
Group 2		Read		2 days later
Massed				
Group 3	Read	Re-Read	Immediate	
Group 4	Read	Re-Read		2 days later
Distributed – One week between readings				
Group 5	Read	Re-Read	Immediate	
Group 6	Read	Re-Read		2 days later

Results
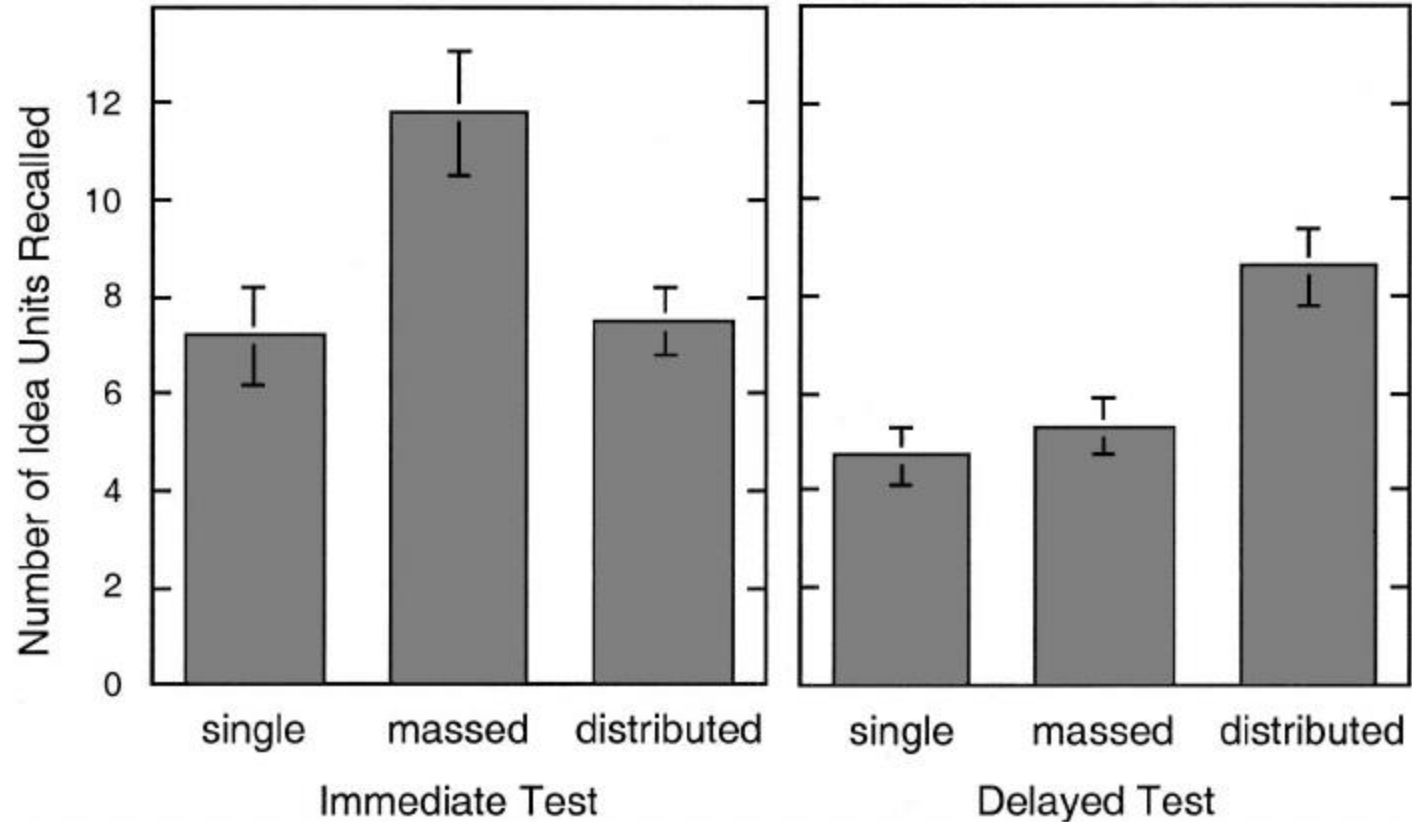
The Testing Effect - Retrieval Practice – Improving Learning by Self Testing

1. Research from Roediger and Karpicke from 2006 illustrates the effect of self-testing. In this experiment learners studied two texts (one about the sun and one about sea otters) for 7 minutes.

1. After a short break one group reread the text (Reread) while the other group wrote down everything they remembered about the texts (Retrieve).

1. Then both groups took three retention tests: one after 5 minutes, another one after 2 days and the last one after 1 week.

