How we learn: cognitive science foundations

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"There is no end to education.

It is not that you read a book, pass an examination, and finish with education.

The whole of life, from the moment you are born to the moment you die, is a process of learning."

— Jiddu Krishnamurti

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Intended Learning Outcomes

- By the end of this video you will be able to:
  - Define and understand the concept of metacognition and its importance in the learning process.
  - Recognise the significance of feedback and active engagement in enhancing comprehension and retention.
  - Illustrate the role of attention in alerting, filtering and emphasising relevant data during learning.
  - Explain different perspectives on sleep and its role in consolidation of information

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What is learning? (cognitive science)

- Learning is the process by which experiences lead to long-lasting new knowledge or behaviour.
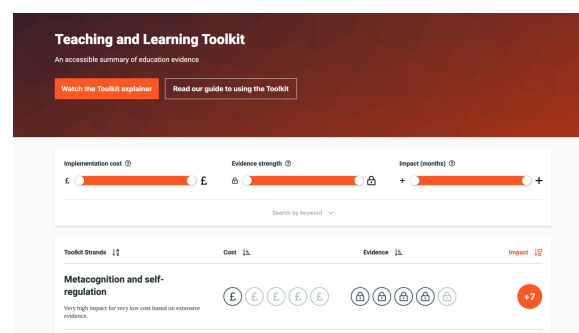
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What are the factors that encourage human learning?

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The most effective strategy to improve learning?

- Learning-to-learn (meta-cognition)

- Identifying specific strategies for planning, monitoring, and evaluating your own learning.
- Develop a repertoire of strategies to choose from and the skills to select the most suitable strategy for a given learning task.
- Self-regulated learning can be broken into three essential components:
  - cognition – the mental process involved in knowing, understanding, and learning
  - metacognition – often defined as 'learning to learn';
  - motivation – willingness to engage our metacognitive and cognitive skills.

Teaching and Learning Toolkit
An accessible summary of education evidence

https://educationendowmentfoundation.org.uk/education-evidence/teaching-learning-toolkit

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Learning from feedback

- Learning is faster when we receive quick and detailed error feedback supervised learning
- Regularly testing your knowledge (retrieval practice) is one of the best ways to ensure learning
    - Testing allows attention to be focused on weaker areas
    - Most students choose to reread notes instead of testing their memory (flashcards)
- How feedback is given is crucial
    - Harsh or overly negative feedback can impair learning (if it induces too much stress/anxiety)

Wisniewski et al., *Frontiers in Psychology*, 2020

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Quiz – blackboard

- How we learn (cog sci) – question 1
- Are exam results an effective form of feedback for learning? Why?

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Inattentional blindness

Transport for London,
Daniel Simons & colleagues

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Attention

- Attention is the mechanism by which the brain selects and enhances relevant information while filtering out distractions. (Cognitive science)
- Major attention systems:
  - Alerting: pay attention now!
  - Orienting: focus on this, not that!
  - Executive attention: do this, then that!
- Shared attention (paying attention to other's attention)
  - accelerates learning in young children
  - involved in some of the most effective teaching interventions (collaborative learning, peer tutoring)
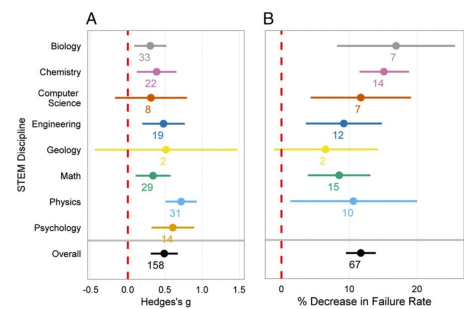
Michael Posner   https://educationendowmentfoundation.org.uk/education-evidence/teaching-learning-toolkit

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Active engagement - proposing & testing hypotheses

- To learn, our brain must first form a mental 'model' of the world, and then comparing its predictions to the sensory information it receives
- Requires attention, effort, testing hypotheses and reflection
- Deeper thinking, better memory.
  - "requiring students to engage more cognitive effort, often leads to enhanced retention." Zaromb, Karpicke & Roediger, 2010
- Across STEM disciplines, active engagement lead to more understanding, higher test scores, and fewer students failing (compared to lectures).

Freeman et al., *PNAS*, 2014

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Quiz – blackboard

- How we learn (cog sci) – question 2
- An unguided environment is one in which learners, rather than being presented with essential information, must discover or construct essential information for themselves.
- Given the apparent benefits of active learning over traditional lecturing, do you think people people learn best in an unguided environment? Why?

