Parimal and Pramod Chaudhari
Centre for Learning and Teaching

Indian Institute of
Technology Bombay

Facilitating Student Use of Metacognitive Learning Strategies

Jeffrey E. Froyd

Professor, Department of Engineering Education

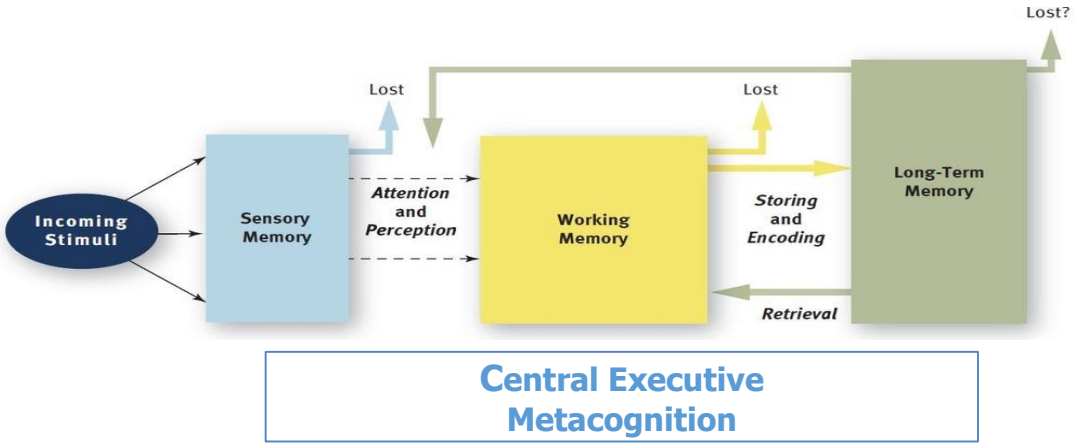
College of Engineering, The Ohio State University

froyd.1@osu.edu

Workshop Overview

- **Part 1:** Writing Effective Course Learning Outcomes
  - Morning, Wednesday, 8 January 2020
- **Part 2:** Applying Research-based Instructional Strategies
  - Afternoon, Wednesday, 8 January 2020
- **Part 3:** Developing Course Assessment Plans
  - Morning, Thursday, 9 January 2020
- **Part 4:** Facilitating Student Use of Metacognitive Learning Strategies
  - Afternoon, Thursday, 9 January 2020

Metacognition

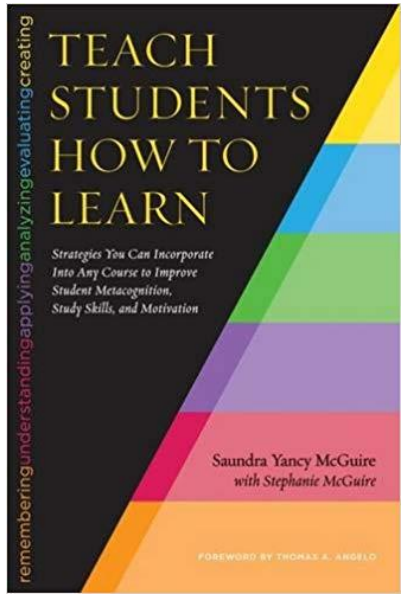


"Thinking about Thinking"

- Maybe accurate, but not too helpful

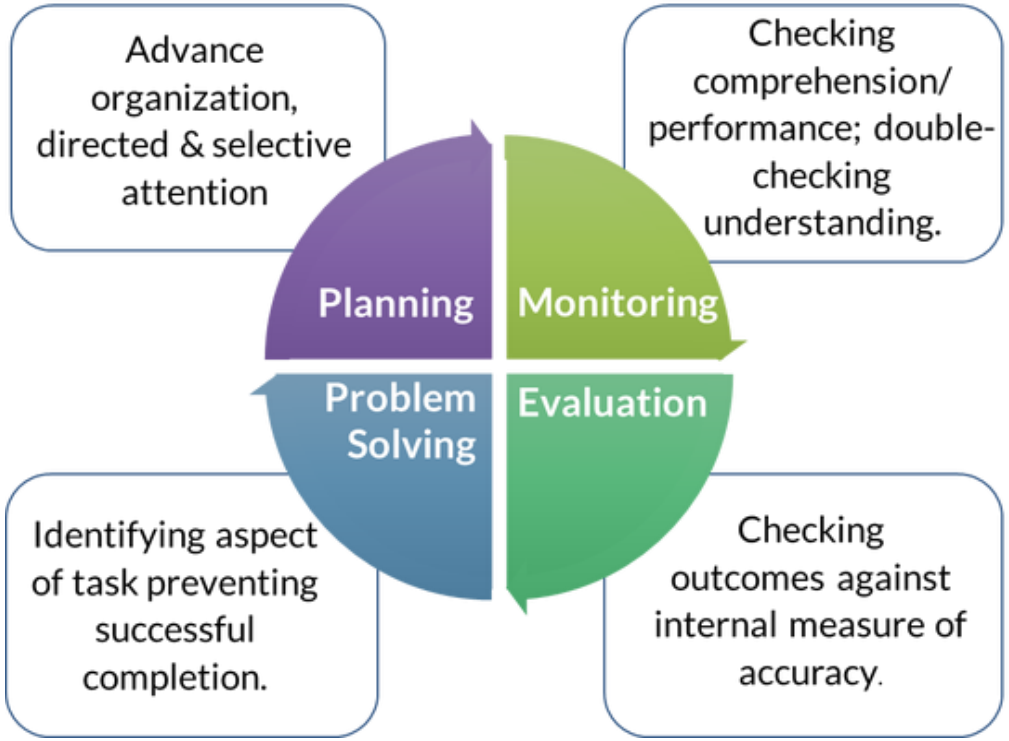
Internal, Real-time Project Management

- Each person has their own internal, real-time project management functionality
- The essence of metacognitive development is helping a person improve theirs
- It is an important function in the central executive in the Information Processing Model