Results
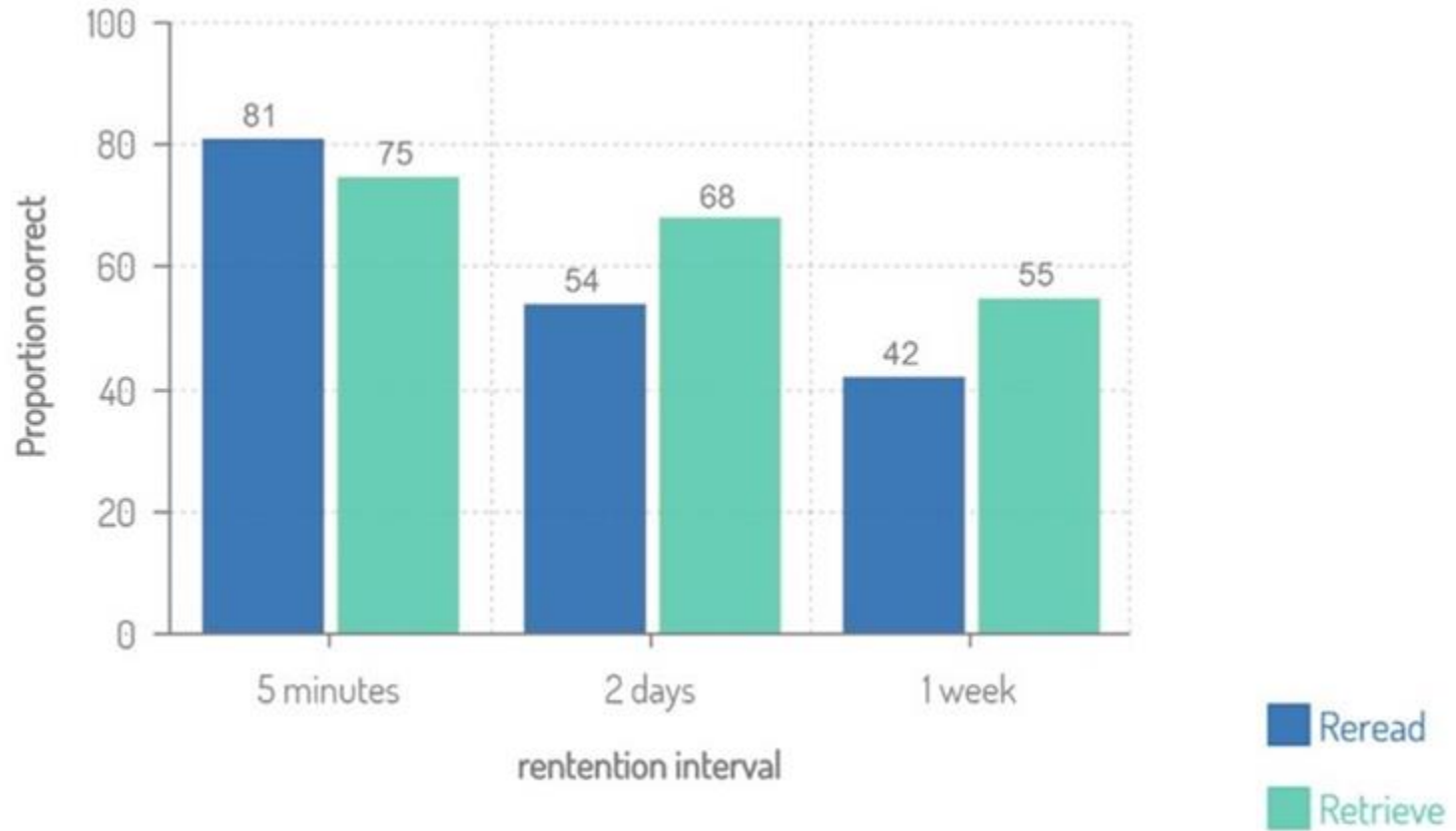
# Bonus Result

Reduced Test Anxiety

Why the Testing Effect Works

Whenever learners try to retrieve information from memory, the memory trace (engram) of that information (and related prior knowledge) is strengthened more than when learners reread the information (Dehaene, 2020).

Question – How do we use edvantagescience.com to support learning?

