

Applying the Science of Learning & Cognition to Teaching Critical Thinking

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What, no handout?

Taking notes by hand results in improved memory performance (Mueller & Oppenheimer, 2014).

Practice what you preach...

Caveats and Opportunities

Caveats – few of these effects have been specifically studied in critical thinking.

Opportunity to collect data applying these techniques to critical thinking.

What is critical thinking?

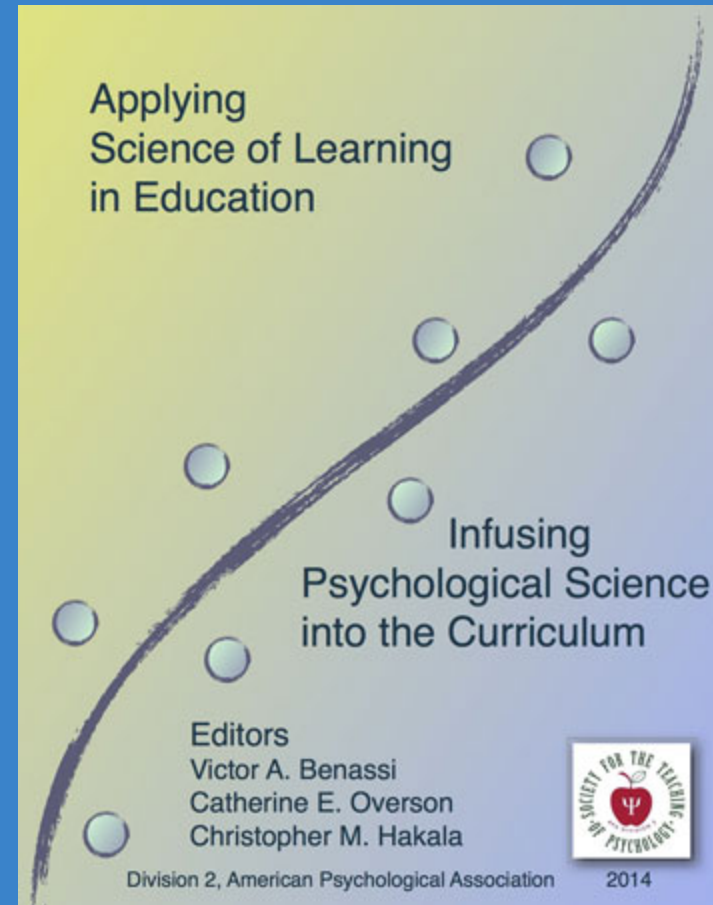
In my view, at least part of critical thinking is a skill which can be acquired through a combination of teaching and practice.

Goals for Today

- Understand how your students really learn (or, don't learn)
- Leave with some ideas about incorporating evidence-based approaches to improving learning to your courses
- Generate some ideas about conducting your own studies

Great Resource from SToP

[http://
teachpsych.org/
ebooks/asle2014/
index.php](http://teachpsych.org/ebooks/asle2014/index.php)



Overview

- I. Metamemory & Metacognition – where many of our misconceptions about learning arise...
- II. Survey of empirically derived techniques to improve learning
- III. Direct Applications to Critical Thinking

I. Introduction to Metacognition and Metamemory



I. Introduction to Metacognition and Metamemory



"There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know."

Donald Rumsfeld

I. Introduction to Metacognition and Metamemory

“The wise man is one
who knows what he
does not know.”

Lao Tzu,
Tao Te Ching



I. Introduction to Metacognition and Metamemory

- What are 'metacognition' and 'metamemory'?
 - Knowledge and awareness of one's own cognitive process or one's own memory
 - Critical to understanding learning – how do we know what we have actually learned vs. think we have learned?

I. Introduction to Metacognition and Metamemory

B. Studying metacognition

- Often ask participants to make *predictive judgments* about their learning using *judgments of learning* (JOLs)
- Other times we are interested in how well a student believes they have performed using *retrospective confidence ratings*.

I. Introduction to Metacognition and Metamemory

C. Predicting later memory performance: JOLs

- In general, we all stink at this.
- We often fall prey to *metacognitive illusions*
 - Rhodes & Castel (2008) – perceptual fluency effects

Fluency Effects...

