

# Make It Stick:

## A Review of the Science of Learning

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Emory University School of Medicine

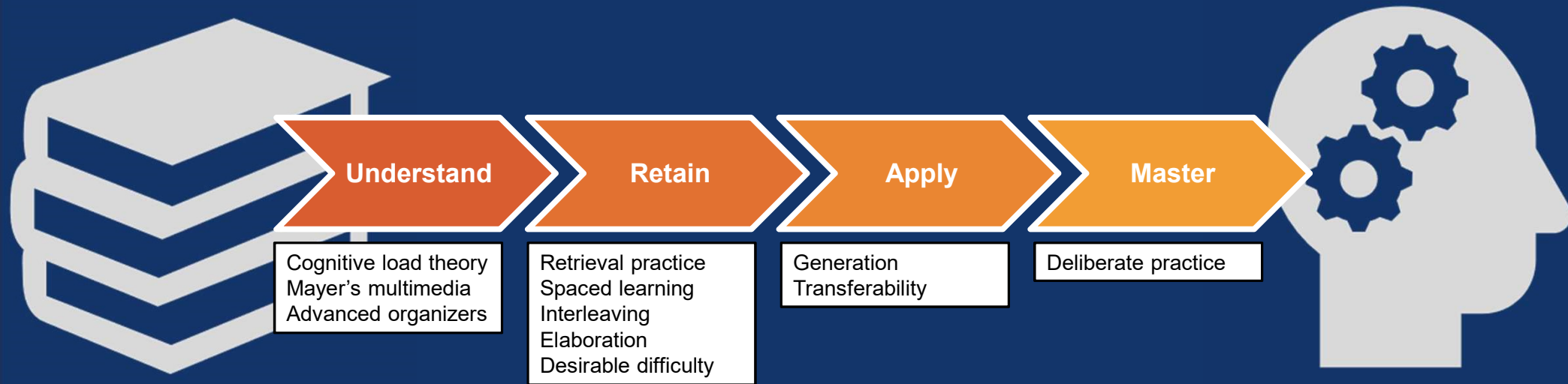
## Disclosures

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

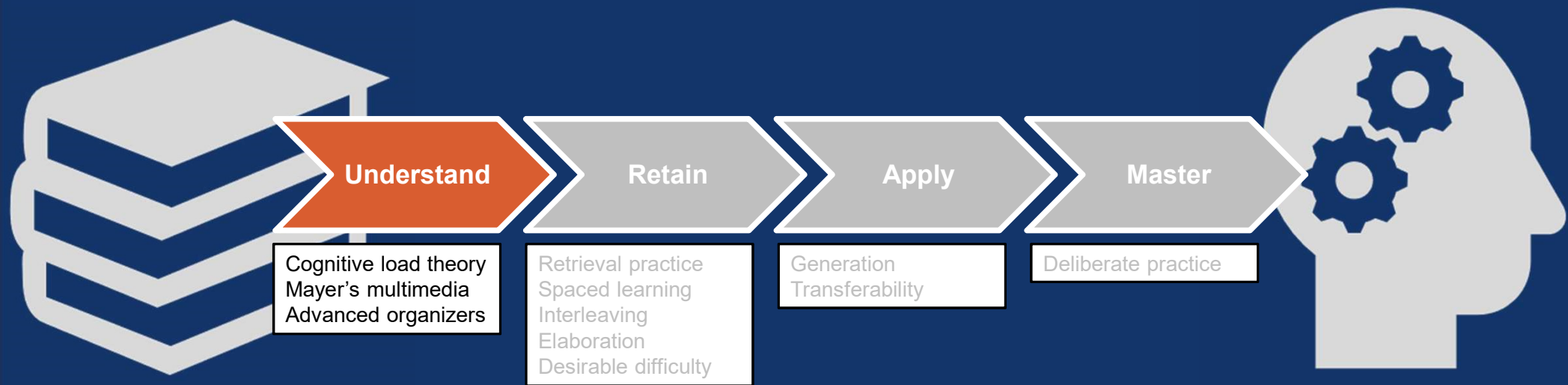
# Learning Objectives

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

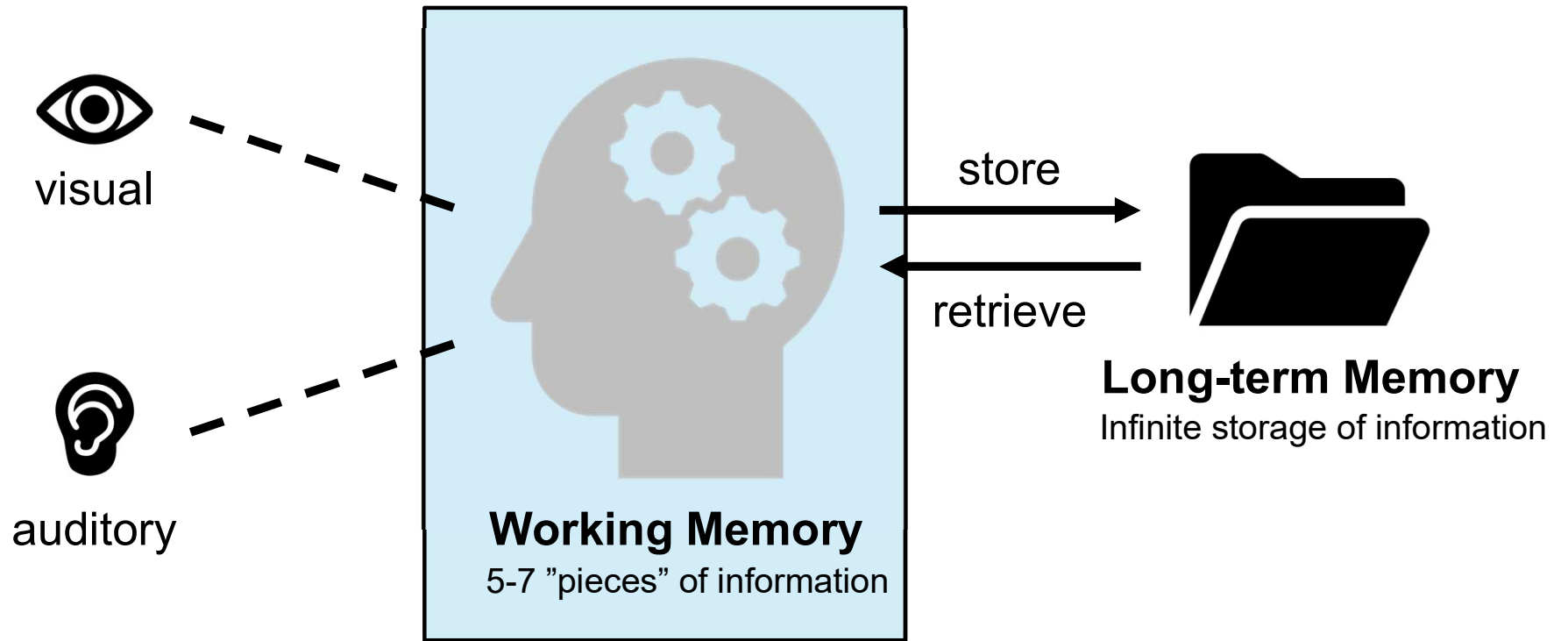
# Evidence-Based Learning Principles



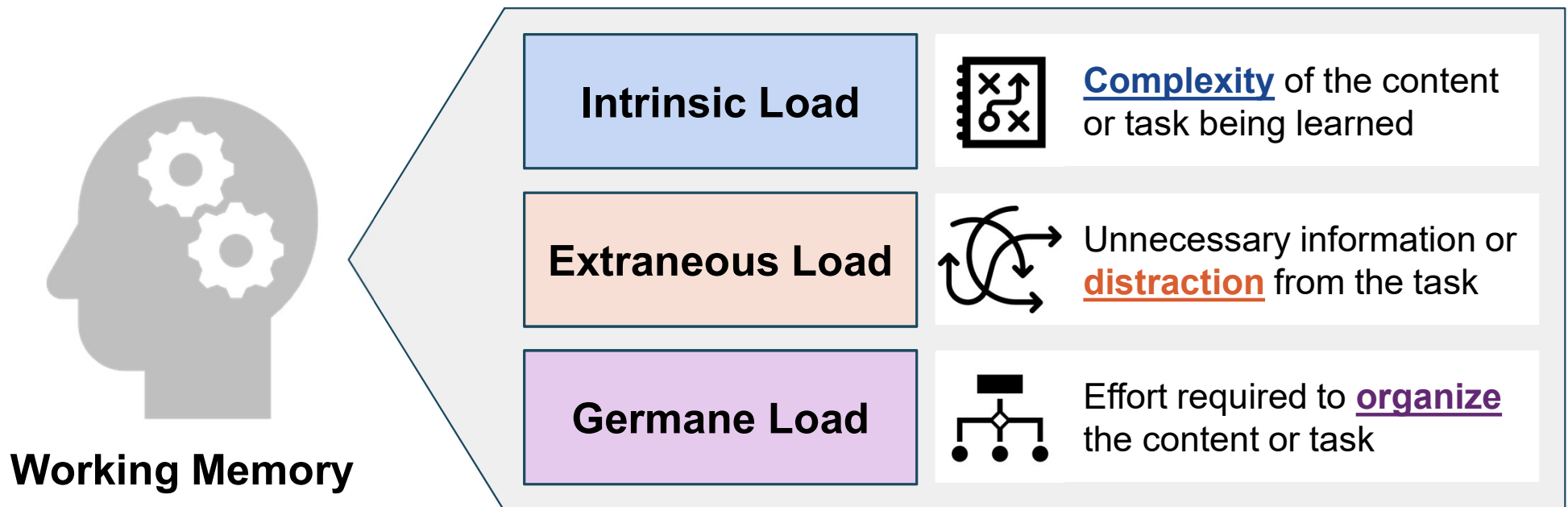
# Evidence-Based Learning Principles






# How we process information



# Cognitive Load Theory: Optimizing information processing







# Strategies to manage cognitive load

	Definition	Strategies
<b>Intrinsic Load</b>	 <b>Complexity</b> of the content or task being learned	
<b>Extraneous Load</b>	 Unnecessary information or <b>distraction</b> from the task	
