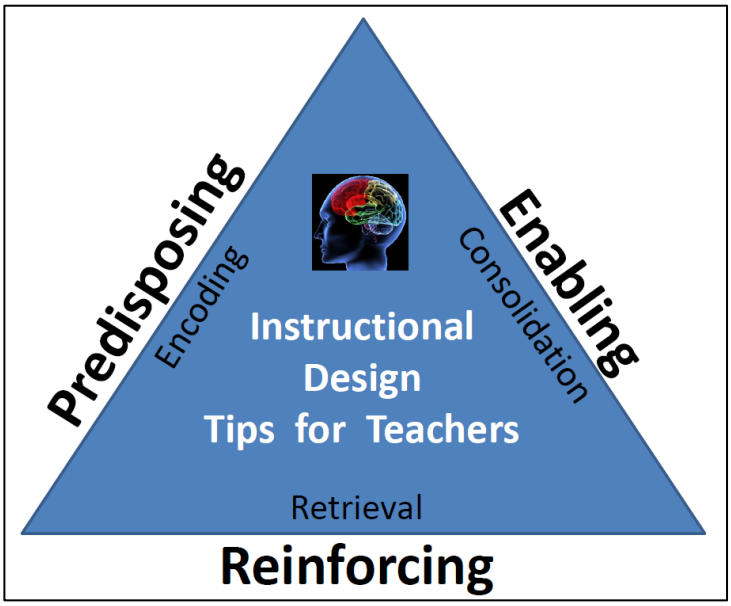
The Science (*and Illusions*) of Learning:

Instructional Design Tips for Teachers to Enhance Learners' Long-term Memory Retention

(Department of Medicine Grand Rounds – Wednesday, July 7, 2021)



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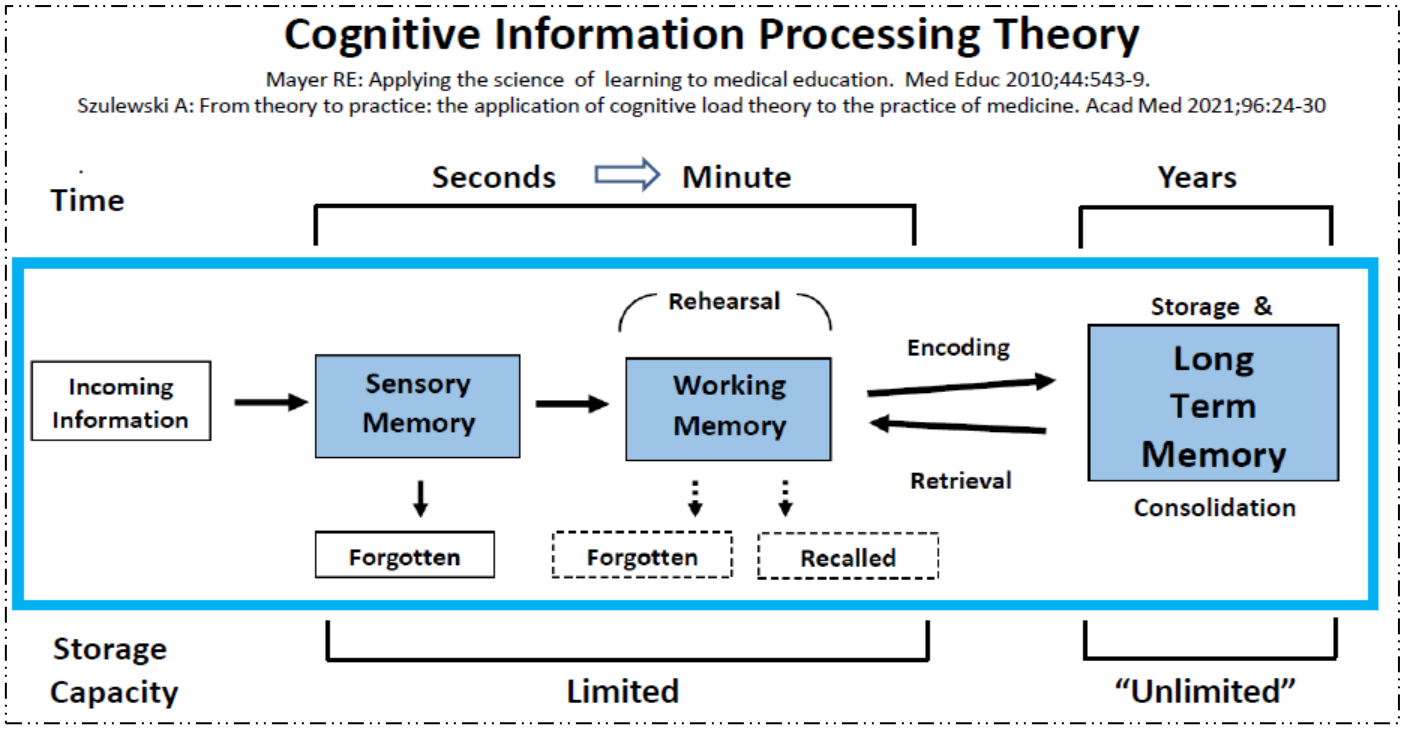


