Old Brain, New Insight:

Leveraging the science of learning to address current challenges in education

Dr. Leanne Ramer
lramer@sfu.ca

1

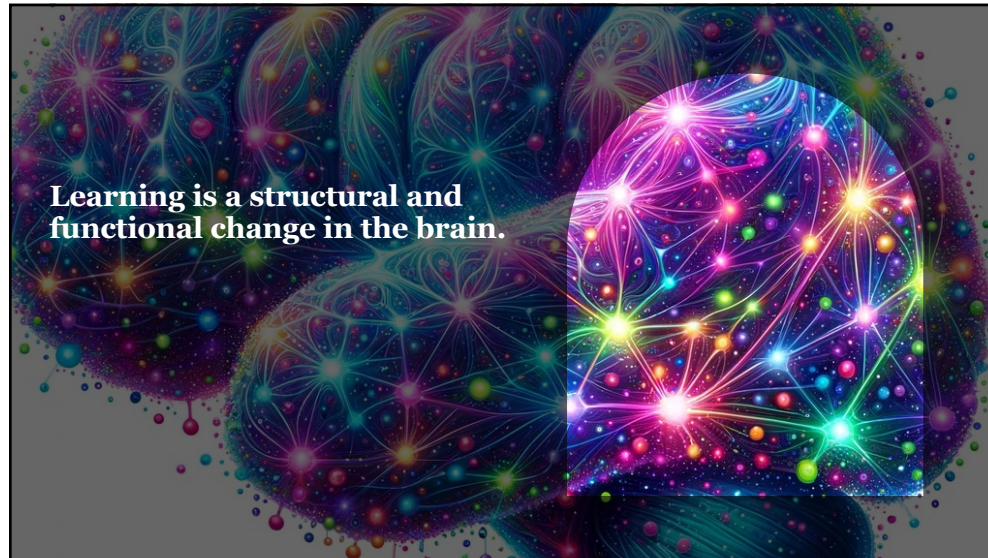A bit about me:

Senior Lecturer at SFU Burnaby

Teach primarily anatomy & neuroscience

Neuroplasticity is a central theme in my life.

Neuroplasticity:
How the nervous system changes with experience

2

Learning is a structural and functional change in the brain.
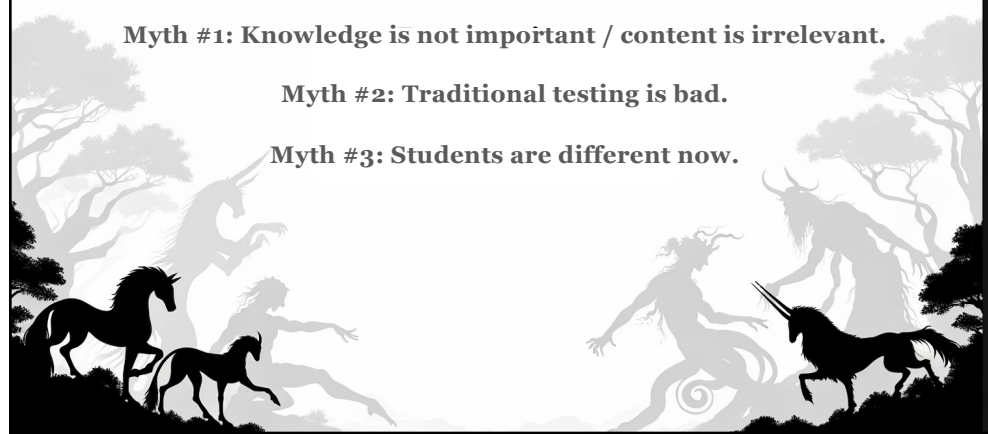
3

In our discussion today, I hope to dispel three myths that currently plague education:
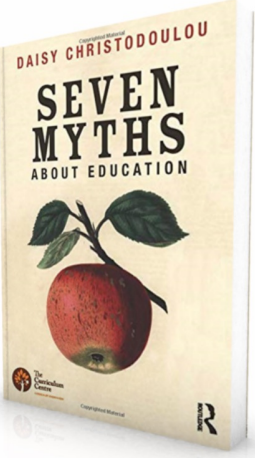
Myth #1: Knowledge is not important / content is irrelevant.

Myth #2: Traditional testing is bad.

Myth #3: Students are different now.

4

Why knowledge matters

In this controversial new book, Daisy Christodoulou offers a thought-provoking critique of educational orthodoxy. Drawing on her recent experience of teaching in challenging schools, she shows through a wide range of examples and case studies just how much classroom practice contradicts basic scientific principles. She examines seven widely-held beliefs which are holding back pupils and teachers:
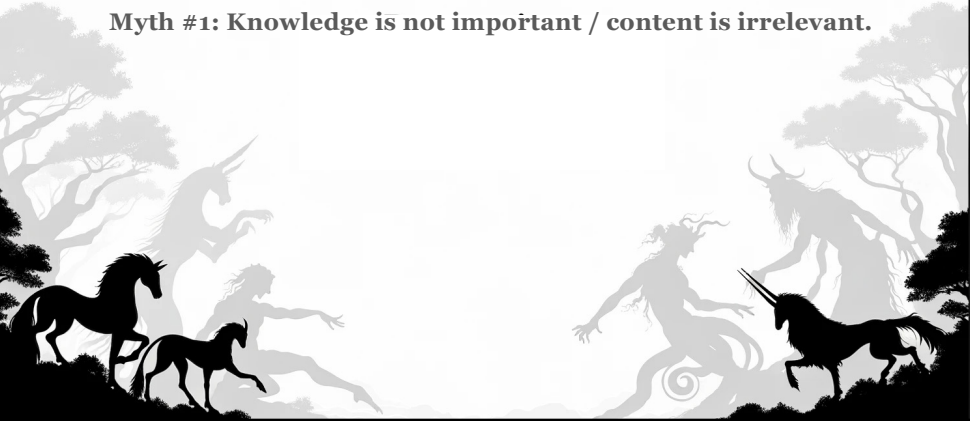
- Facts prevent understanding
- Teacher-led instruction is passive
- The 21st century fundamentally changes everything
- You can always just look it up
- We should teach transferable skills
- Projects and activities are the best way to learn
- Teaching knowledge is indoctrination.

In each accessible and engaging chapter, Christodoulou sets out the theory of each myth, considers its practical implications and shows the worrying prevalence of such practice. Then, she explains exactly why it is a myth, with reference to the principles of modern cognitive science. She builds a powerful case explaining how governments and educational organisations around the world have let down teachers and pupils by promoting and even mandating evidence-less theory and bad practice.