<b>Germane Load</b>	 Effort required to <b>organize</b> the content or task	






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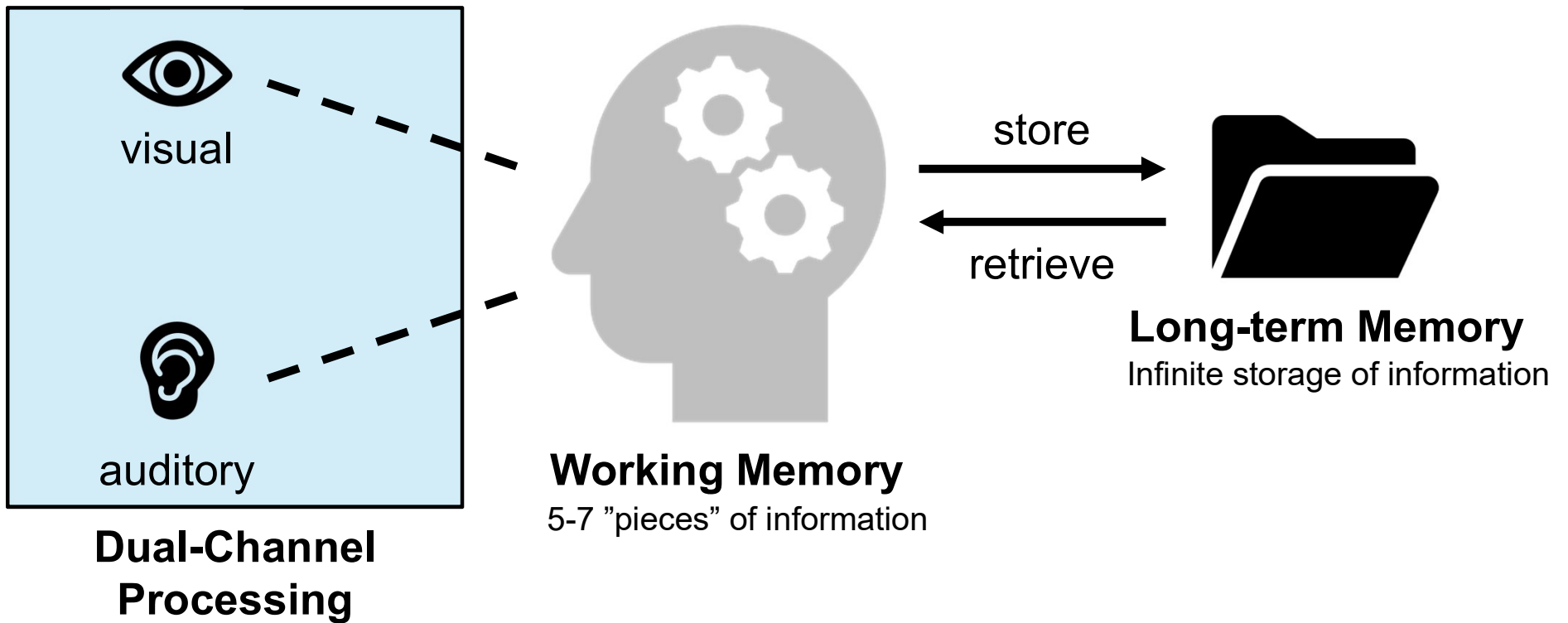
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 <b>Germane Load</b>	 Effort required to <b>organize</b> the content or task	<ul style="list-style-type: none"> <li>- Refer to previously learned content</li> <li>- Organize information for learners</li> </ul>

# Dual-Channel Processing: Improving Presentations



# 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:

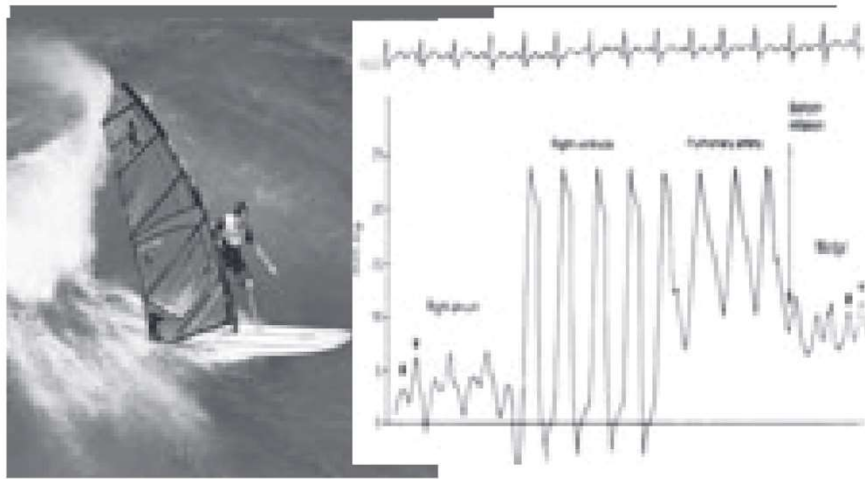
Conversational > formal



# Applying Mayer's multimedia principles improves learning

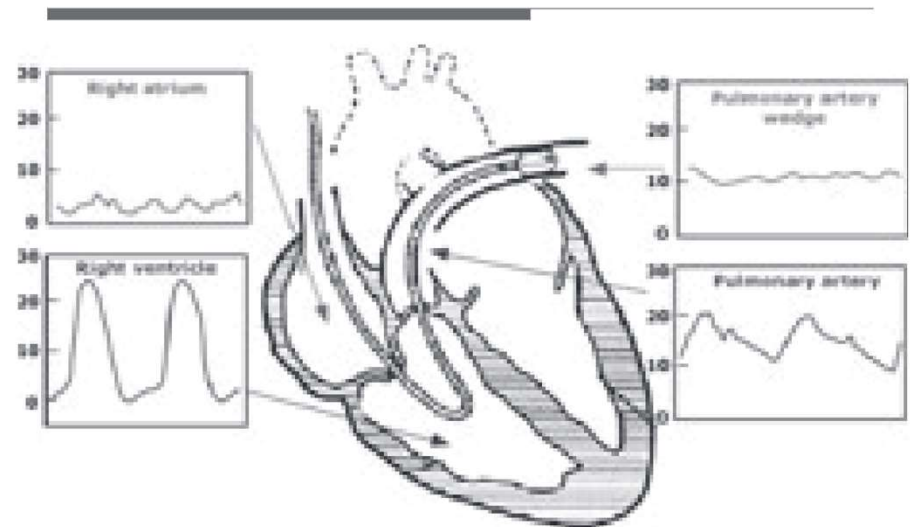
## BEFORE

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.