Making It Stick

(Adapted by Lawrence Loo, MD, from the AAIM Conference – October 21, 2017: Klein A, Carter A, McNeil M: Applying the Science of Learning to Everyday Teaching during Lectures, in Clinic, and on the Wards)

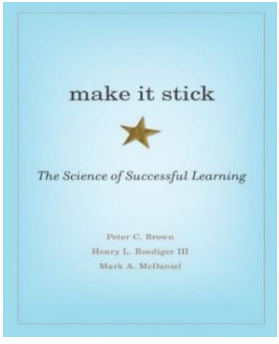
Truths about Learning:

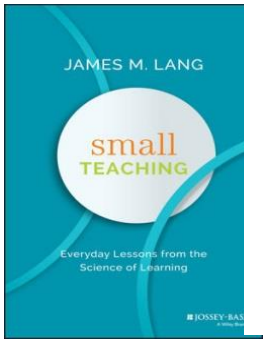
- To be useful, learning requires memory. What we have learned needs to be there later when we need it.
- Learning is an acquired skill. The most effective strategies are often counterintuitive.
- **Learning is deeper and more durable when it is effortful**. The greater the effort the longer the memory retention. (Myth: Learning is better when it's easy.)
- Paths in the brain that are worn deeper and used repetitively over time are easier to follow the next time.
- **We are poor judges of when we are learning well.**
- Re-reading and massed practice (i.e. cramming) give rise to a false sense of fluency and mastery but lead to learning that is often shallow and less durable.

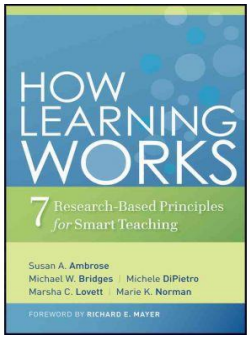
Four Evidence-based Cognitive Learning Strategies:

1. **Testing Effect** (or Retrieval Practice): Repeated testing promotes better retention of learning.
2. **Spacing Effect** (or Distributed Practice): Learning is more resilient when spread out over time.
3. **Interleaving**: Learning that is varied and shuffled tends to be more flexible and adaptable.
4. **Self-explanation, Elaboration, Generation & Reflection**: Learning is more durable if it is meaning and relevance comes from the learner.

Highly Recommended Resources:







- *Make It Stick*: Peter Brown, et al.
- *Small Teaching*: James M. Lang
- *How Learning Works*: Susan Ambrose
- *The Learning Scientists @ https*://www.*learningscientists*.org
- *Retrieval Practice* website: https//www.retrievalpractice.org
- Learning and Memory Strategy Demonstrations for the Psychology Classroom*: JA MCCabe @ https://teachpsych.org/Resources/Documents/otrp/resources/mccabe14.pdf*

Metacognitive Learning Strategies

Evidence-based Education & the Science of Learning: Key Summary

(Revised January 30, 2018 – Lawrence Loo, MD)

*"**Evidence-based Education**" bridges the gap between the practice of learning in real world situations and research from the medical education literature, general education, neurosciences and cognitive psychology.
Adv Health Sci Educ Theory Pract 2012;17(2):225-240

1) No particular learning "style" is more effective than another. Most medical learners use more than one learning approach (i.e., there is no "holy grail" of study methods where one is clearly better).