5

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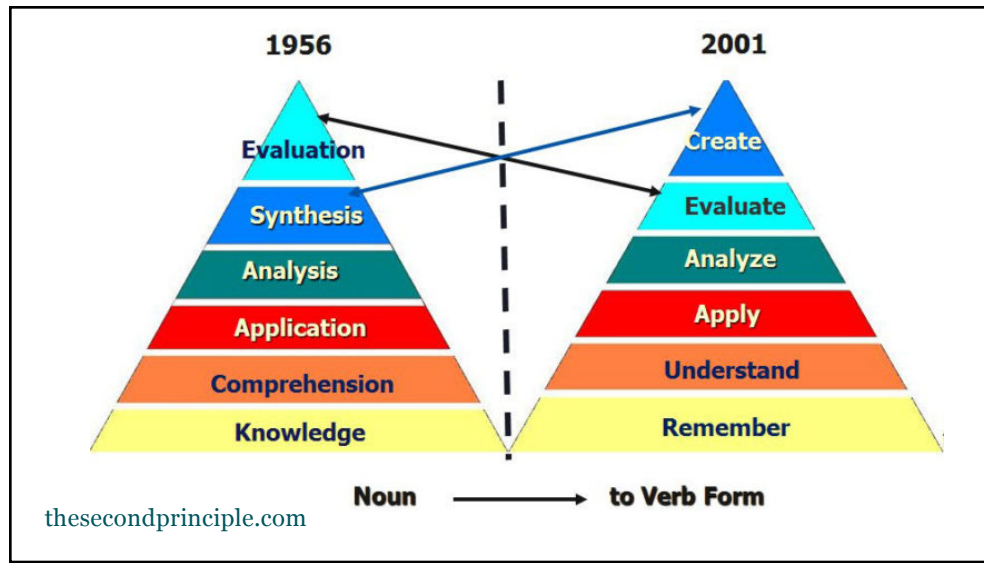
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3

FACT:
Foundational knowledge that is contextualized and readily retrievable is the prerequisite for analysis, evaluation, and creativity.

How did the knowledge and content become so maligned?

7

thesecondprinciple.com
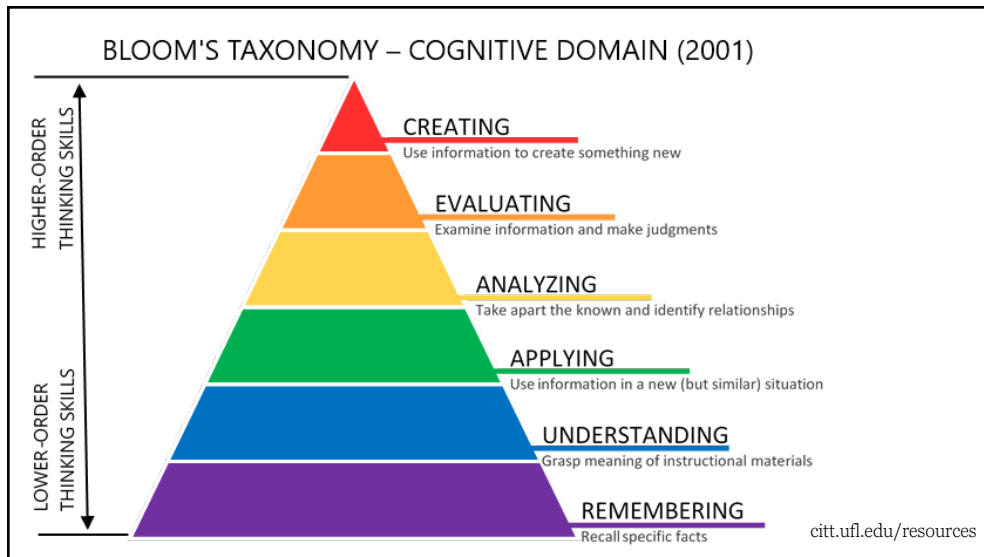
8

Here are my specific restrictions on usage.

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If you would like to use my material for a course, or in citing for a course or non-profit academic publication, I am usually happy that other professionals and students have found my materials helpful and will grant you access under the following conditions:

*This is my most important requirement! Because I believe that we can actively work toward creating a better, kinder world, users are duty bound to commit at least one random act of beauty or kindness for each concept used — no kidding!!!

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BLOOM'S TAXONOMY – COGNITIVE DOMAIN (2001)

HIGHER-ORDER THINKING SKILLS

CREATING — Use information to create something new

EVALUATING — Examine information and make judgments

ANALYZING — Take apart the known and identify relationships

APPLYING — Use information in a new (but similar) situation

UNDERSTANDING — Grasp meaning of instructional materials

REMEMBERING — Recall specific facts

LOWER-ORDER THINKING SKILLS
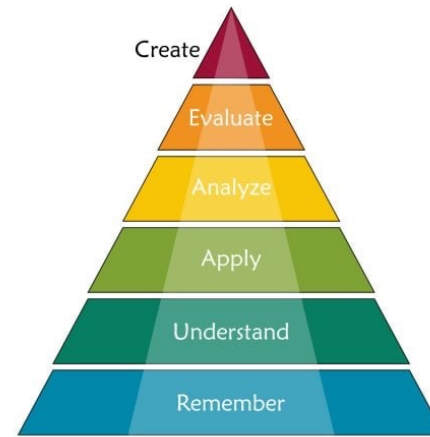
citt.ufl.edu/resources

10

Depicting Bloom's Taxonomy as a pyramid has created the widespread perception that knowledge & basic skills are inferior to critical thinking, making judgements, and creating new knowledge.

... And this is particularly prevalent in higher education.

REVISED BLOOMS TAXONOMY

Create
Evaluate
Analyze
Apply
Understand
Remember

simplypsychology.org

11

academic ego

12

Knowledge matters!

Photo 4. Paddy straw mushroom, *Volariella volvacea*, showing the lack of a ring on the stem or stipe. Compare with the death cap (Photo 5).

Photo 5. Death cap, *Amanita phalloides*, clearly showing the ring on the stem. This mushroom is deadly poisonous.

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Foundational knowledge has never been more important than right now.

1. In the information age, educators are compelled to select, evaluate, distill and contextualize knowledge.

2. Cognitive neuroscience has demonstrated that without foundational knowledge in long term memory that can be readily retrieved, "higher" level thinking is impossible.