BIRD

DOG

HORSE

CANARY

I. Introduction to Metacognition and Metamemory

C. Predicting later memory performance: JOLs

- In general, we all stink at this.
- We often fall prey to *metacognitive illusions*
 - Rhodes & Castel (2008) – perceptual fluency effects
 - Carpenter et al. (in press) – instructor fluency
 - The problem is, we *feel* like we have learned because the material seems easier

I. Introduction to Metacognition and Metamemory

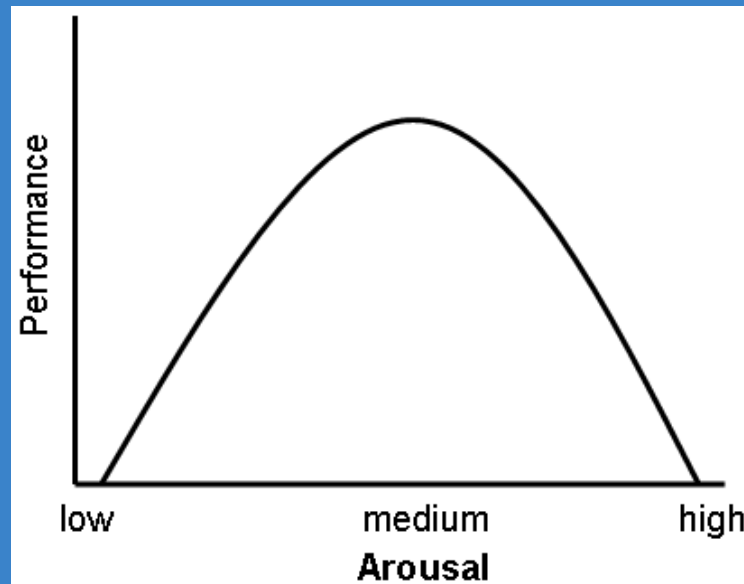
D. Improving metamemory through testing

- In the cognitive literature metamemory is improved by *delayed judgments-of-learning*
- Essentially, students evaluate their learning by trying to remember
- Suggestion – using iclickers or tophat?
Consider asking students to rate their understanding of material later in the lecture or at the next lecture.

I. Introduction to Metacognition and Metamemory

E. The problem of *desirable difficulties*

- Learning that requires effort is generally superior.
- Similar to the Yerkes-Dodson Effect



I. Introduction to Metacognition and Metamemory

- F. Try to get your students in 'the zone'
- The *region of proximal learning* (Metcalfe & Kornell, 2005).
 - In teaching critical thinking, consider what your students can do already, and what is beyond their ability. In between, is where they can learn the most.

I. Introduction to Metacognition and Metamemory

G. Metacognition is tied to critical thinking

- Ku & Ho (2010) found a strong correlation between university students' use of metacognitive planning, monitoring, and evaluating strategies and their performance on critical thinking tasks

I. Introduction to Metacognition and Metamemory

H. Classroom Suggestions

1. Use metacognitive prompting (Girash, 2014)

- *What (exactly) are you doing? (Can you describe it precisely?)*
- *Why are you doing it? (How does it fit into the solution?)*
- *How does it help you? (What will you do with the outcome when you get it?)*

I. Introduction to Metacognition and Metamemory

H. Classroom Suggestions

2. Be mindful of the problems with metacognition
3. Provide students means to test themselves
 1. Online review quizzes
 2. Review assignments
4. Does providing slides online lead to metacognitive failure?

I. Introduction to Metacognition and Metamemory

I. Important take-home message.

- Students are unable to realize when they are truly learning
- Asking students if they felt like they learned more using a particular technique is a poor strategy
- We must always have objective measures of performance

Take a moment...

A. Everybody stand-up!

- Standing facilitates group performance & creativity
- Knight, A.P. & Baer, M. (2014). Get up stand up: The Effects of a Non-Sedentary Workspace on Information Elaboration and Group Performance. *Social Psychology & Personality Science*.

B. Questions?

C. Ideas?

II. Empirically Derived Techniques

- The Spacing Effect
- Testing Effects
- How we study is more important than how much we study – elaboration, distinctiveness, etc.

A. The Spacing Effect

1. Essential issue – spaced vs. massed study
2. See also *interleaved study*
3. One of the oldest and most robust findings in the literature (e.g. Ebbinghaus, 1885).

A. The Spacing Effect

4. Examples:

- Learning to identify artist's painting styles (an inductive learning paradigm). Kornell & Bjork (2008).
- Grammatical structure in English learning adults (Bird, 2010).
- Abstract mathematics (Rohrer & Taylor, 2006, 2007).
- Identifying animal species (Birnbaum et al., 2012).
- Piano Melodies (Abushanab & Bishara, 2013)

A. The Spacing Effect

5. The problem with massed study

- Another metacognitive illusion
- Massed practice results in *an illusion of competence*
- As massed practice continues, learners use an *ease of acquisition* heuristic to guide learning
- Unfortunately, this results in little long-term retention

A. The Spacing Effect

6. Why does the spacing effect work?

- Important to understand the relationship between *episodic memory* and *knowledge*
- Episodic memory is linked to specific contexts such as time and place
- Knowledge is independent of any learning context
- Episodic memory supports knowledge (Merritt et al., 2006)
- Spacing learning results in multiple contexts