2) Proven methods of *long term* (i.e. months to years) memory retention:
   a) Practice **Testing Effect** (or Test-enhanced Learning): When studying material previously learned, repeated testing of information produces superior retention relative to repeated studying.
      i) **Effort retrieval**: When testing, recall questions (e.g. short answers, fill in responses) promote better retention that recognition tests (e.g. multiple choice questions [MCQ]).
      ii) One can turn a MCQ into a short answer question by covering up the answer options and asking oneself what the correct answer would be.
      iii) Multiple methods of "testing" including writing down everything one thinks they know about a topic; flash cards (but you must write your own flash cards, not use others); verbal questioning from a colleague, small group discussions, etc.
   b) **Spacing Effect (**or **Distributed Practice)**: Intermittent testing or studying distributed over time confers better memory retention than mass-practicing at a single point in time (i.e. it's better to study repeatedly over time than trying to "cram" everything in a single session).
      i) The optimal number of times to retest and space in between varies with the goal of long term memory retention. The longer one wants to remember, the greater the frequency of retesting and the interval in between.
      ii) For example in a 10 week cycle of major retesting, one may ideally want to test oneself three times: immediately after studying the material, one week later and 2-3 weeks later.
   c) **Interleaving Effect**: Is it better to study in blocks (i.e. one subject at a time until "mastery") or mix subject topics while studying (i.e. interleaving)? Surprisingly, mixing subject topics reinforces long term memory better.
   d) Why learners don't use the above 3 methods? Unfamiliar and takes more effort. *In short term testing, often results in poorer performance; but long term testing, memory retention is clearly better.*
   e) **Elaborate Interrogation, Self-Explanation & Generation**: Learners generate explanations for an explicitly stated fact or concept or explaining how new information is related to known information or explaining the steps taken during problem solving. Examples: think-pair-share, discussions, organizing maps & tables, etc.
      i) underlying theory: facilitates organization and discrimination (similarities & differences)
      ii) possible use as a form of testing effect and spaced effect to quiz oneself

Evidence-based Education & the Science of Learning: Key Summary

("Don't bother to take notes. Half of what you are taught as medical students will in five years have been shown to be either wrong or out of date. The trouble is, none of your teachers know which half. ***So the most important thing to learn is 'how to learn on our own.'*** " From the opening address to the entering class of medical students by the Dean at the Harvard Medical School. BMJ 1956;2:113-6)

3) "**Retroactive Inhibition**": Studying material in a highly emotional state (e.g. cramming the night before a national exam) may displace long term memories (i.e. learners might remember the material studied most recently but will often forget key information studied in the past). *Always get a good night's rest before a major exam.* Remember the brain is working to consolidate and store information while sleeping.

4) ***Less*** **Effective Techniques** for Improving Learning: Possibly helpful to *some* students under *some* circumstances but the following cannot be recommended as a general evidence-based learning strategy for everyone.

a) **Rereading**: Overall utility ranking is "low." Comparative studies to distributed practice, elaborative interrogation and self-explanation (see first page), rereading has been shown to be a "consistently inferior" technique for learning

- spaced rereading (i.e. rereading a second time several days, weeks or even months later) is superior to rereading immediately after the first time

b)**Highlighting/Underlining**: Overall utility ranking "low." The greatest problem is the variability in how learners use this technique. For some learners, training is required to optimize learning.

i) Marking too much text reduces its utility as a learning technique.

ii) Several authors suggest that one impose explicit limits on the amount of highlighting (e.g. a single sentence per paragraph).