14

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15

```
I      I   I        I     IIIIIII     I          I  I     IIIIIII  IIIIIIII    IIIIIII    IIIIIII
N      N   NN       N     N       N   N          N  N     N        N         N  N       N  N
F     F    F F      F     F       F   F   F   F  F  F     F        F         F  F          F
O   O      O  O     O  O  O       O   O   O   O  O  O     O        O         O  O          O
R R        R    R   R     R       R   R   R   R  R  R     RRRRR     R         R  R    RRRR   RRRRR
MMM        M     M  M     M       M   M   M   M  M  M     M        M         M  M      M    M
A   A      A      A A  A  A       A   A   A   M  A  A     A        A         A  A      A A   A
T    T     T        TT T  T       T   T   T   T  T  T     T        T         T  T      T T   T
I    I     I        I  I  I       I   I   I   I  I  I     I        I         I  I      I I   I
O      O   O        O  O  O       O   O   O   O  O  O     O        O         O  O      O O   O
N      N   N        N     NNNNNNN     NNN NNN    NNNNNNN  NNNNNNN  NNNNNNNN    NNNNNNN   NNNNNNN
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What do you see in this image?

Gerace, 1992

16

Information does not equal knowledge.

Educators are curators:

From the Latin *curare*, to care.

- We pick what we value.

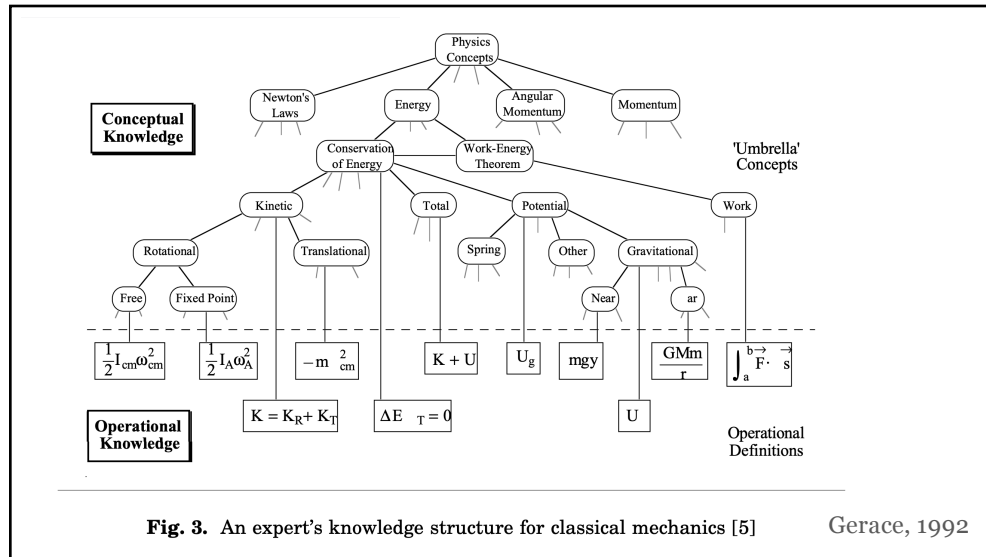- We find, critically evaluate, and foster meaningful connections among "pieces" of information.

17

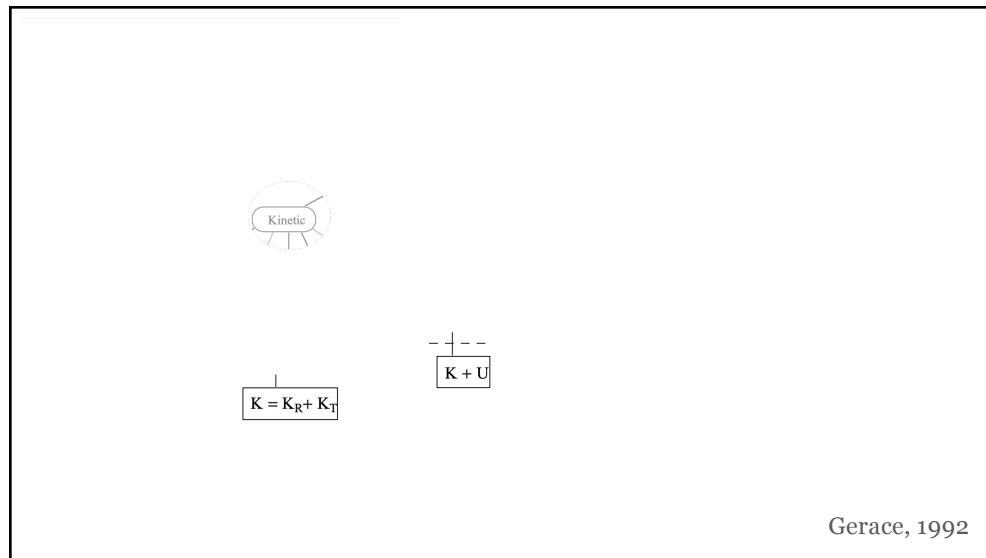**Table 1.** A summary of expert–novice differences

	Experts	Novices
Knowledge Characteristics	Large store of domain-specific knowledge	Sparse knowledge set
	Knowledge richly interconnected and hierarchically structured	Disconnected and amorphous structure
	Integrated multiple representations	Poorly formed and unrelated representations
Problem-Solving Behavior	Conceptual knowledge impacts problem solving	Problem solving largely independent of concepts
	Performs qualitative analysis	Manipulates equations
	Uses forward-looking concept-based strategies	Uses backward-looking means–ends techniques

Gerace, 1992

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Fig. 3. An expert's knowledge structure for classical mechanics [5]

Gerace, 1992

19

Gerace, 1992

20

```
KK       KK   KK    KKKKK    KKKKK       KKK      KKK      KKK
NN   NN  NN   NN    NNN NNN  NNNNNN      NNNNN    NNNN    NNNN
OO   OO  OO   OO    OO    O  OO    OO    OO   OO  OO   OO  OO
WW   WW  WW   WW    WW       WW    WW    WW   WW  WW   WW  WW
LL   LL  LL   LL       LLL   LL    LL    LL   LL  LL   LL  LL
EE   EE  EE   EE          EE EE    EE    EE   EE  EE   EE  EE
DD   DD  DD   DD    D    DD  DD    DD    DD   DD  DD   DD  DD
 GGGGGGGG     GG    GGG GGG  GGGGGG      GGGGG    GG   GG  GG
  EEE EEE     EE    EEEEE    EEEEE       EEE      EE         EE


