Make It Stick: A Review of the Science of Learning

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Assistant Professor of Medicine
Emory University School of Medicine
Disclosures

None of the faculty for this educational activity have relevant financial relationships with ineligible companies to disclose.
Learning Objectives

- Describe evidence-based learning principles
- Provide concrete examples of their use
- Incorporate into classroom & clinical teaching
Evidence-Based Learning Principles

Understand
- Cognitive load theory
- Mayer’s multimedia
- Advanced organizers

Retain
- Retrieval practice
- Spaced learning
- Interleaving
- Elaboration
- Desirable difficulty

Apply
- Generation
- Transferability

Master
- Deliberate practice

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Evidence-Based Learning Principles

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How we process information

- Visual
- Auditory

Working Memory
5-7 "pieces" of information

Store
Retrieve

Long-term Memory
Infinite storage of information

Cognitive Load Theory: Optimizing information processing

- **Intrinsic Load**: Complexity of the content or task being learned
- **Extraneous Load**: Unnecessary information or distraction from the task
- **Germane Load**: Effort required to organize the content or task

# Strategies to manage cognitive load

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| **Extraneous Load** | Unnecessary information or distraction from the task |

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Dual-Channel Processing: Improving Presentations

Dual-Channel Processing

- Visual
- Auditory

Working Memory
5-7 "pieces" of information

Store
Retrieve

Long-term Memory
Infinite storage of information

Mayer’s Multimedia Principles: reduce **extraneous** load

- **Pre-training:** Key terms & concepts
- **Multimedia:** Words + pictures > words
- **Coherence:** Eliminate the “extra”

- **Spatial & temporal contiguity:** Words & pictures near each other and simultaneous
- **Signaling:** Cues that highlight
- **Personalization:** Conversational > formal

---

Applying Mayer’s multimedia principles improves learning

**BEFORE**

Swan-Ganz (PAC) insertion is like ‘Surfing through Blood Stream’

**AFTER**

Changes in wave tracings during PAC insertion indicate it’s position relative to the R ventricle.

Applying Mayer’s multimedia principles improves learning

**Before**

Coherence principle: exclude unnecessary pictures

Swan-Ganz (PAC) insertion is like 'Surfing through Blood Stream'

**After**

Changes in wave tracings during PAC insertion indicate it's position relative to the R ventricle.

Applying Mayer’s multimedia principles improves learning.

BEFORE

Swan-Ganz (PAC) insertion is like ‘Surfing through Blood Stream’

AFTER

Signaling principle: highlight essential material

Changes in wave tracings during PAC insertion indicate its position relative to the R ventricle.

Spatial contiguity principle: place words & pictures near to each other

Advanced Organizers: optimize **germane** load

<table>
<thead>
<tr>
<th>Process/Timeline</th>
<th>Hierarchy</th>
<th>Compare &amp; Contrast</th>
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<tr>
<td><img src="image1" alt="Diagram" /></td>
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Advanced Organizers: Examples

Venn Diagrams

2x2 Tables

Anatomic Drawings

Visual Paradigms

Pathways

Simple Graphs
Summary: practical strategies to help people “understand”

- **Prep materials** before session to familiarize with terms & concepts
  - Flashcards
  - Videos
  - Text (short!)
- **Break down** concepts into small chunks and **build** over time
  - Non-expert review
- **Eliminate** material that isn’t absolutely essential
  - Clean up slides
- **Organize** terms & concepts to help learners see connections
  - Guided handouts
  - Advanced organizers
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<td><strong>Elaboration</strong></td>
<td>Explaining concepts &amp; connecting them to prior knowledge</td>
<td>&quot;How&quot; &amp; &quot;why&quot; questions, Creating concept maps</td>
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Cognitive science principles: **clinical** examples

- **Patient care**
  - Clinical decision-making (retrieval)
  - Seeing varied patients (spacing, interleaving)

- **Case Discussions**
  - Asking learners questions (retrieval, elaboration)

- **Chalk Talks**
  - Asking learners questions (retrieval, elaboration)
  - Applying to patients (spacing)
Explicitly teach **interleaving**: Compare & contrast table

<table>
<thead>
<tr>
<th></th>
<th>Epidemiology</th>
<th>Time course</th>
<th>Imaging Features</th>
<th>Diagnostic testing</th>
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<tbody>
<tr>
<td>Tuberculosis</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Anaerobic abscess</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td></td>
<td></td>
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<table>
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<tr>
<th></th>
<th>Geographic Location</th>
<th>Seasonality</th>
<th>Rash</th>
<th>Characteristic Lab Findings</th>
</tr>
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<tbody>
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<td>Anaplasma</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ehrlichia</td>
<td></td>
<td></td>
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<tr>
<td>Lyme</td>
<td></td>
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<tr>
<td>RMSF</td>
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RMSF = Rocky Mountain spotted fever
Cognitive science principles: classroom examples

- In-class questions
- Partial lecture outlines
- Flashcards
- Quizzes
- Study partners

Retrieval +/-
Elaboration
Spaced practice
Interleaving
Example: In-class questions (Poll Everywhere)

When poll is active, respond at PollEv.com/jspicer
Text JSPICER to 22333 once to join

How does Mycobacterium tuberculosis avoid intracellular killing in macrophages?