c)**Summarization**: Overall utility ranking is "moderate." Main problem is again students may not know how to summarize (i.e. identify the main points while excluding unimportant material). Students may need considerable training before ensuring this technique optimizes learning.

i) Higher-quality summaries that contained more information and that were linked to prior knowledge were associated with better performance. For students who already know how and effectively use summaries, probably can continue. A trickier issue is whether to use this strategy with those who are less skilled at creating summaries.

ii) In comparative studies a "middle of the pack" technique. More useful than rereading, as useful as note-taking, but less powerful than elaborative interrogation and self-explanation.

d)**Key word Mnemonic** and **Imagery Use**: Overall utility is "moderate." May be very context specific (mnemonics for vocabulary words, lists of names and for imagery-friendly materials)

i) learners need to be trained; instructors may have to supply the mnemonics and images to be optimally used

ii) studies examining the durability of learning and variety of learning outcomes are preliminary

Recommended Resources:

(1) Pahler H, et al.: Organizing Instruction & Study to Improve Student Learning (NCER 2007-2004). Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Dept. of Education. 2007. http://ncer.ed.gov

(2) Dunloshy J, Rawson KA, et al.: Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science 2013*; 14(1):4-58.

(3) Fiorella L, Mayer RE: Eight ways to promote generative learning. *Educ Psychol Rev* 2016; 28:717-741.

Learning-Oriented Teaching Model (LOT) Worksheet

(Revised 1/4/2018 – Lawrence Loo, MD)

How to get a "LOT" out of your conferences: Demonstration of the LOT Model

Learning Process Component	Learner's Concerns	Teachers' Concerns and Issues
Cognitive Level	Study **what**?	Presenting (facilitating the provision of relevant information
Affective Level	**Why** Study?	Motivating (stimulating students to invest in studying)
Metacognitive Level	**How** to learn?	Instructing (helping students to go about studying)

Table Adapted from: TenCate, O., Snell, L., Mann, K. & Vermunt, J. (2004). Orienting teaching toward the learning process. *Academic Medicine, 79(3), 219-228. Clinical implications for medical education of LOT model:* Kusurkar RA, et al.: Have motivation theories guided the development and reform of medical education curricula? a review of the Literature. *Acad Med 2012;87:735-43.*

WHAT IS OUR ROLE AS INSTRUCTORS?	STRATEGY TO IMPLEMENT
What to present to learners: What are the most important points you would like learners to remember?	Learning goals and objectives: -Medical Students: -Interns/Residents: -Faculty:
How to motivate learners: **Why** is this important not only now but for the future?	
How to instruct learners: How will you create a ***learning climate*** to optimize learning? How will the learner best remember this material?	

Effective Lectures for Adult Learners –

Incorporating the Science of Learning & Active Learning Strategies

(Revised September 16, 2018 – Lawrence Loo, MD)

1) **Applying Principles of Adult Learning to Large Group Interactive Lectures**: Growing evidence supports the role of active learning in favor over the traditional lecture model.[1-3] Moreover, today's learners expect and want more interactive presentation formats.[4] Effective medical educators should move from the "sage on the stage" approach (in which the faculty "talks at" the student) to a more "guide on the side" model (in which faculty facilitate discussion, elaboration, and application of material).[5]

2) **Attention Span in Large Group Lectures**:[2]