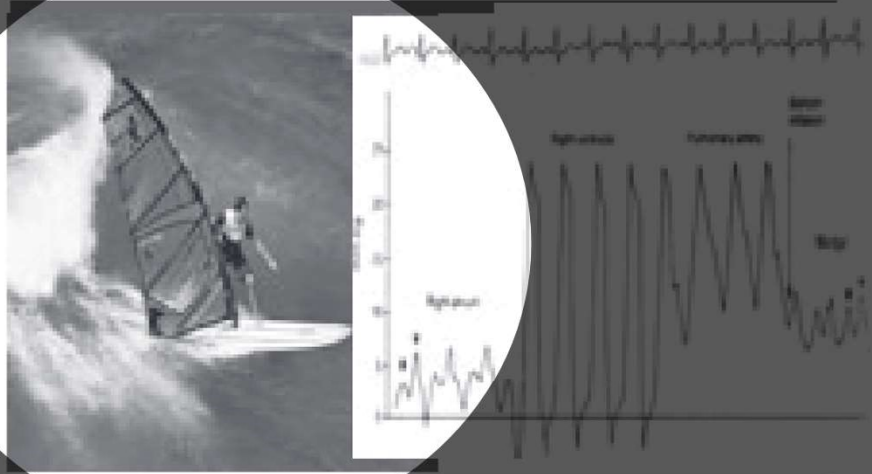


# Applying Mayer's multimedia principles improves learning

Coherence principle: exclude unnecessary pictures

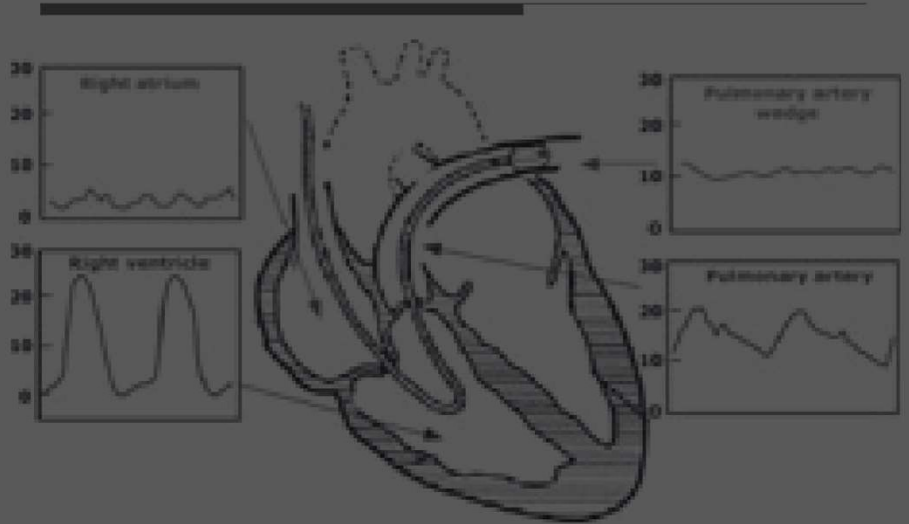
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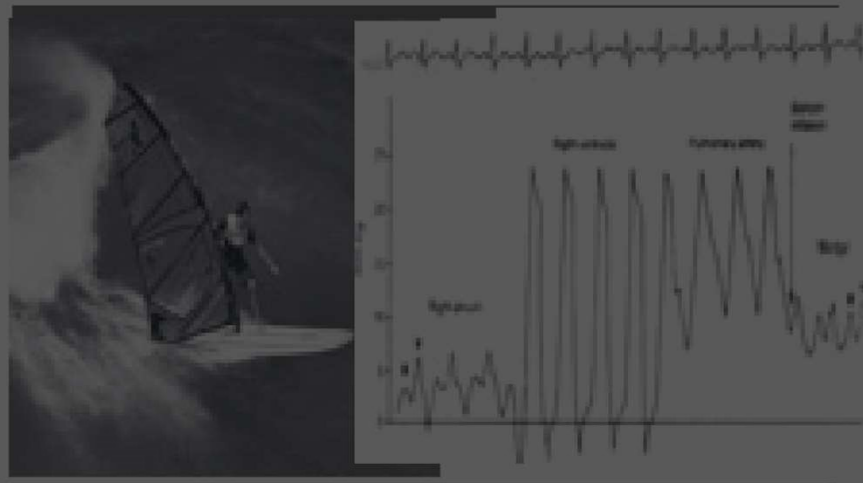
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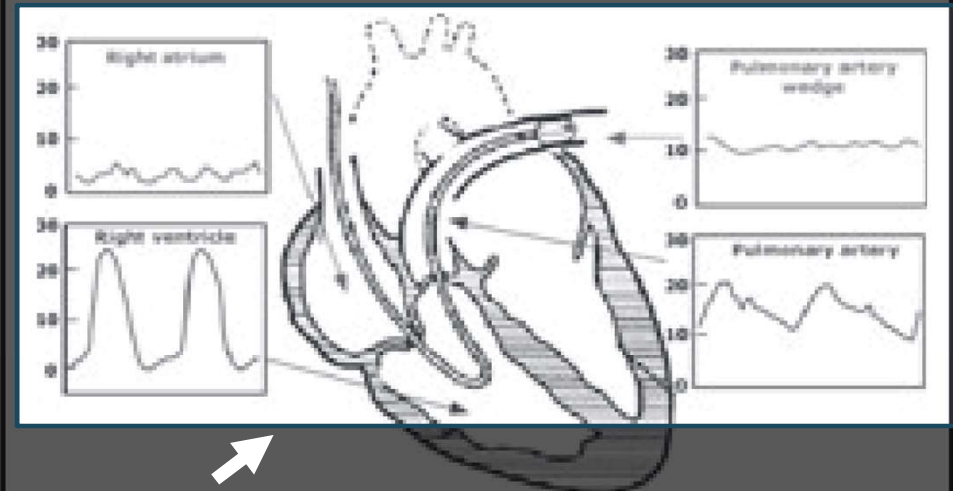
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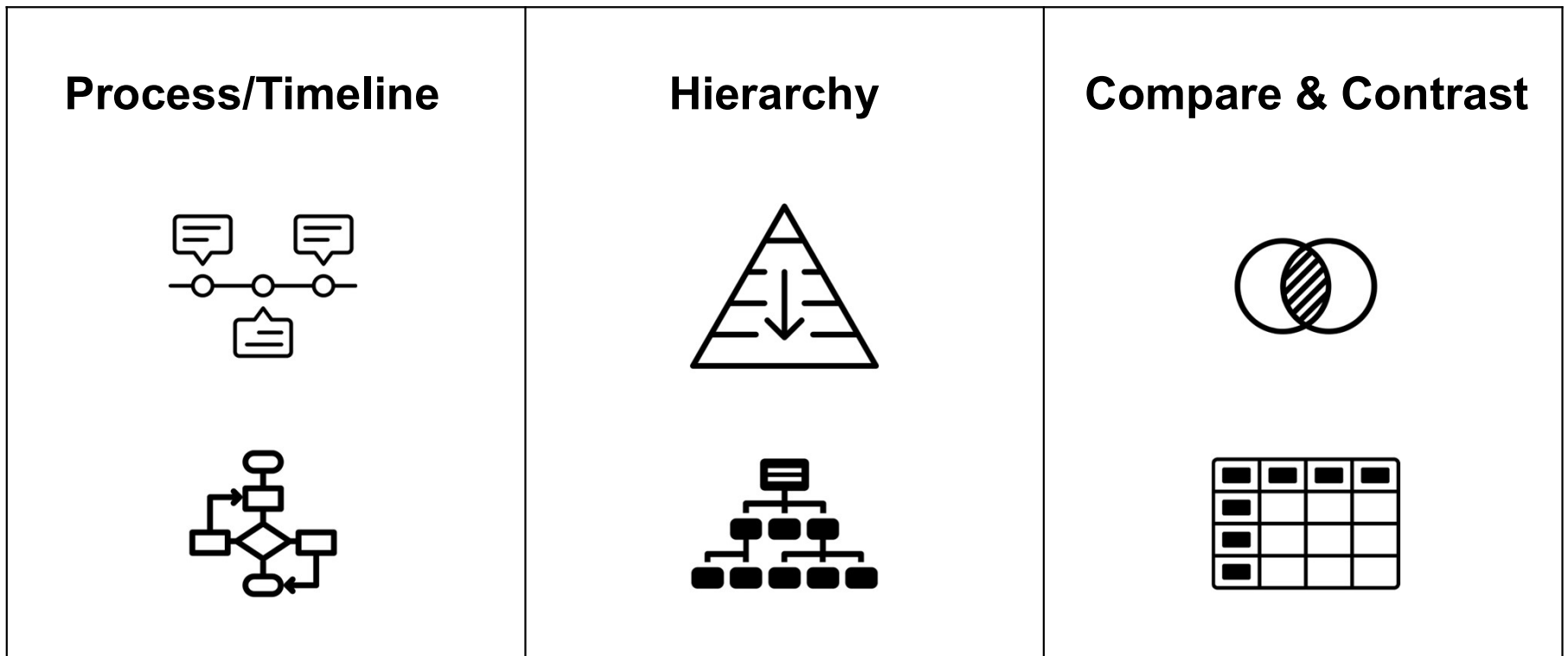
Signaling principle: highlight essential material