I    I  I      I   IIIIIII   I      I  I  IIIIIII IIIIIIII  IIIIIII  IIIIIII
N    N  NN     N   N      N  N      N  N  N       N      N  N      N N
F   F   F F    F   F      F  F  F   F  F  F       F      F  F      F        F
O   O   O  O   O   O      O  O  O   O  O  O       O      O  O      O        O
R R     R  R   R   R   R  R  R  R   R  RRRRR      R      R  R   RRRR   RRRRR
MMM     M  M M M   M   M  M  M  M  M   M          M      M  M   M M    M  M
A  A    A  A A A   A   A  A  M  A      A          A      A  A      A    A
T   T   T    TT A   T   T  T  T  T      T          T      T  T      T    T  T
I   I   I    I   I   I   I  I  I  I      I          I      I  I      I    I  I
O     O O    O   O   O   O  O  O  O      O          O      O  O      O    O  O
N     N N    N   NNNNNNN   NNN NNN  NNNNNNN NNNNNNN NNNNNNNN  NNNNNNN  NNNNNNN
```

Foundational knowledge has never been more important than right now.

1. In the information age, educators are compelled to select, evaluate, distill and contextualize knowledge.

2. Cognitive neuroscience has demonstrated that without foundational knowledge in long term memory that can be readily retrieved, "higher" level thinking is impossible.
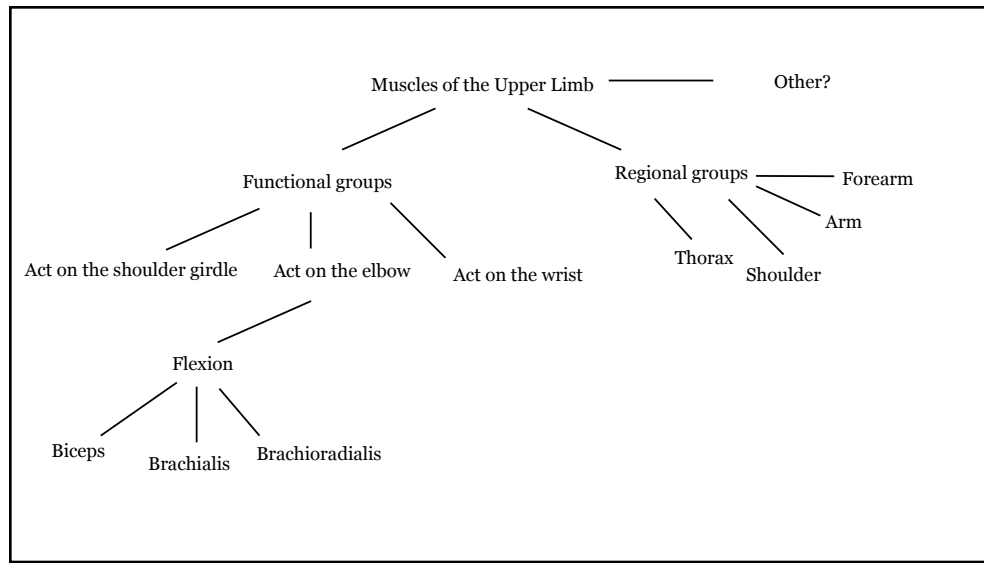
How can we reinforce the importance of foundational knowledge in our teaching?

Make our expert knowledge structure visible to students.

- Create a knowledge structure for courses/lessons (and complete it with students)

- Use a knowledge structure as a living syllabus

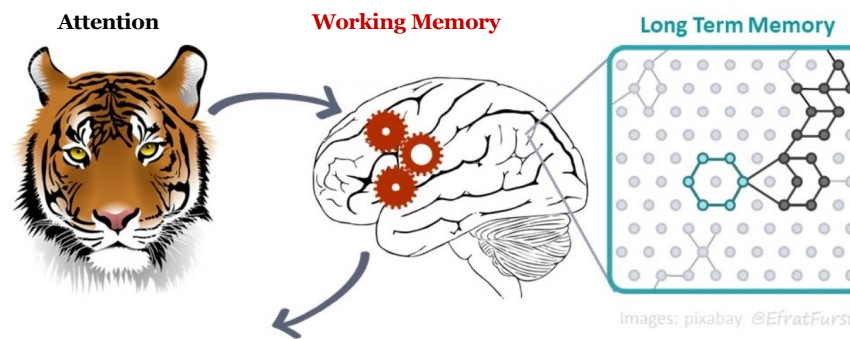- Offload nodes of the structure to create explicit direction for independent learning

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24

Foundational knowledge has never been more important than right now.

1. In the information age, educators need to select, evaluate, distill and contextualize knowledge.

2. Cognitive neuroscience has demonstrated that without foundational knowledge in long term memory that can be readily retrieved, "higher" level thinking is impossible.

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Our knowledge is stored in specific patterns of activity in the brain.

Attention   Working Memory   Long Term Memory

Images: pixabay @EfratFurst

https://sites.google.com/view/efratfurst/learning-in-the-brain

26
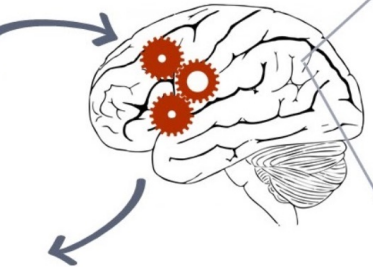
Working memory is very limited:

It can hold small amounts of information for a short time and using it is energetically costly & challenging.

Working Memory

The limited capacity and high energetic cost of working memory creates **cognitive load.**

https://sites.google.com/view/efratfurst/learning-in-the-brain
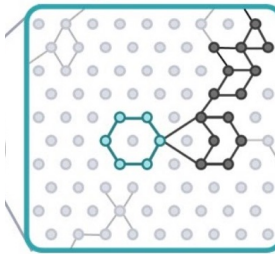
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Long term memory is unlimited (in comparison): It can store large amounts of information semi-permanently.

With extensive practice, information can be automatically recalled from long term memory with minimal conscious effort. This 'automation' reduces cognitive load, because when information can be accessed automatically, the working memory is freed up to learn new information.