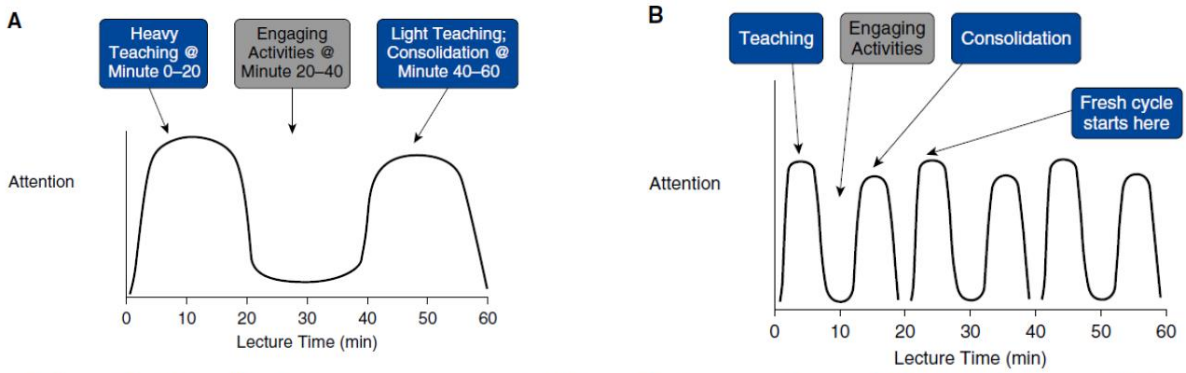


Figure 1. Using the "primacy-recency effect" to optimize engaging activities in a lecture. (*A*) Proper positioning of audience participation within a lecture. The *line* depicts the level of audience attention during a 60-minute lecture and includes periods of high attention and low attention. The *blue boxes* highlight the proper timing for instruction (prime time) relative to the level of attention, and the *gray box* (down time) highlights the appropriate placement for engaging activities to activate the audience. (*B*) Use of multiple prime time-down time cycles. To counteract low attention periods, a 60-minute lecture can also be divided into three segments lasting 20 minutes each. The engaging activities are then placed in the middle of each 20-minute cycle. New and multiple speakers can be used for each cycle. Modified with permission from Reference 14.

3) Incorporating Active Learning Strategies in a Large Group Lecture:[1-5] See accompanying **Primer** for additional suggestions and one evidence-based approach – the **ACTIVE** teaching format.

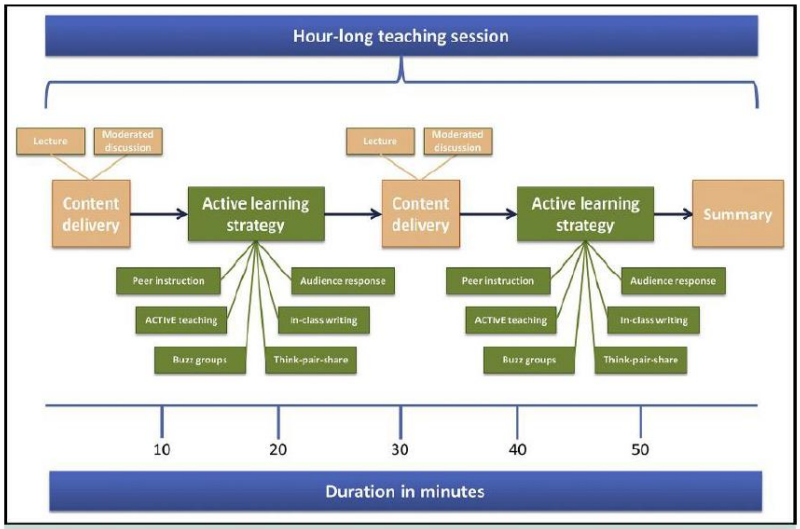


Figure This is a framework for how to structure an hour-long lecture, to maintain learner engagement and enhance efficacy, by using active learning strategies interspersed with content delivery.

Active Learning Strategies Primer to Promote Learner-centered Education & Long Term Memory Retention

[Adapted from Am J Pharm Educ 2011;75(9):Article 186, J Emerg Med 2015;48(1):85-93; and College Teaching 1993;41(1):30-35; and https://ablconnect.harvard.edu/do-now-research]