- "prevents phagolysosome fusion and if it does occur prevents phagolysosome maturation"
- "catalase"
- "prevents fusion of lysosome with phagosome"
- "prevents phagosome-lysosome fusion"

Powered by Poll Everywhere
Example: In-class questions (PollEverywhere)

```
What is your microbiological differential diagnosis for this patient based on this sputum Gram stain?

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>2</td>
<td>Streptococcus pneumoniae</td>
</tr>
<tr>
<td>0</td>
<td>Staphylococcus aureus</td>
</tr>
<tr>
<td>-1</td>
<td>Moraxella catarrhalis</td>
</tr>
</tbody>
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```

Choices typed & added by audience

Audience can up/down vote responses
Cognitive science principles: classroom examples

- In-class questions
- Partial lecture outlines
- Flashcards
- Quizzes
- Study partners

- Retrieval
- Elaboration
- Spaced practice
- Interleaving

- +/- Elaboration
- +/- Retrieval
- Spaced practice
- Interleaving
Example: Partial lecture outline

D. A time-kill curve is shown below. An antibiotic is added at the time point indicated by the downward pointing arrow, and then removed at the upward pointing arrow. Which line (red or green) corresponds to the curve that would be seen with a bactericidal vs. bacteriostatic antibiotic?

E. Complete the pro/con chart of bactericidal vs. bacteriostatic antibiotics

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F. Explain what kind of antibiotic (-cidal or -static) may be preferable in the following clinical scenarios:

1. Immunocompromised patient
2. Organism with a propensity to develop resistance
3. High inoculum infection without many actively dividing cells
Cognitive science principles: classroom examples

- In-class questions
- Partial lecture outlines
- Flashcards
- Quizzes
- Study partners

- Retrieval +/-
- Elaboration
- Spaced practice
- Interleaving

- Retrieval
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- Elaboration
Example: Electronic Flashcards (Anki)

An organism in the microbiology laboratory has the following characteristics: Gram positive cocci, catalase positive, & coagulase positive. What organism is this?

How does Protein A help Staphylococcus aureus evade the immune system?

Protein A binds the heavy chain portion (i.e. the "wrong" side) of IgG antibodies thus preventing the antibodies from doing their normal job.

Protein A prevents proper antibody binding
Cognitive science principles: classroom examples

- In-class questions
- Partial lecture outlines
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Retrieval +/- Elaboration
Spaced practice
Interleaving

Elaboration +/- Retrieval
Spaced practice
Interleaving

Retrieval Spaced Practice
Interleaving Elaboration

Retrieval Spaced Practice
Interleaving

Retrieval Elaboration +/-
Spaced Practice Interleaving
Create **desirable difficulty** to enhance learning

- Able to do **without** assistance
- Able to do **with** assistance
- Not able to do even **with** assistance

**Zone of proximal development**

---

The zone of proximal development: **clinical** examples

**Example**
Placing a difficult IV

**Assistance provided**
Direct supervision w/ demo
The zone of proximal development: clinical examples

Zone of proximal development

Example
Placing a difficult IV
Dosing an aminoglycoside

Assistance provided
Direct supervision w/ demo
Handout with instructions
The zone of proximal development: clinical examples

Example
Placing a difficult IV
Dosing an aminoglycoside
Breaking bad news

Assistance provided
Direct supervision w/ demo
Handout with instructions
Role play → supervision
The zone of proximal development: classroom examples

Zone of proximal development

Example
Multiple-choice questions

Assistance provided
Answer with explanation
The zone of proximal development: classroom examples

Zone of proximal development

Example
- Multiple-choice questions
- Clinical problem set

Assistance provided
- Answer with explanation
- Group work
Evidence-Based Learning Principles

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  - Transferability

- Master
  - Deliberate practice
Application of Knowledge

**Generation**

Ability to **solve problems** independently prior to seeing the solutions

**Transfer**

Ability to apply learning to **new** and **varied** contexts

---

Generation & Transfer: **clinical** example

Patient with FUO

Patient #1

Patient #2

Patient #3

Develop & present a plan for varied contexts
Generation & Transfer: *classroom* example

Case-based learning

PBL (Problem-based learning)

TBL (Team-based learning)
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Deliberate Practice: experience does not equal expertise

Figure 4. Two trends for development of medical performance as a function of experience and instruction.
Deliberate practice requires feedback
Deliberate practice: examples

Communication → Feedback: Patient response

Clinical reasoning → Feedback: Clinical outcomes

Procedures → Feedback: Procedure success
Evidence-Based Learning Principles

- Simplify & organize content.
- Practice repeatedly on difficult... and realistic scenarios... with targeted feedback.

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Practice repeatedly on difficult and realistic scenarios with targeted feedback.