Long Term Memory

Images: pixabay @EfratFurst

https://sites.google.com/view/efratfurst/learning-in-the-brain

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David Didau
learningspy.co.uk/learning/novice-expert-model-learning/

29

In problem-solving, experts exhibit less brain activity in working memory centres than non-experts.

30

15

Experts exhibit less brain activity in the working memory centres than non-experts.

31

David Didau
learningspy.co.uk/learning/novice-expert-model-learning/

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Two main hallmarks of expertise:

1. Automaticity of foundational/procedural knowledge

2. Ability to see deep structure

(In order to achieve higher levels of cognitive function), we need to master procedural knowledge to the point where we no longer have to think about it **so that it doesn't take up space in working memory.**

David Didau

https://learningspy.co.uk/learning/novice-expert-model-learning/
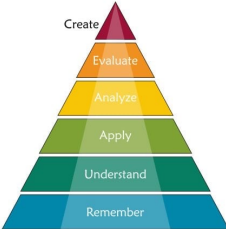
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Novices	Experts
Little relevant background knowledge	Lots of relevant background knowledge
Relies on working memory	Relies on long-memory
Lacks effective mental representations of successful performance	Has a clear mental representation of successful performance within a domain
Has not automatised necessary procedural knowledge	Necessary procedural knowledge has been automatised.
Only has explicit knowledge	Possesses huge reserves of tacit knowledge
Problem solving requires following clear steps	Problem solving is intuitive
Sees superficial details	Sees underlying structures
Learns little when exposed to new information	Learns a lot when exposed to information about which they are already knowledgeable
Learns best through explicit instruction and worked examples	Learns best through discovery approaches
Is more likely to experience cognitive overload as attention is swamped by new information	Is less likey to experience cognitive overload as attention is buttressed by memorised 'chunks' of knowledge
Struggles to transfer principles to new contexts	Is able to transfer principles between related domains

David Didau

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Novice Stage Learning	Proficient Stage Learning
Characteristics	**Characteristics**
Follows the rules and plans. Acquires information as a prerequisite to learning; Does not feel responsible except for following the rules; Has no discretionary judgment; Spends time remembering information; Attempts to conform behavior to the rules; Learning is context dependent.	Increased sense of responsibility and confidence; Clearly and quickly sees what is relevant and irrelevant; Perceives appropriate deviations from normal rules or patterns; Anchors solving new problems in the context of prior experience; Deep understanding of rules, theories and alternative options; Decision-making less labored, more automatic and starts to develop intuition.

Moving from Novice to Expertise and Its Implications for Instruction
Adam M. Persky, PhD   [a] and Jennifer D. Robinson, PharmD