Knowledge Probe	Posing questions at the start of a lecture is a good way to stimulate thinking about the content you will cover for the day. It primes the mind to apply concepts. Examples: Prepare 2-3 short answer questions or 5 multiple-choice questions from the lecture content. Have the students work individually or in pairs to answer the questions and have them save their answers. The questions can be readdressed in a mid-lecture or end-of-lecture activity to help students see how their understanding has increased.
Think-Pair-Share	Pose a question or problem. Students spend 1-2 minutes thinking about the problem alone, then discuss in pairs. Pairs may be asked to report to the entire class. Works well in any size classroom at any time during the class. Effective way to involve learners, especially those apprehensive about speaking up in front of the class. Provides the instructor with feedback on what learners have (or have not) grasped.
Pause & Clarify	Pause lecture for 2-3 minutes while learners chat with neighbors about their respective understanding of key or difficult conceptual content. Aim is for each student to clarify their own understanding by comparing their perspective with that of their partner. Works bests for questions asking about application of understanding, rather than simply recall of information
Quick Think	Every 15-20 minutes insert a "quick think" exercise to increase attention, interest and learning. Participation options vary and can include: Think-pair-share, generate an answer with a neighbor, or silently think about a possible response. Examples include: multiple choice – single best answer question, correct the error, complete a sentence starter, compare of contrast, support a statement, re-order the steps, reach a conclusion, take opposing sides to a controversial issue, or paraphrase the main idea.
Socratic Questioning	Query students in a manner that helps them uncover answers. Ask learners about thought processes, probe assumptions, and ask for evidence. Can be used in large and small classes. Establish learning climate guidelines first: respect all around, non-judgmental attitudes.
Mini-case	Begin the conference with a realistic case involving the concepts that will be discussed that day. Include a brief question that requires application of key concepts. Can use the case to tie in key points during and at the end of the conference. Give time for the students to work on applications of the topic to the case.
One-minute Paper	Often used at the end of the teaching session (although can be adapted for use mid-way after teaching a major section of a topic), asks two questions and given 1-2 minutes to give a written response to (1) "What was the most important thing you learned today?" and (2) "What questions remains the uppermost in your mind from today?" Instructor collects the responses and without revealing names, shares sample responses & gives feedback. Works in large of small groups. An effective technique for determining learners' progress – understanding course material, reaction to course.
Muddiest Point	Similar to the "One-minute Paper" (or can be added as a third question), learners write down their responses to the question "What was the muddiest (unclear/uncertain) point from today?" in 1-2 minutes. Can provide feedback to the instructor about their teaching and learners' progress.
Critical Thinking or Activity	Provide a small group breakout session designed around a thought provoking question/case that builds upon concepts recently presented. Students may be asked to take different perspectives (e.g. patient, nurse, family member, etc.) or take opposing sides to a controversial issue. Select a student from each group to summarize and report back to the larger group.
Guided Reciprocal Peer Questioning	Students work in groups of 3-4. Everyone is provided a set of *generic questions* (see below) and each student generate 2-3 thought provoking questions based on the material recently taught. Students pose their questions to the group and take turns answering each other's questions. *Generic questions* (designed to promote higher order thinking) can include: What is the main idea of . . .? How does . . . affect . . .? Why is . . . important? What is a new example of . . .? Explain why/how . . . ? How does this relate to what I've learned before (or in other classes)? How are . . . and . . . similar (or dissimilar)?
Jigsaw Learning Activity	Requires that learners become experts in a subject area and then teach that topic to peers who have become experts in other related topics. Steps: (1) Divide the class into small groups or 4-6 students. (2) Assign each group a subject area to learn. (3) Rearrange groups so that there are 2 reporters in each group – one "rotating" reporter and one "stationary" reporter. (4) The "rotating reporter" moves to the other groups explaining that group's findings. (5) The "stationary reporter" explains that group's finding to each of the "rotating reporters" as they move from one group to another.

Three Recommended Metacognitive Learning Strategies

Predisposing: KWL Method previewing prior to a learning experience.

(Ogle DM: K-W-L: A teaching model that develops active reading of expository text. *Reading Teacher* 1986;39:564-70)

Ask yourself:

K: What do I already know?

W: What do I want to know?

L: (Afterwards ask) What did I learn?