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



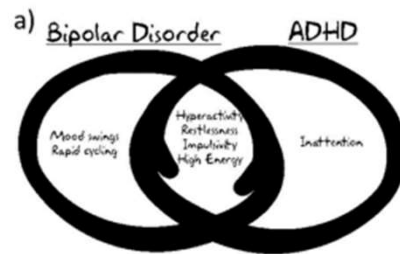
Spatial contiguity principle: place words & pictures near to each other

# Advanced Organizers: optimize germane load

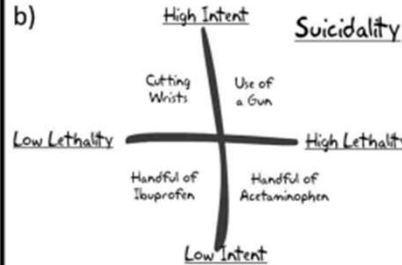


# Advanced Organizers: Examples

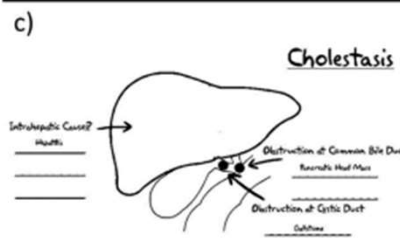
Venn Diagrams



2x2 Tables



Anatomic Drawings



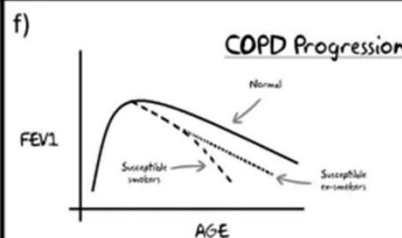
Visual Paradigms



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

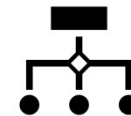


## Eliminate

material that isn't absolutely essential



Clean up slides

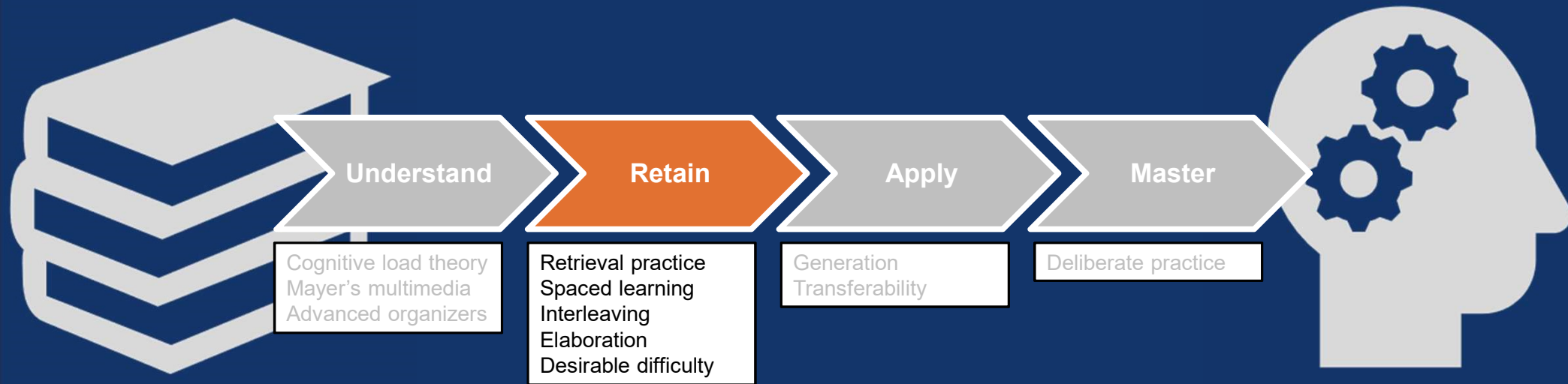


**Organize** terms & concepts to help learners see connections







Guided handouts  
Advanced organizers

# Evidence-Based Learning Principles







# Cognitive science principles





	<b>Term</b>	<b>Definition</b>	<b>Example</b>
	<b>Retrieval</b>		
	<b>Spaced Practice</b>		
	<b>Interleaving</b>		
	<b>Elaboration</b>		







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


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	<b>Interleaving</b>		
	<b>Elaboration</b>		

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	<b>Interleaving</b>	Mixing up topics when studying	Mixed problem sets Compare & contrast tables
	<b>Elaboration</b>		

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	<b>Elaboration</b>	Explaining concepts & connecting them to prior knowledge	"How" & "why" questions Creating concept maps

# 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

	<b>Epidemiology</b>	<b>Time course</b>	<b>Imaging Features</b>	<b>Diagnostic testing</b>
<b>Tuberculosis</b>				
<b>Anaerobic abscess</b>				
<b>Lung cancer</b>				

	<b>Geographic Location</b>	<b>Seasonality</b>	<b>Rash</b>	<b>Characteristic Lab Findings</b>
<b>Anaplasma</b>				
<b>Ehrlichia</b>				
<b>Lyme</b>				
<b>RMSF</b>				

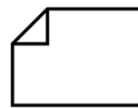
# Cognitive science principles: **classroom** examples



**In-class  
questions**



**Partial lecture  
outlines**



**Flashcards**



**Quizzes**



**Study  
partners**

Retrieval  
+/-  
Elaboration  
Spaced practice  
Interleaving

## Example: In-class questions (PollEverywhere)

When poll is active, respond at [Pollev.com/jspicer](https://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)