Am J Pharm Educ. 2017 Nov; 81(9): 6065.
 doi: 10.5688/ajpe6065
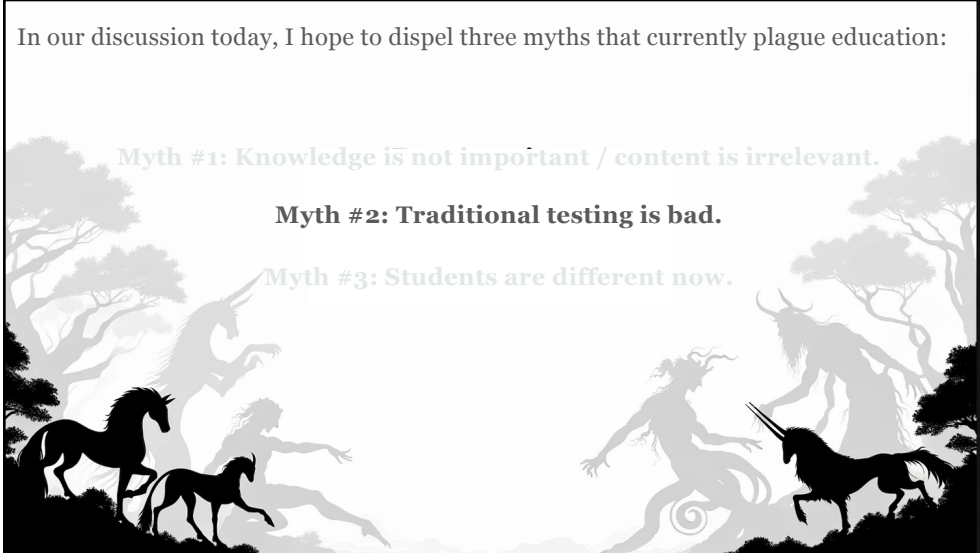
Create
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36

18

In our discussion today, I hope to dispel three myths that currently plague education:

Myth #1: Knowledge is not important / content is irrelevant.

Myth #2: Traditional testing is bad.

Myth #3: Students are different now.

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FACT: Testing is an extremely effective learning strategy that is supported by evidence and based in cognitive neuroscience.

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In 1620, Francis Bacon wrote, "If you read a piece of text through twenty times, you will not learn it by heart so easily as if you read it ten times while attempting to recite from time to time and consulting the text when your memory fails."

Bacon identified the importance of **retrieval practice**.

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Retrieval Practice Produces More Learning than Elaborative Studying with Concept Mapping

JEFFREY D. KARPICKE AND JANELL R. BLUNT   Authors Info & Affiliations

- 80 undergraduate students studied a science text under one of four conditions:

   i) Single study period
   ii) Four consecutive study periods
   iii) Concept mapping (with instruction on CM and examples)
   iv) Single study period + free recall + restudy + free recall

- They asked students to predict how much they learned through each approach (based on how they expected to perform on a test one week later)
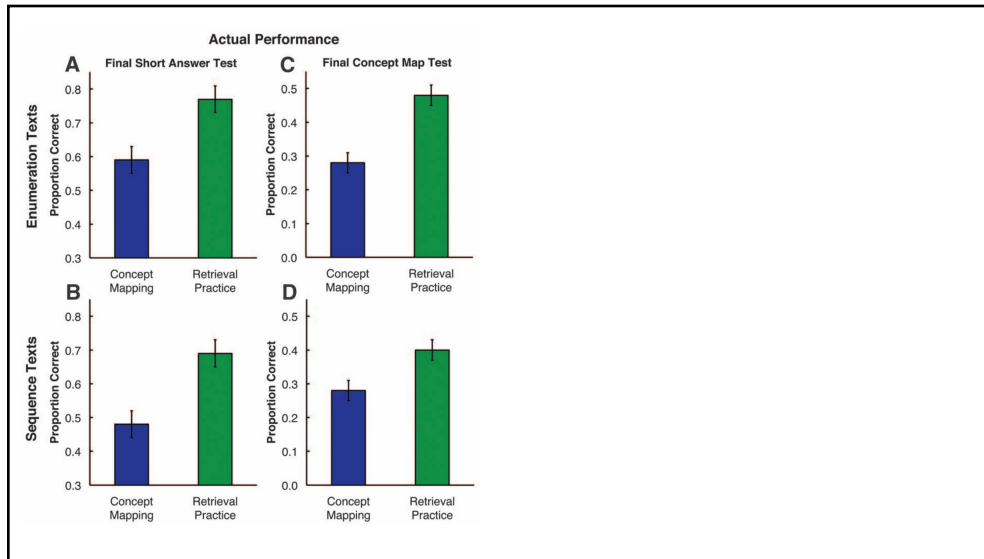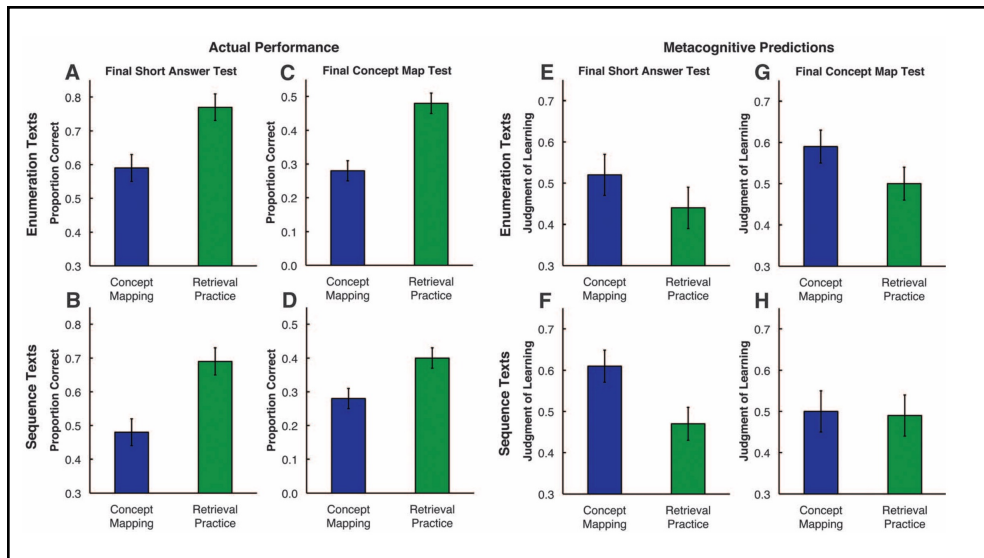
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Retrieval practice resulted in ~50% improvement.

41

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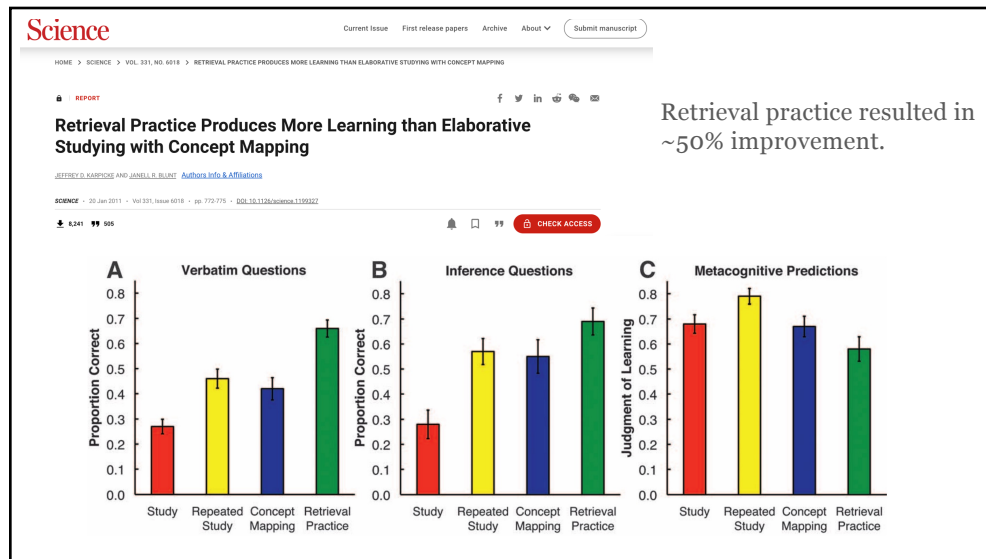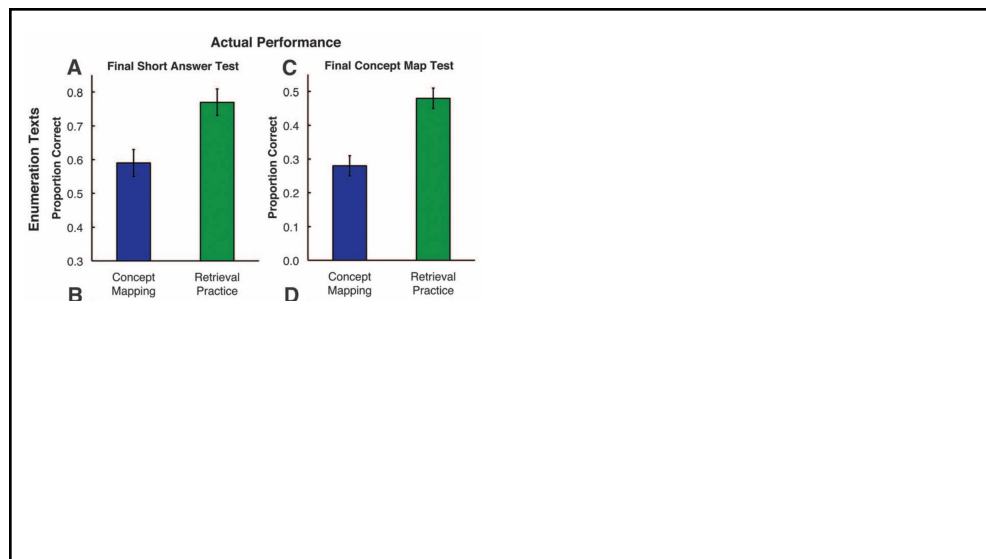
43

44

This single study showed that, in undergraduate science:

- Testing outperformed even complex learning strategies, like concept mapping

- Testing outperformed concept mapping, even when the final test involved concept mapping

- Students had little-to-no metacognitive insight into the testing effect.

45

The testing effect is supported by an enormous body of evidence, across every age group and level of learning, from elementary school students to university undergraduates to medical students, residents, and faculty.
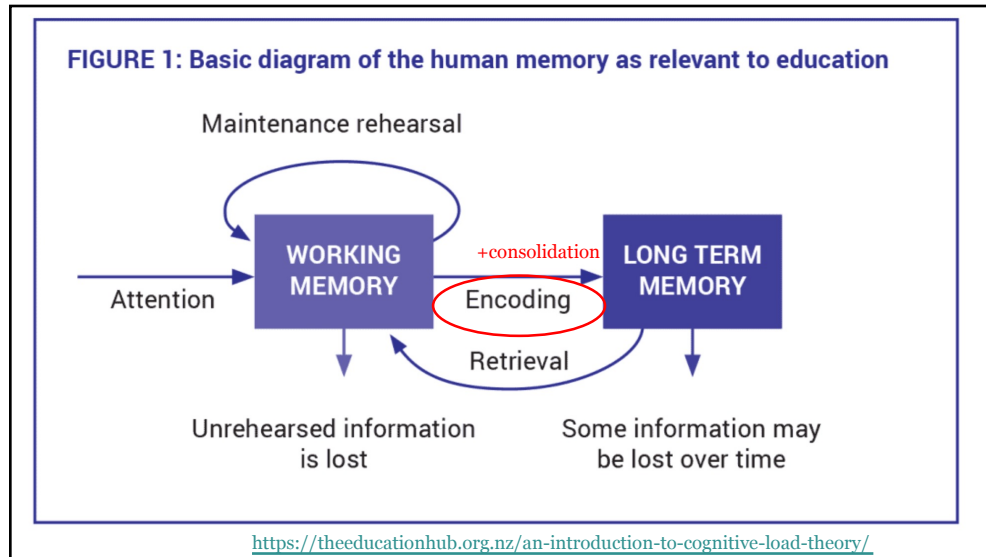
Long-standing debates around optimizing the testing effect but the summary is simple:
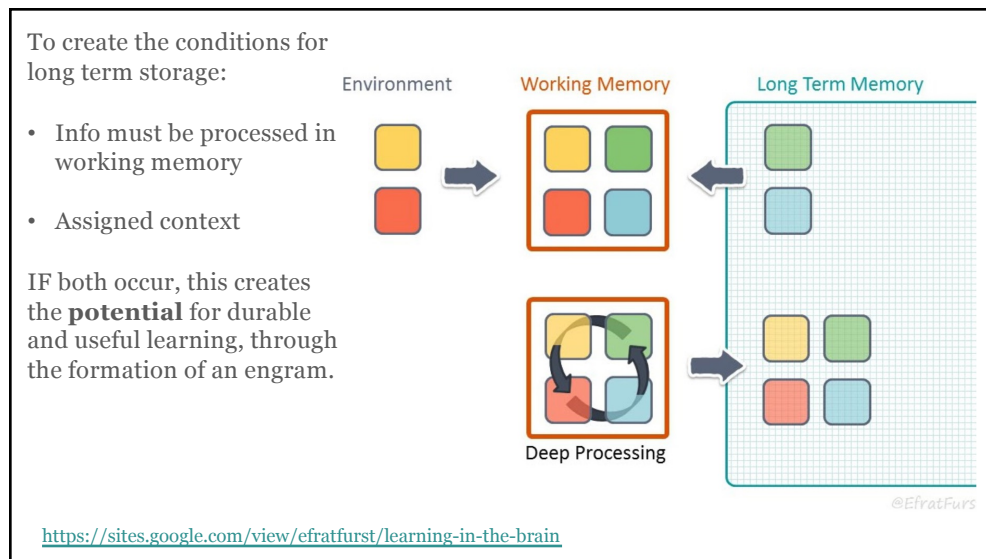**Any testing is better than no testing.**

Predictive power or pre-testing effect: testing before mastery primes for encoding

- Can be pure guesswork, and effective even when feedback is delayed (Zawadzka et al., 2023)
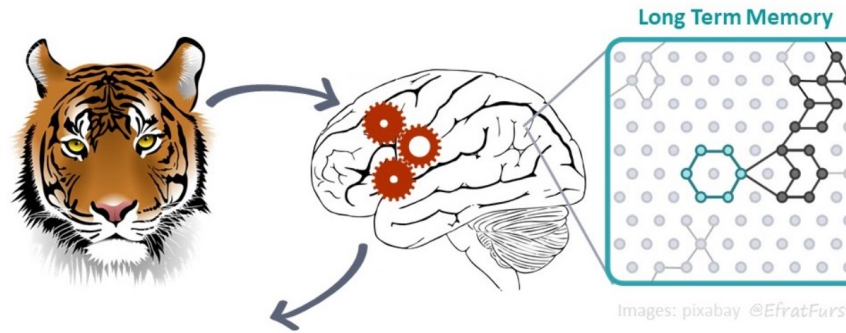
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FIGURE 1: Basic diagram of the human memory as relevant to education

Maintenance rehearsal

WORKING MEMORY → +consolidation → LONG TERM MEMORY

Attention

Encoding

Retrieval

Unrehearsed information is lost

Some information may be lost over time