Other Practice Retrieval Options

Leitner Box: Flashcards
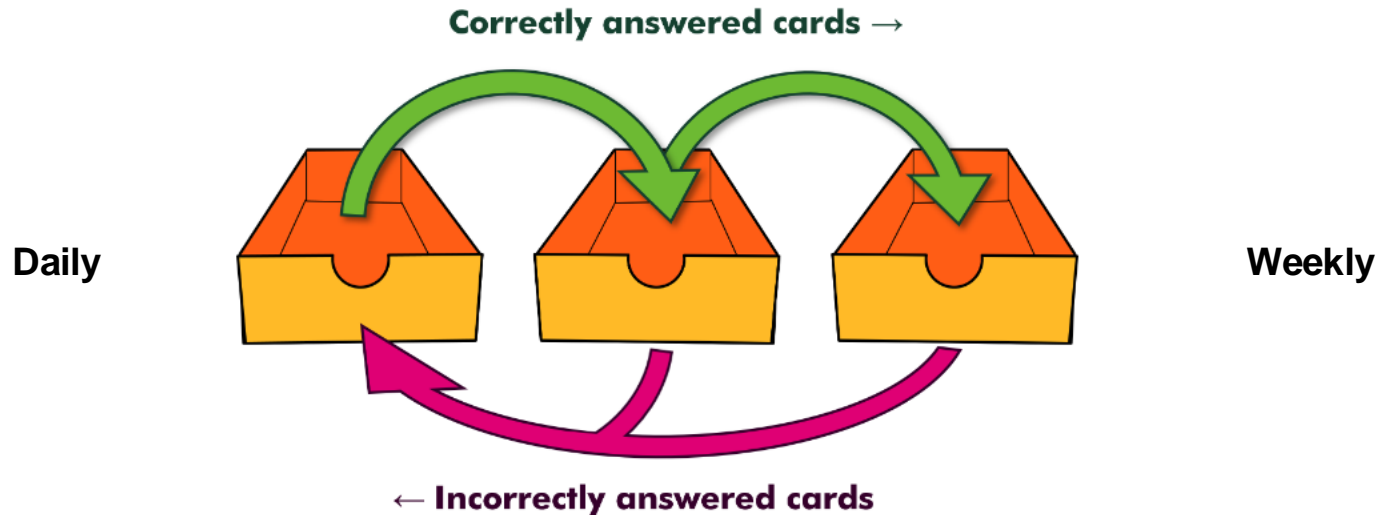
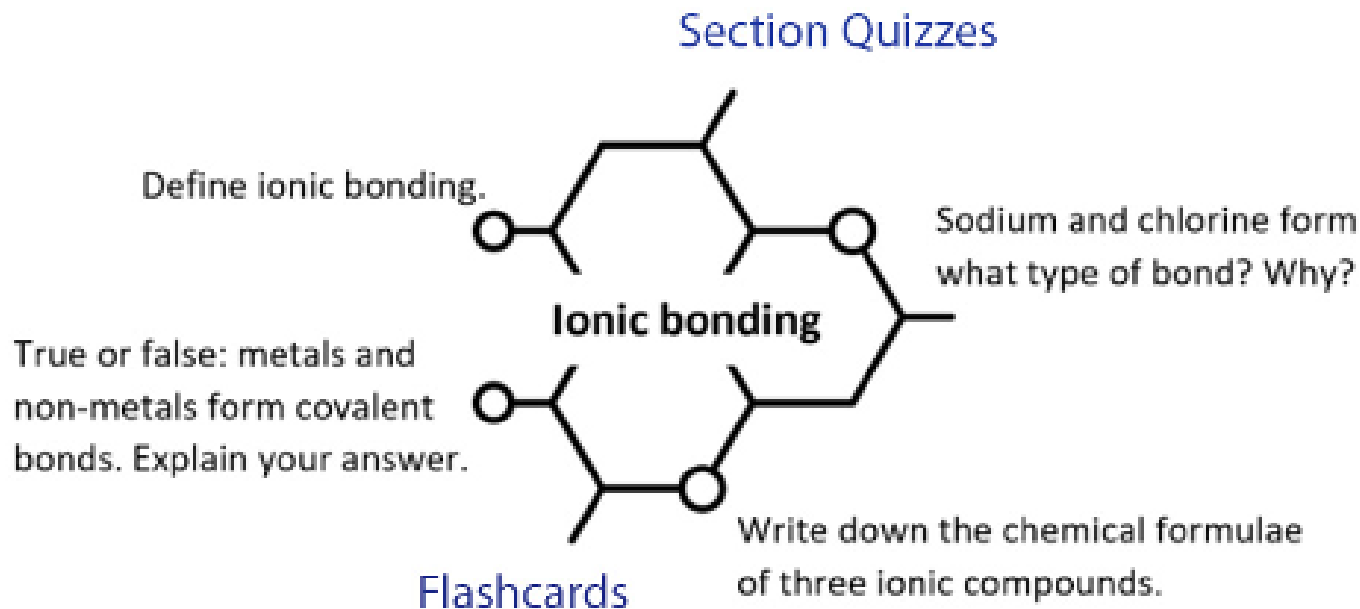# Retrieval Practice - Marking

❌ Wrong

✅ Correct, but not perfect

✅✅ Perfect

A Word of Caution about Retrieval Practice

Retrieval practice should vary between structure and choice as suggested by the graphic

Section Quizzes

Define ionic bonding.

Sodium and chlorine form what type of bond? Why?

Ionic bonding

True or false: metals and non-metals form covalent bonds. Explain your answer.

Write down the chemical formulae of three ionic compounds.

Flashcards

Solving Problems – Non-recurrent and Well Structured

Worked Example Effect

A *worked example* provides a step-by-step solution to a problem or task. The *worked example effect* occurs when learning is enhanced by studying worked examples to problems rather than by trying to solve the original problems. *Search: John Sweller*

Partially Worked Examples - scaffolding

Expertise Reversal Effect

Somethings to consider and coming soon to Edvantage Interactive

- Certainty Based Marking
- Gamification through badges

THANK YOU

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Organize images into four or more groups that make sense to you.

→

Give a label to each group

Study Habits

GOOD Study Habits

BAD Study Habits