Respond at [PollEv.com/jspicer](https://PollEv.com/jspicer)

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

Top

2	Streptococcus pneumoniae
0	Staphylococcus aureus
-1	Moraxella catarrhalis

Choices typed & added by audience

↑  
Audience can up/down vote responses

# Cognitive science principles: **classroom** examples



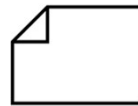
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Retrieval  
+/-  
Elaboration  
Spaced practice  
Interleaving



## **Partial lecture outlines**

Elaboration  
+/-  
Retrieval  
Spaced practice  
Interleaving



## **Flashcards**



## **Quizzes**

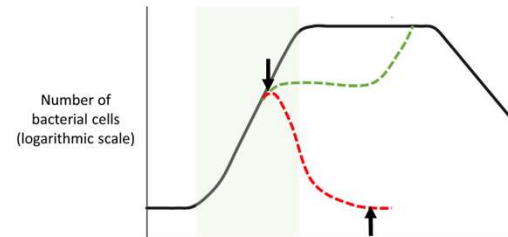


## **Study partners**



# 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

	Pros	Cons
Bactericidal		
Bacteriostatic		

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



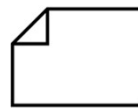
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## **Partial lecture outlines**

Elaboration  
+/-  
Retrieval  
Spaced practice  
Interleaving



## **Flashcards**

Retrieval  
Spaced Practice  
Interleaving  
Elaboration



## **Quizzes**



## **Study partners**

# Example: Electronic Flashcards (Anki)

User 1 - Anki

Decks Add Browse Stats Sync

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

---

Staphylococcus aureus

```
graph TD
    A[GRAM +] --> B[Cocci]
    A --> C[Bacilli]
    B --> D[Catalase + Staphylococcus]
    C --> E[Catalase - Streptococcus/Enterococcus]
    D --> F[Coagulase + S. aureus]
    D --> G[Coagulase -]
    E --> H[Beta-hemolytic]
    E --> I[Alpha-hemolytic]
    E --> J[Gamma-hemolytic]
    H --> H1[S. pyogenes Group A]
    H --> H2[S. agalactiae Group B]
    I --> I1[S. pneumoniae Viridans group]
    I --> I2[Strep]
    J --> J1[Enterococcus]
```

<1m <10m 3d 7d

Edit Again Hard Good Easy More ▾

User 1 - Anki

Decks Add Browse Stats Sync

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

Staphylococcal Protein A

Binds the heavy chain of IgG i.e. the wrong orientation for effective antibody binding and neutralization

<1m <6m <10m 7d

Edit Again Hard Good Easy More ▾

# Cognitive science principles: **classroom** examples



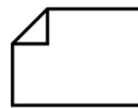
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+/-  
Elaboration  
Spaced practice  
Interleaving



## **Partial lecture outlines**

Elaboration  
+/-  
Retrieval  
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## **Flashcards**

Retrieval  
Spaced Practice  
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Elaboration



## **Quizzes**

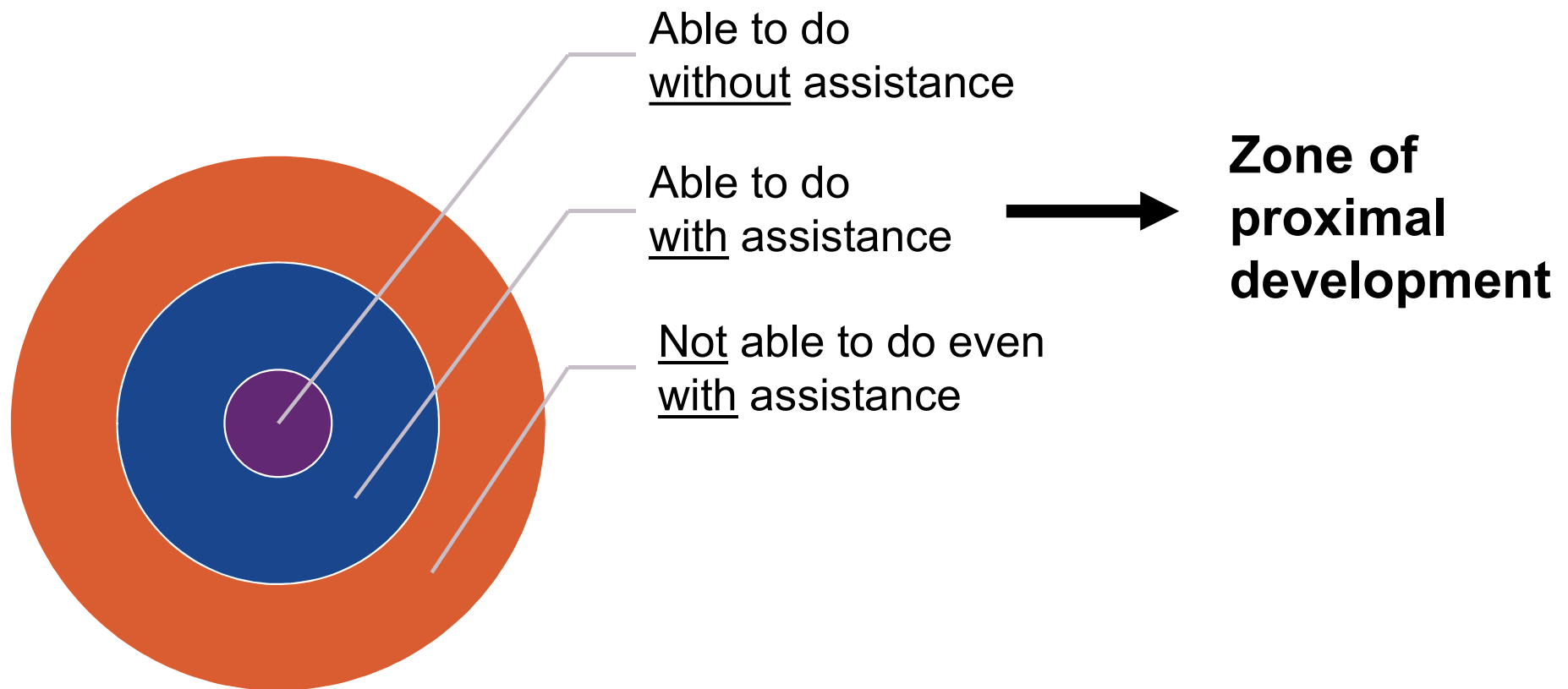
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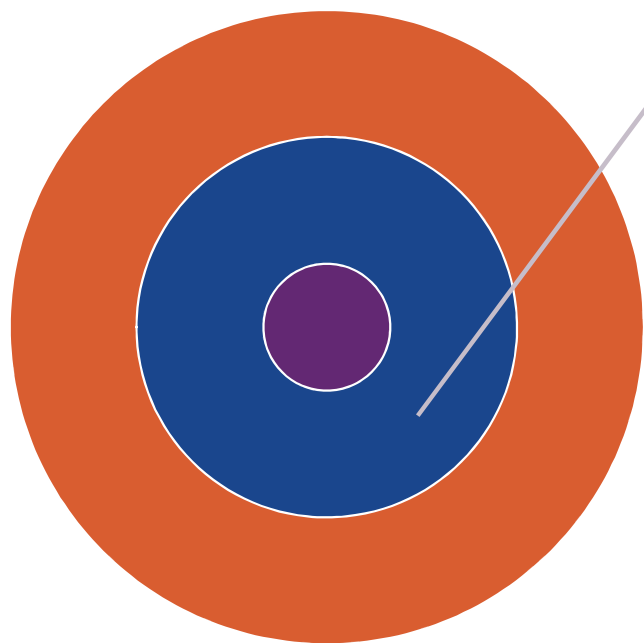
## **Study partners**