https://theeducationhub.org.nz/an-introduction-to-cognitive-load-theory/

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To create the conditions for long term storage:

• Info must be processed in working memory

• Assigned context

IF both occur, this creates the **potential** for durable and useful learning, through the formation of an engram.

Environment   Working Memory   Long Term Memory

Deep Processing

@EfratFurs

https://sites.google.com/view/efratfurst/learning-in-the-brain

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An "engram" refers to the enduring offline physical and/or chemical changes in the brain that are elicited by learning and underlie the newly formed memory associations.

Long Term Memory

Images: pixabay @EfratFurst

https://sites.google.com/view/efratfurst/learning-in-the-brain

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The initial pattern of activity does not constitute durable or useful knowledge:
Reconsolidation (through retrieval practice) is essential.

https://www.nature.com/articles/nrn4000.pdf

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25
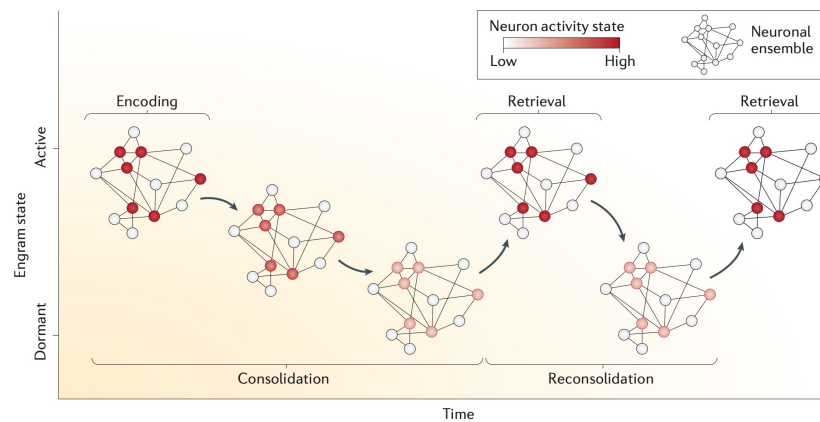
The robustness of the testing effect means that it is relatively easy to incorporate:

Small teaching tweaks, big learning wins.

- Implicit retrieval practice – what do you remember from last class?

- Explicit retrieval practice – Brain, Book, Buddy

- Be transparent about why and how we use tests – including summative tests

   Transparency is key for students – they need to be reminded WHY.

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CBE Life Sciences Education

Metacognition in Upper-Division Biology Students: Awareness Does Not Always Lead to Control

Kathryn Morris Dye and Julie Dangremond Stanton*

The authors used qualitative methods to study the metacognitive skill of evaluation in upper-division biology students. They explored when, why, and how students evaluate their approaches to learning and found that most students adjust their approaches after evaluation, but some choose not to use effective strategies in order to avoid discomfort.

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In interviews, this student acknowledged that re-reading the textbook and re-writing notes weren't working for them:

HOWEVER, they had worked in the past and the student described them as "comfort food" – and used them anyway.

53

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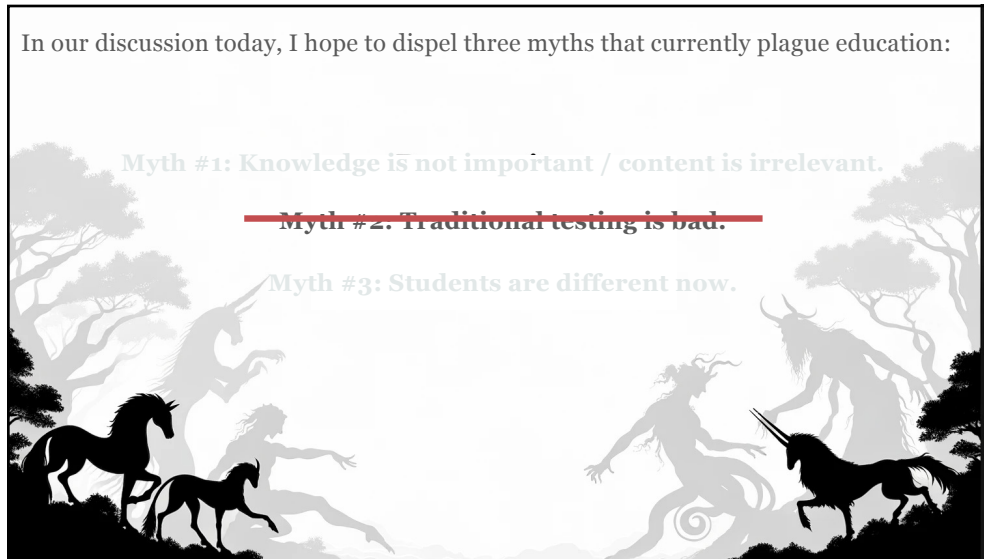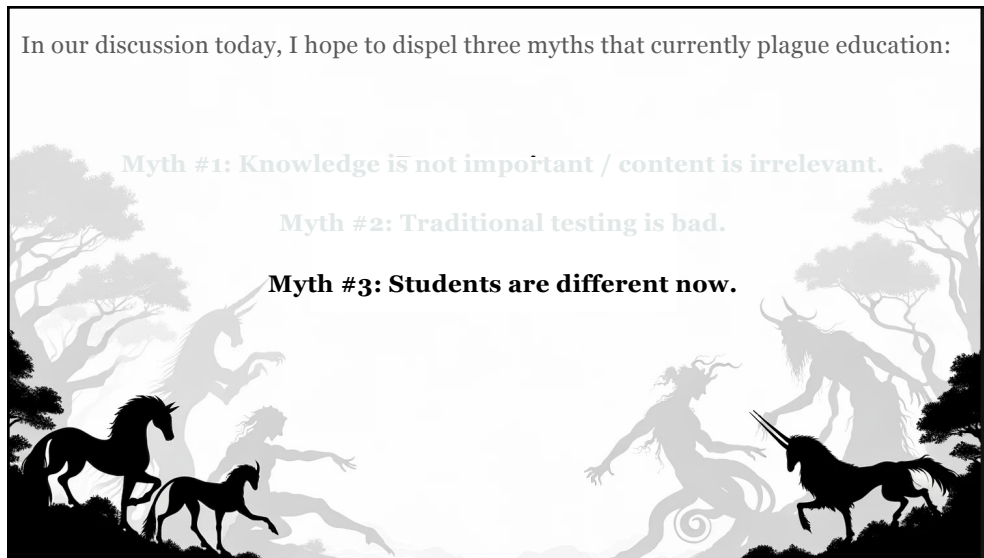
Myth #3: Students are different now.

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These two myths are particularly damaging to education.

Students who grew up with the internet and social media (and now AI):

i) Have inherent technological expertise

ii) Can multitask

Teaching and Teacher Education
Volume 67, October 2017, Pages 135-142

The myths of the digital native and the multitasker

Paul A. Kirschner [a] [b] , Pedro De Bruyckere [c]

57

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Teaching and Teacher Education
Volume 67, October 2017, Pages 135-142