A. The Spacing Effect

7. Pedagogical Recommendations (Carpenter et al., 2012)

- Include regular review of previous material (after several weeks).
- Homework designed to review earlier material
 - Easy change – move assignments to come after the material has been covered.
- Cumulative quizzes and exams

A. The Spacing Effect

8. Thoughts? Barriers?

B. Testing Effects

1. Tests are not just a means of assessment, they are learning opportunities (Karpicke & Roediger, 2008).
2. Based on a long-standing, robust finding – the *generation effect*
 - Generated vs. read items
 - Hot: _____
 - Car: Bus

B. Testing Effects

3. Students engage in *retrieval practice*

4. Testing is superior to re-studying

5. Works with a variety of test types

- Multiple Choice
- Short answer essay
- Open book and closed book similar for long-term retention

B. Testing Effects

6. Feedback is important

- Increases retention of low-confidence, correct responses
- Reduces later false memory for incorrect responses

B. Testing Effects

7. Spacing out testing results in dramatic improvements in retention (Karpicke & Bauernschmidt, 2011).
8. Students do not often test themselves when studying (Karpicke et al., 2009).
 - **Illusion of competence**
 - Most often report repeated reading of material.

B. Testing Effects

10. Pedagogical Recommendations

- Quizzes – two advantages, force spaced study and reinforce material
- Provide review questions
- Provide feedback on exams – students need to be able to review their performance
- Goal for developing critical thinking is to get them practicing their skill

Thoughts on the testing effect?

Barriers?

Ideas?

C. Memory Encoding – A Key to Learning

1. Repetition or rote memorization is the *least effective* form of study.

- In what hand does the Statue of Liberty hold her torch?
- What is on the back of a \$20 bill?
- What room number is your department mail room in?

C. Memory Encoding – A Key to Learning

2. Effortful processing is the key

- Desirable difficulties...
- Effects include perception such as difficult to read fonts
- Generation leads to significant improvements in performance
- Elaboration & Self-reference effects

C. Memory Encoding – A Key to Learning

3. Maximize effectiveness using generation, elaboration and self-reference all at once:

- S.E.E.I.
- State, elaborate, exemplify, illustrate
- Using this technique students are generating their own understanding of the material!

C. Memory Encoding – A Key to Learning

4. Encourage Self-Explanation (Chiu & Chi, 2014).

- Prompt or assign self-explanation
- Including diagrams with text improves self-explanation
- Ask students to select the best explanation from competing alternatives
- As students advance, show incorrect examples

III. Applications to CT

- Goals & Feedback
- Worked Examples
- Operation ARA – a critical thinking computer game

A. Goals & Feedback (Hattie & Yates, 2014)

1. The role of goals – the point of feedback is to let a student know where they are, relative to a goal state.
2. Students should know where they stand – how far they have progressed.
3. Feedback should guide them towards the next steps

A. Goals & Feedback (Hattie & Yates, 2014)

4. When is feedback effective? (see Benassi et al, 2014 p. 55)

- Feedback must engage a learner at, or just above, the current level of functioning.
- Feedback is therefore, individual in nature.
- Feedback is powerful when the classroom climate is one of welcoming errors

A. Goals & Feedback (Hattie & Yates, 2014)

5. Applications to CT seminars

- Think about a series of assignments
- Develop rubrics using Turnitin Grademark (makes submitting artifacts quick and easy)
- Spend some time providing individual feedback and consider looking back at previous assignments

B. Worked Examples

1. What is a worked example?

- A highly structured step-by-step demonstration process of how to complete a problem or perform a task with a solution.
- Take students from problem to solution

B. Worked Examples

2. Instructional Principles for Effective Learning

- **Self-explanation** – elaborating on individual examples and comparing examples
- **Meaningful Building blocks** – provide salient sub-goals to guide self-explanations

B. Worked Examples

2. Instructional Principles for Effective Learning

- **Studying Errors** – only for learners with sufficient prior knowledge
- **Focus on learning domain** – keep in mind the region of proximal learning, students will be overwhelmed by unfamiliar problems
- **Fading principle** – gradually fade worked steps, provide less information to promote learning

C. Operation ARA

1. Intelligent tutor which teaches science and critical thinking in a game format
2. <https://www.youtube.com/watch?v=a4It dauF3h8>
3. Data show medium to strong effect sizes using intelligent tutors.

IV. Final Thoughts

- Think of adopting course changes as part of an experiment – manipulate one variable at a time.
- Be creative
- Do not let the perfect be the enemy of the good
- Explain to your students the reason you've adopted a new technique

Questions?