Retrieval  
Elaboration  
+/-  
Spaced Practice  
Interleaving

# Create desirable difficulty to enhance learning



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



Zone of proximal development

**Example**

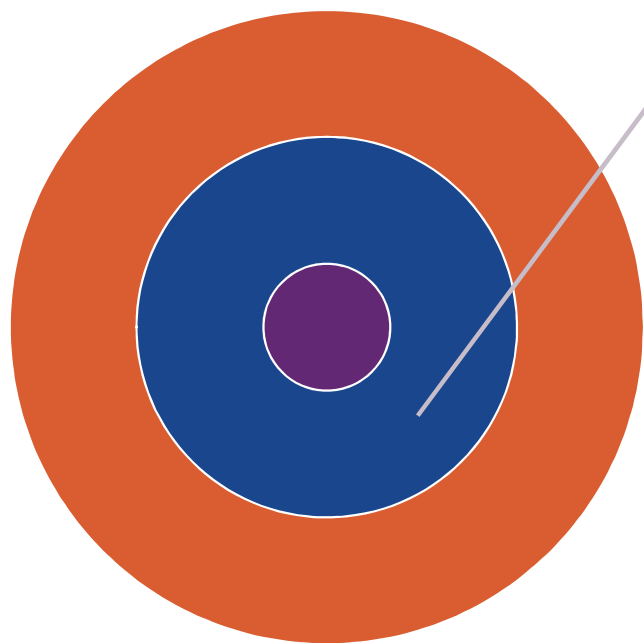
Placing a difficult IV

**Assistance provided**

Direct supervision w/ demo



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



Zone of proximal development

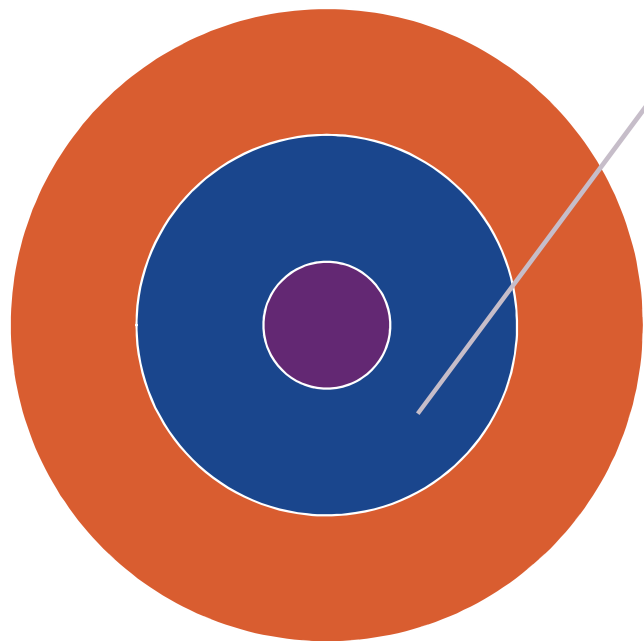
## **Example**

Placing a difficult IV  
Dosing an aminoglycoside

## **Assistance provided**

Direct supervision w/ demo  
Handout with instructions

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



Zone of proximal development

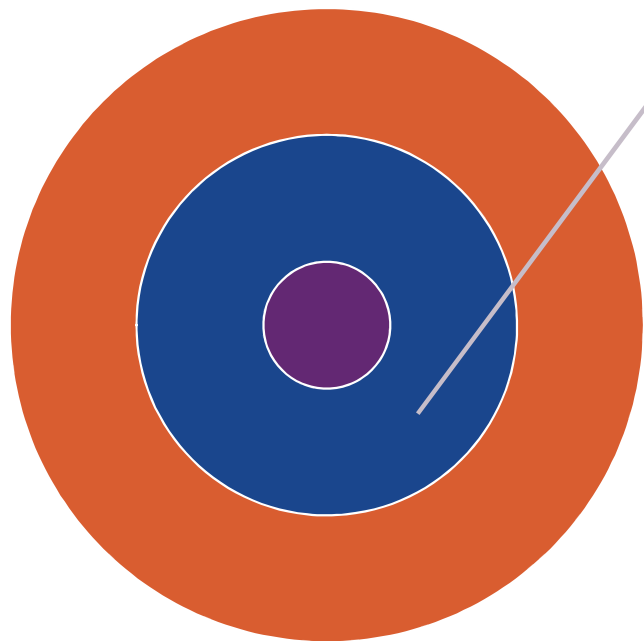
## **Example**

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

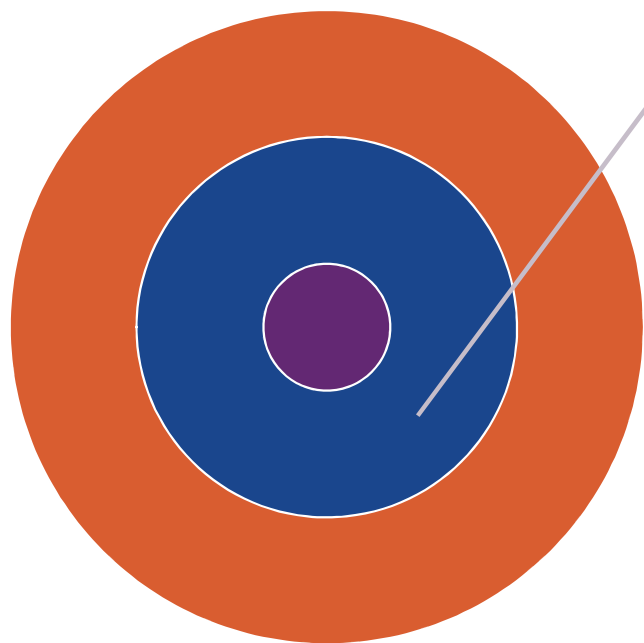
**Example**

Multiple-choice questions

**Assistance provided**

Answer with explanation

# The zone of proximal development: **classroom** examples



Zone of proximal development

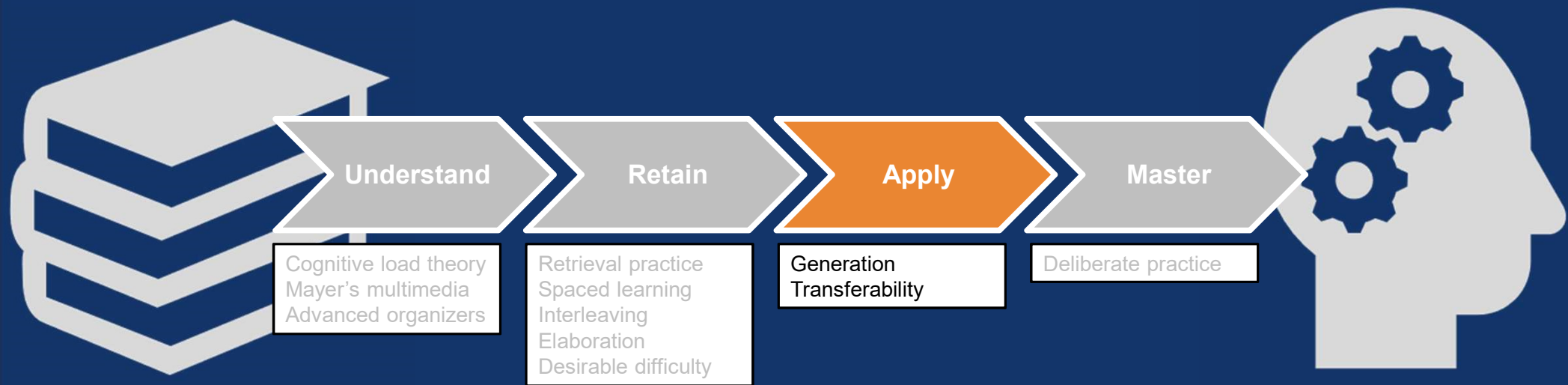
## **Example**

Multiple-choice questions  
Clinical problem set

## **Assistance provided**

Answer with explanation  
Group work

# Evidence-Based Learning Principles



# Application of Knowledge

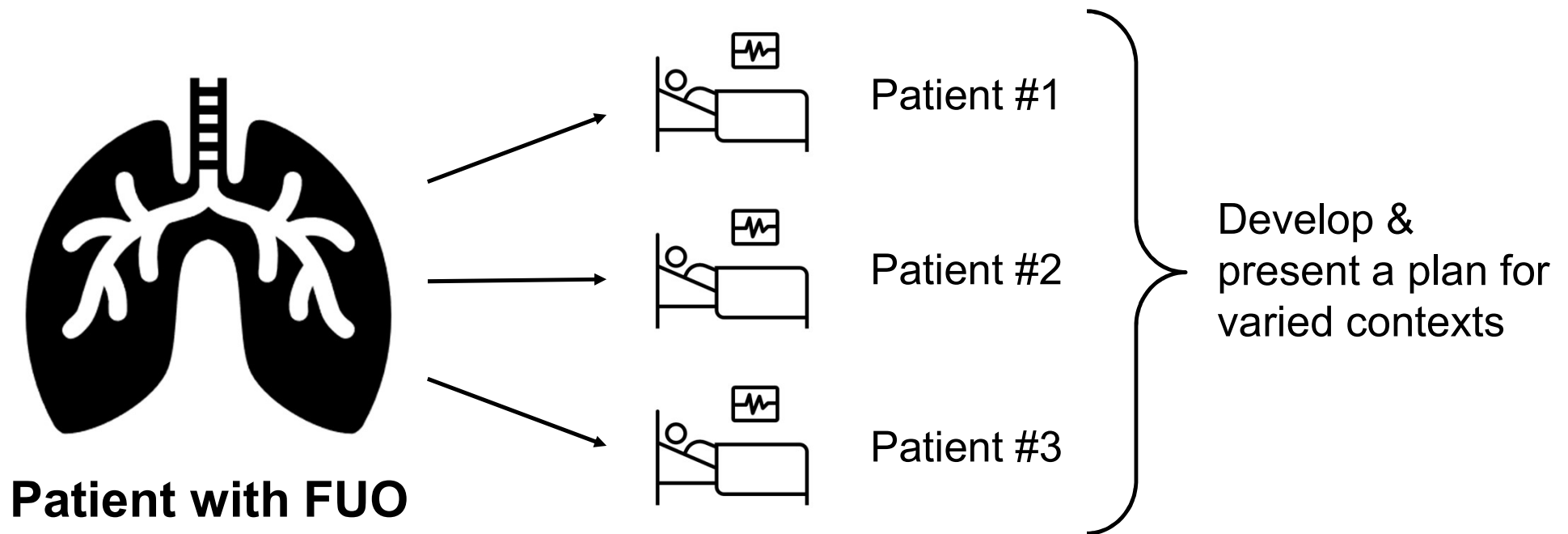
## Generation

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

## Transfer

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

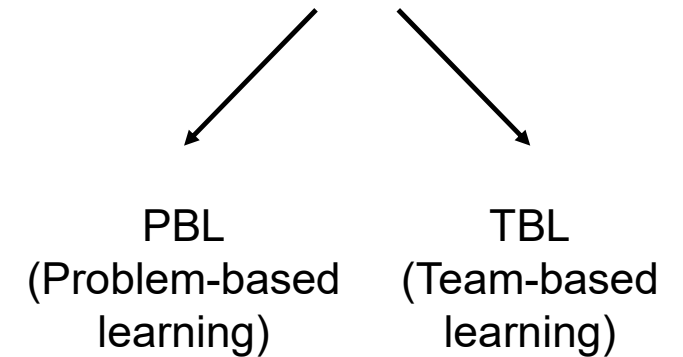
# Generation & Transfer: **clinical** example