The myths of the digital native and the multitasker

Paul A. Kirschner [a] [b] , Pedro De Bruyckere [c]

- Digital exposure does not equate to digital literacy.

- Evidence suggests that generation Google uses a few technological applications extensively, but do not (automatically) leverage technology effectively for learning

- If we expect students to use technology in education, we need to be explicit

58

29

These two myths are particularly damaging to education.

Students who grew up with the internet and social media (and now AI):

i) Have inherent technological expertise.

ii) Can multitask.

- Multitasking is a myth: time cost, financial cost, brain cost

- Americans 8-18 y old spend 7.5 h per day on media; 30% MMT (2009)

- Evidence on the impact of MT experience as cognitive training is mixed... and some studies show that **heavy MMTs have more limited working memory**

Teaching and Teacher Education
Volume 67, October 2017, Pages 135-142

The myths of the digital native and the multitasker

Paul A. Kirschner [a] [b], Pedro De Bruyckere [c]

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Stanford | News

Home   Find Stories   For Journalists   Contact

OCTOBER 25, 2018

A decade of data reveals that heavy multitaskers have reduced memory, Stanford psychologist says

People who frequently engage with multiple types of media at once performed worse on simple memory tasks, according to the last decade of research. However, it's still too soon to determine cause and effect, says psychology Professor Anthony Wagner.
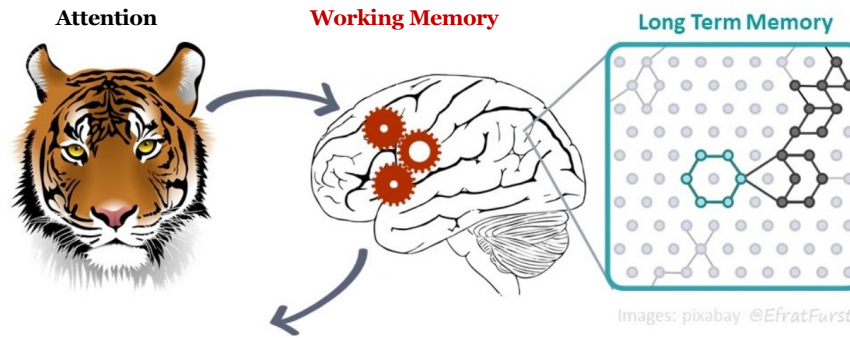
B. WM: Common objects task

B. Common objects task

60

Students today (as a group) may have impaired working memory.

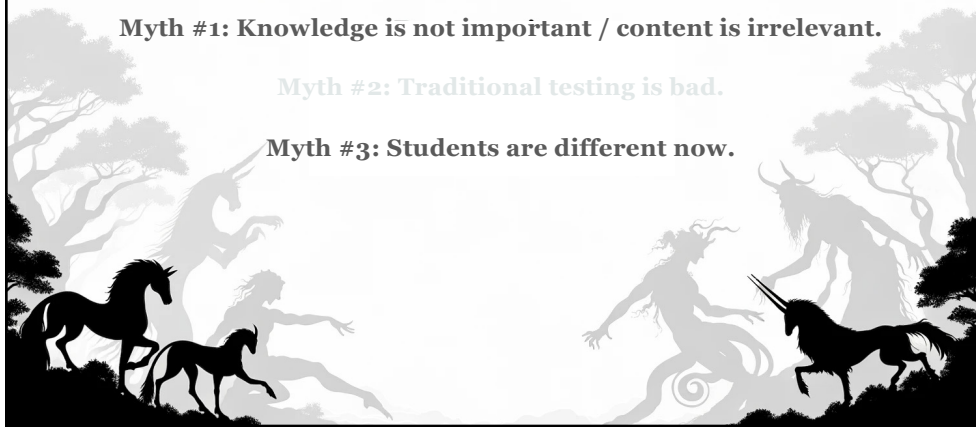https://sites.google.com/view/efratfurst/learning-in-the-brain

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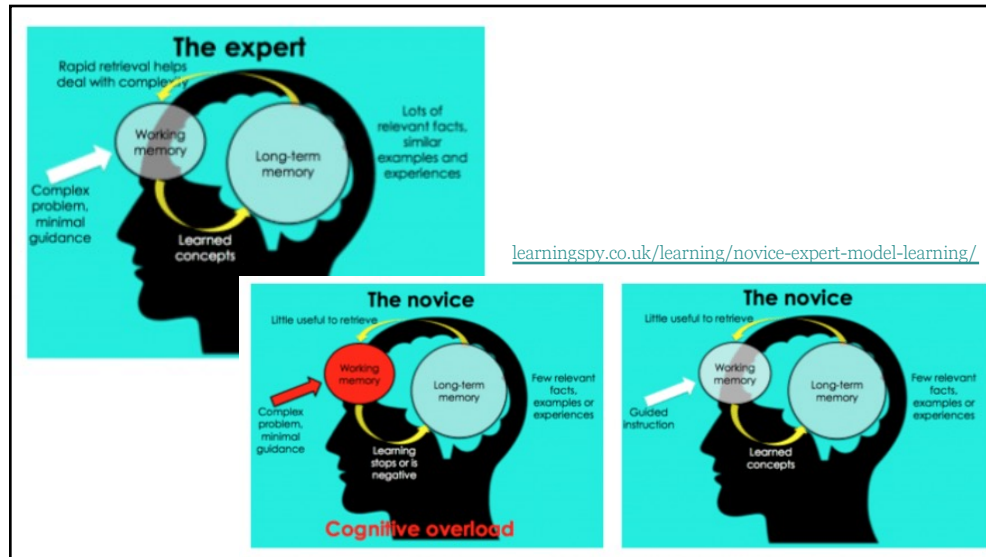
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Tackling multiple challenges:
- Accommodation
- Financial pressure
- Independent living
- Loneliness
- Overwhelm in the transition to independent learning

Bridging the Gap: Exploring the Unique Transition From Home, School or College Into University

Joanne Deborah Worsley[1], Paula Harrison[2] and Rhiannon Corcoran[1]*

[1] Department of Primary Care and Mental Health, University of Liverpool, Liverpool, United Kingdom, [2] Student Administration and Support, University of Liverpool, Liverpool, United Kingdom

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Tackling multiple challenges:
- Accommodation
- Financial pressure
- Independent living
- Loneliness
- Overwhelm in the transition to independent learning

When we explore all these issues, it's important to remember one thing:

The brain hasn't changed.

Bridging the Gap: Exploring the Unique Transition From Home, School or College Into University
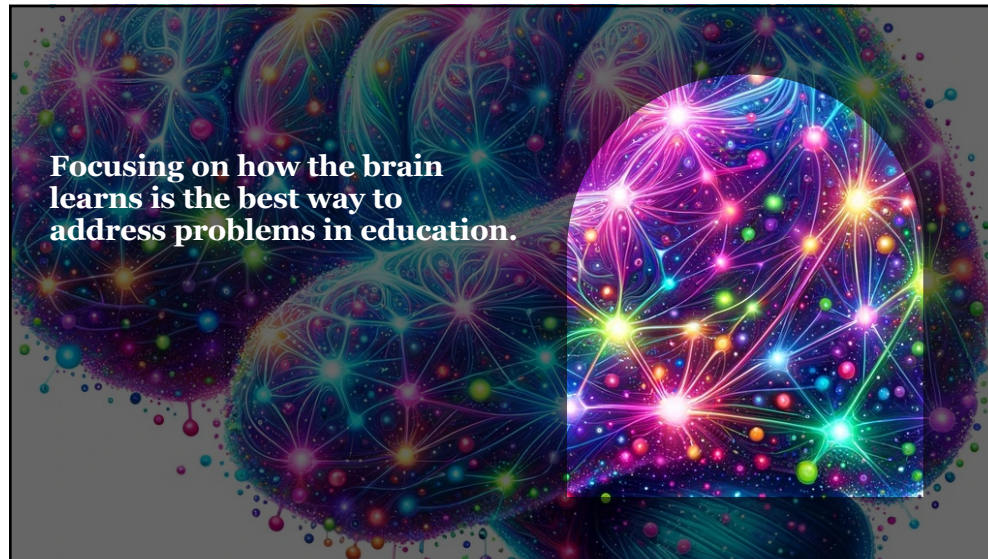
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Focusing on how the brain learns is the best way to address problems in education.

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