Enabling: Reflection using the Four-Questions Technique

(Dietz-Uhler B, Lanter JR: Using the four-questions technique to enhance learning. *Teach Psychol* 2009;36:38-41)

1. Identify one important concept, research finding, theory or idea that you learned while completing this activity. *(Analyzing)*
2. Why do you believe that this concept, research finding, theory or idea is important? *(Reflecting)*
3. Apply what you have learned from this activity to some aspect of your life. *(Relating)*
4. What question(s) has the activity raised for you? What are you still wondering about? *(Questioning)*

Reinforcing: The "One-Minute" Paper:

A quick guide to assessing student learning after an educational experience

(Sinclair M, Rowe K, Brown G: NT Learn Curve 1998 2:4-5 – modified by LLoo Jan. 2017*)

Directions: Take a moment to think about the educational experience you just completed and then answer the following three questions.

1. What was the ***most important thing*** you learned from this educational experience?
2. What ***question remains*** the uppermost in your mind at the end of this educational experience?
3. What was the ***"muddiest*** (i.e. unclear) ***point"*** from this educational experience?

(1) Stead DR: **A review of the one-minute paper**. Active Learning in Higher Education Aug 2015; 6(2):118-131.

(2) Colbert CY, et al.: **Teaching Metacognitive skills: Helping your physicians in trainees in the quest to "Know what they don't know."** Am J Med March 2015; 128(3):318-324.

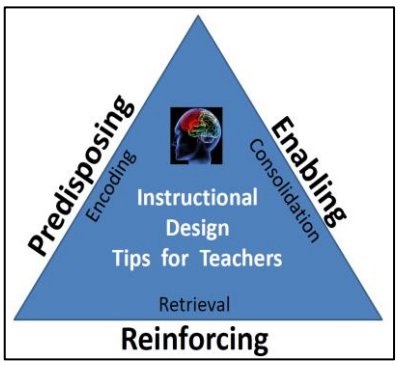
(3) NIcol DJ, et al: **Formative assessment and self-regulated learning: a model and seven principles of good feedback practice**. Studies in Higher Education 2006:31(2):199-218.

How can we apply evidence-based education strategies to enhance long-term learning?

	Topic	Course	Year
Spaced Retrieval Practice: Studying information more than once but leaving considerable time between practice sessions.			
Self-Elaboration: Giving new meaning by expressing it in your own words and connecting it with what you already know.			
Generation: Trying to answer a question or solve a problem before being presented any cues, information, or solution.			
Reflection: Reviewing what has just been learned as a tool for consolidating knowledge.			
Interleaving: Learning more than one concept at a time so that you can alternate between different problems that call for different solutions.			

Adapted from Winn AS, et. al.: Applying cognitive learning strategies to enhance learning and retention in clinical teaching. MedEdPORTAL 2019;15:10850

Instructional Design: The systematic process of arranging ***how*** learning can happen in a more consistent and reliable fashion.



A) Predisposing: Activate prior knowledge

1) Turn off distractions (e.g. mobile phone, texting, pagers, ?wifi)

2) Activate prior knowledge (e.g. ask a question, give a quiz, recall a past similar experience, encourage the **K-W-L method** [pg. 8] etc.)

3) Tell a story, show a video (from a movie, of a patient, etc.)

4) Other _____

5) Other _____

Of the above, I am willing to try _____

B) Enabling: Self-explanation, reflection, elaboration, generation

1) See "Effective Lectures" & "Active Learning Strategies" [pgs. 6-7]

2) Case-based, tell a story, show a video, try **4-question reflective technique** [pg. 8]

3) "Incomplete" handouts (i.e. make them write / type or fill out something)

4) Other _____

5) Other _____

Of the above, I am willing to try _____

C) Reinforcing: Testing effect, spacing, and interleaving

1) Give a post-quiz or periodic "low stakes" quizzes (@ end of a lecture, one day later, one week later, etc. – spaced retrieval [pg. 9])

2) Give an open book exam, make all quizzes & exams comprehensive

3) Encourage use of the **One-Minute Paper** *post* learning experiences [pg. 8]

4) Other _____

5) Other _____

Of the above, I am willing to try _____