# Generation & Transfer: **classroom** example

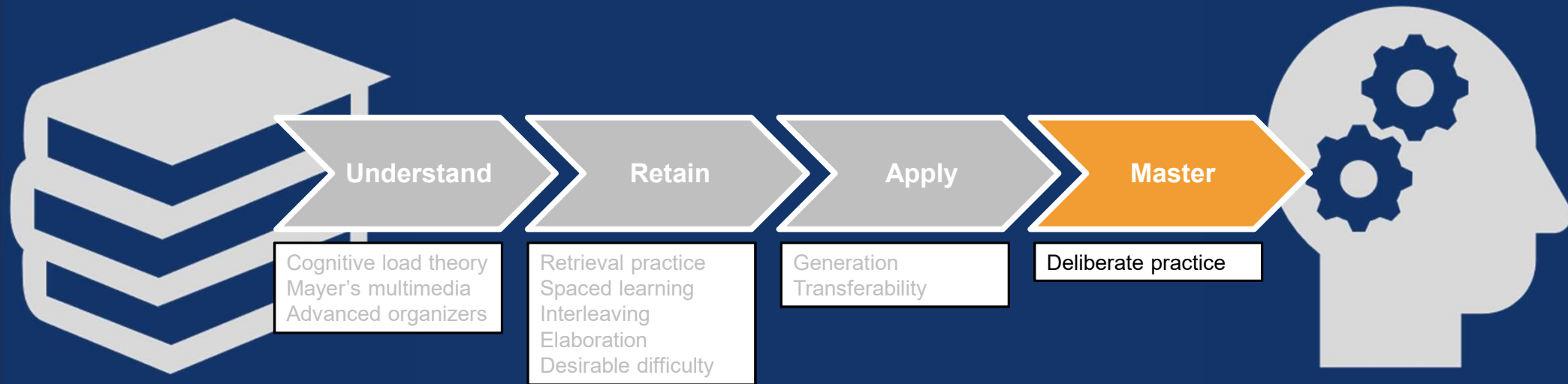


## Case-based learning





# Evidence-Based Learning Principles



# Deliberate Practice: experience does not equal expertise

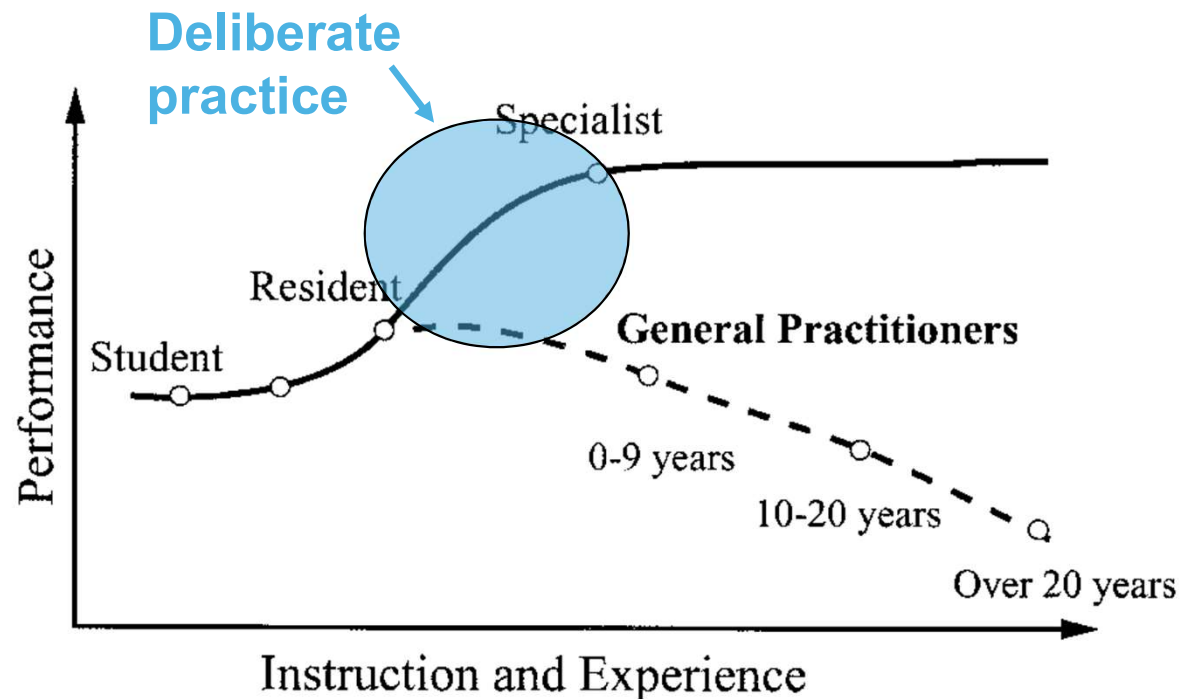
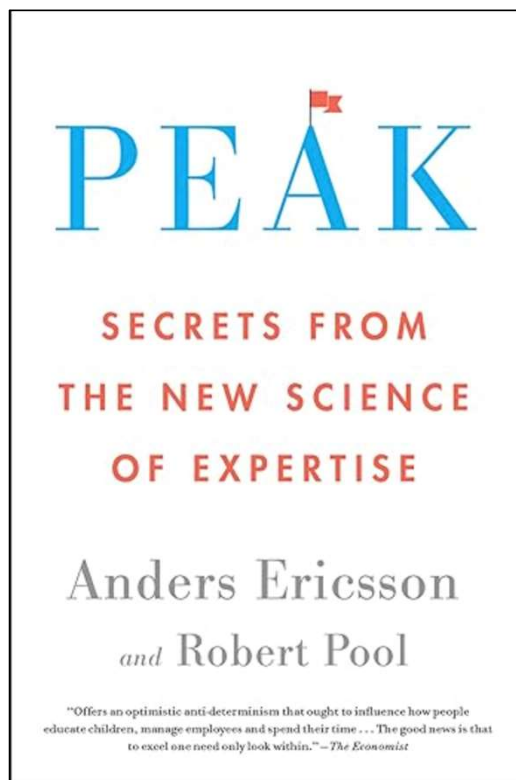
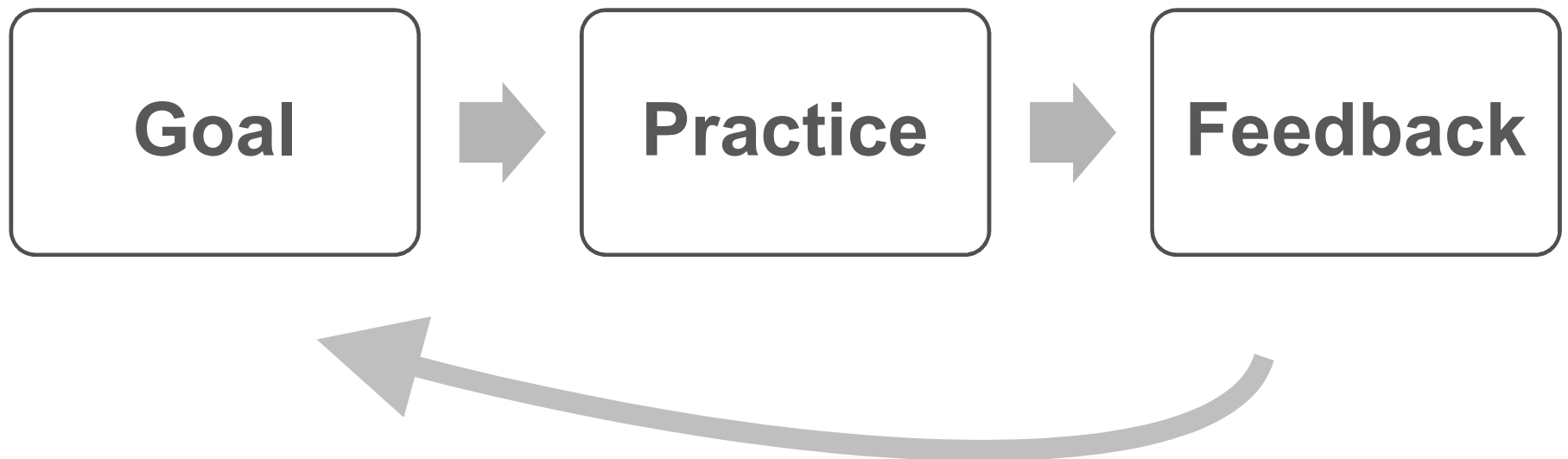


Figure 4. Two trends for development of medical performance as a function of experience and instruction.

# 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.**

**Understand**

Cognitive load theory  
Mayer's multimedia  
Advanced organizers