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Active engagement – curiosity and laughter

- Curiosity occurs whenever we detect a gap between what we want to know and what we already know. (Loewenstein, 1994)
- Curiosity is driven by the value of acquiring information
- Greater curiosity is associated with greater academic achievement (Shah et al., 2018)
- We laugh when we discover one of our assumptions is wrong, forcing us to change our mental model
- Laughter increases curiosity and subsequent memory (Esseily et al., *Cognition & Emotion*, 2016).
- Laughter is a contagious social response that spreads as we draw each other's attention to an unexpected piece of information. (Hurley, Dennett & Adams, 2011)

Neil deGrasse Tyson
(astrophysicist & science communicator)

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Quiz

- How we learn (cog sci) – question 3
- Which aspects of active engagement do you think current machine learning uses?
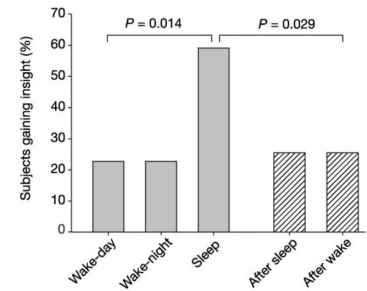- Could incorporating other aspects be useful? Why?

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Consolidation

- Consolidation is the process of change from slow, conscious, effortful processing to fast, unconscious, automatic expertise.
- A lot of consolidation occurs during sleep
  - more sleep → stronger memories & better generalisation
- Sleep strengthens existing knowledge, but also inspires insight
- Are dreams fabricated data to help brain training?

Dehaene, 2020

Wagner et al., *Nature*, 2004

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Recap

- Learning is the process by which experiences lead to long-lasting new knowledge or behaviour
- Some of the most effective ways to promote human learning include
  - learning about learning
  - high quality, rapid feedback
    - retrieval practice
  - active engagement
    - proposing and testing hypotheses
    - curiosity
    - humour
  - paying attention
  - learning socially
  - sleeping well (consolidating information)

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Still curious? You can dive in deeper to any of today's topics:

- Ranking teaching/learning strategies (metacognition top)
  - https://educationendowmentfoundation.org.uk/education-evidence/teaching-learning-toolkit
  - Dehaene, Stanislas. *How we learn: The new science of education and the brain.* Penguin UK, 2020
- Learning from feedback
  - Wisniewski, Benedikt, Klaus Zierer, and John Hattie. "The power of feedback revisited: A meta-analysis of educational feedback research." *Frontiers in psychology* 10 (2020): 3087
- Attention:
  - Posner, Michael I., and Steven E. Petersen. "The attention system of the human brain." *Annual review of neuroscience* 13, no. 1 (1990): 25-42.
  - Simons, Daniel J., and Christopher F. Chabris. "Gorillas in our midst: Sustained inattentional blindness for dynamic events." *perception* 28, no. 9 (1999): 1059-1074.
- Social aspects of learning:
  - Csibra, Gergely, and György Gergely. "Natural pedagogy." *Trends in cognitive sciences* 13, no. 4 (2009): 148-153.
- Active engagement:
  - Freeman, Scott, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. "Active learning increases student performance in science, engineering, and mathematics." *Proceedings of the national academy of sciences* 111, no. 23 (2014): 8410-8415.
  - Zaromb, Franklin M., Jeffrey D. Karpicke, and Henry L. Roediger III. "Comprehension as a basis for metacognitive judgments: Effects of effort after meaning on recall and metacognition." *Journal of experimental psychology: learning, memory, and cognition* 36, no. 2 (2010): 552.
  - Shah, Prachi E., Heidi M. Weeks, Blair Richards, and Niko Kaciroti. "Early childhood curiosity and kindergarten reading and math academic achievement." *Pediatric research* 84, no. 3 (2018): 380-386.
  - Esseily, Rana, Lauriane Rat-Fischer, Eszter Somogyi, Kevin John O'Regan, and Jacqueline Fagard. "Humour production may enhance observational learning of a new tool-use action in 18-month-old infants." *Cognition and Emotion* 30, no. 4 (2016): 817-825.
  - Hurley, Matthew M., Daniel Clement Dennett, and Reginald B. Adams. *Inside jokes: Using humor to reverse-engineer the mind.* MIT press, 2011.
- Consolidation
  - Wagner, Ullrich, Steffen Gais, Hilde Haider, Rolf Verleger, and Jan Born. "Sleep inspires insight." *Nature* 427, no. 6972 (2004): 352-355.

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