**Retain**

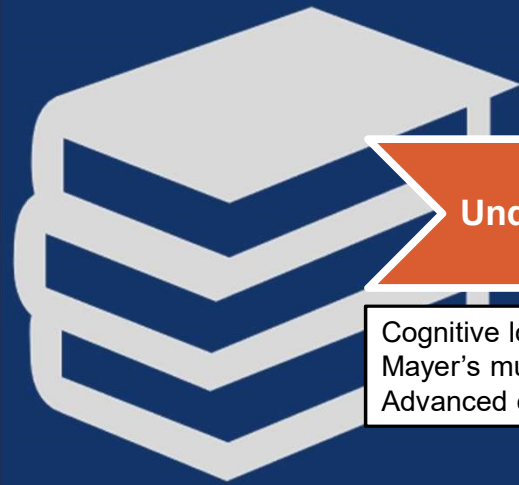
Retrieval practice  
Spaced learning  
Interleaving  
Elaboration  
Desirable difficulty

**Apply**

Generation  
Transferability

**Master**

Deliberate practice



## References

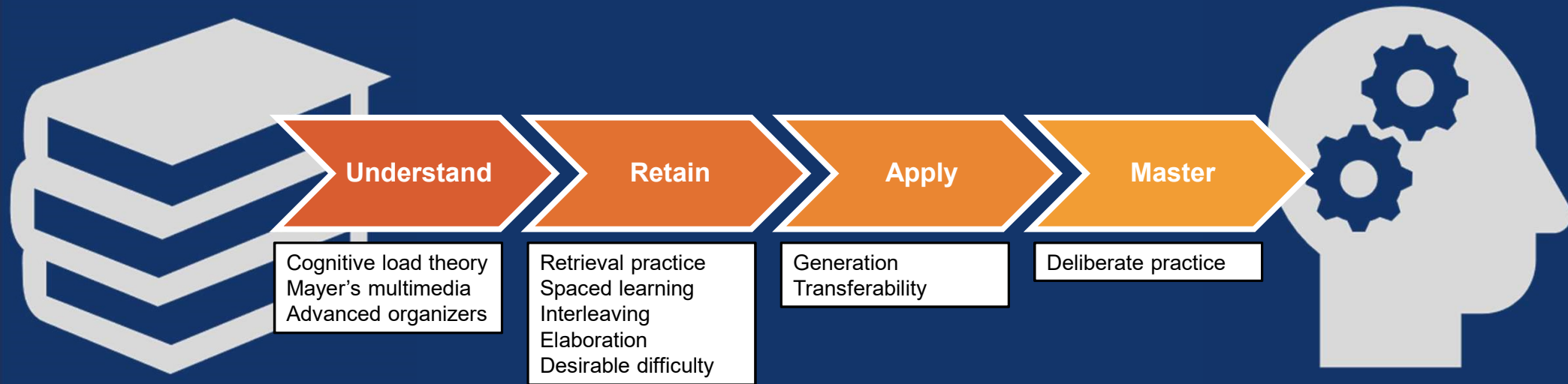
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# Evidence-Based Learning Principles



# Evidence-Based Learning Principles

**Simplify & organize content.**

**Practice repeatedly on difficult**

**...and realistic scenarios**

**...with targeted feedback.**

Understand

Retain

Apply

Master

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