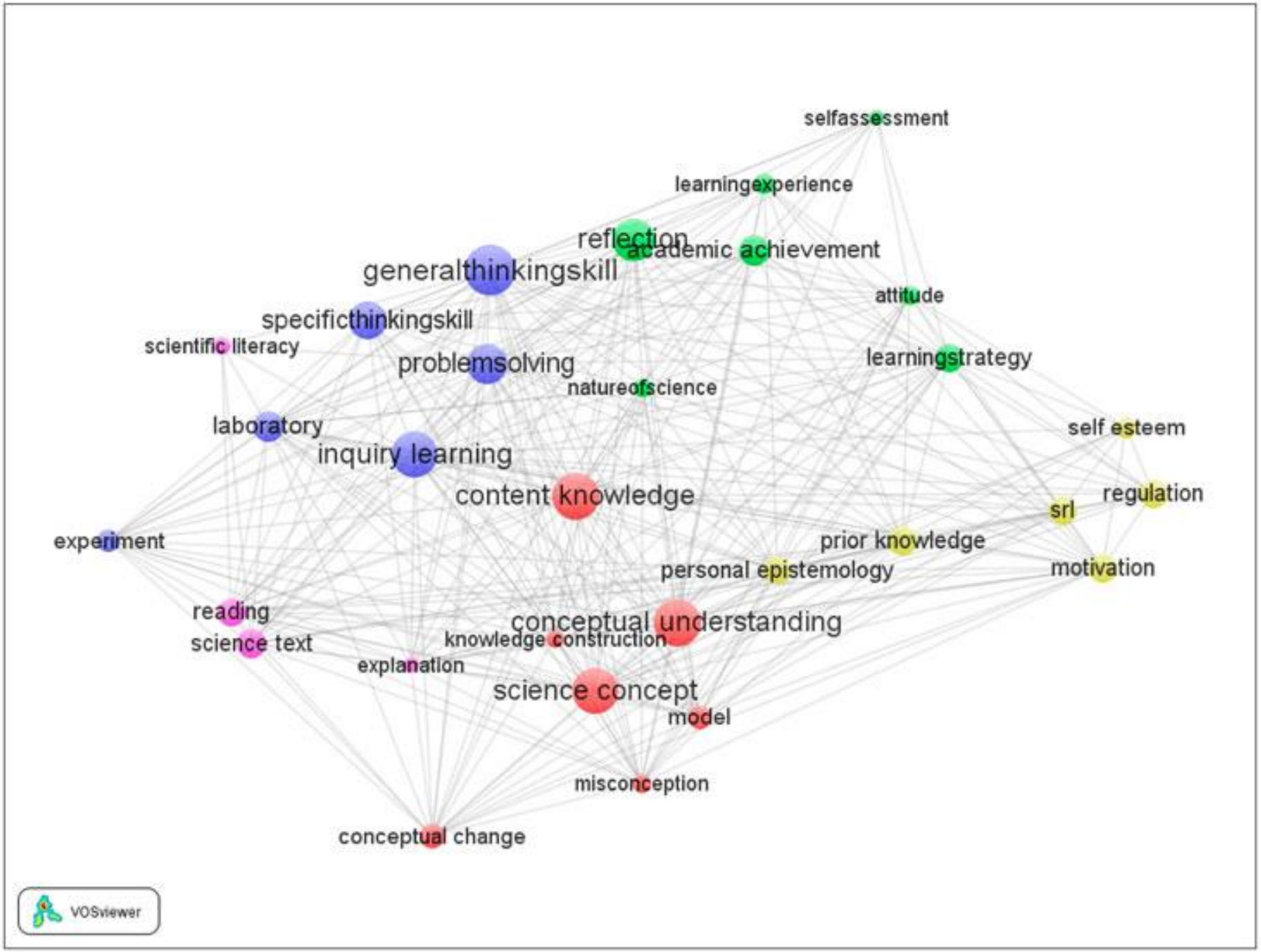
Metacognition

- Planning
- Monitoring
- Evaluation
- Reflection, Revising, Problem Solving



Metacognition is not doing the task. It operates while the task is being done

https://miriamvoth.weebly.com/introduction.html



A map of the recurring constructs studied in the field of metacognition in science education

Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. Studies in Science education, 49(2), 121-169. doi:10.1080/03057267.2013.847261

Metacognition: Knowledge and Implementation

Knowledge

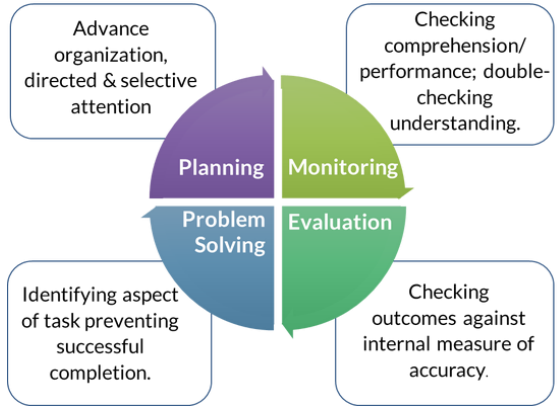
- Learning Principles
- Retrieval
- Spaced Retrieval
- Interleaved Retrieval
- Generative Retrieval
- Elaborative Retrieval
- Calibration
- Reflection

Implementation

- Planning
- Monitoring
- Evaluation
- Reflection, Revising, Problem Solving

Metacognition is not doing the task. It operates while the task is being done

Metacognitive Learning Strategies: Why do you care?



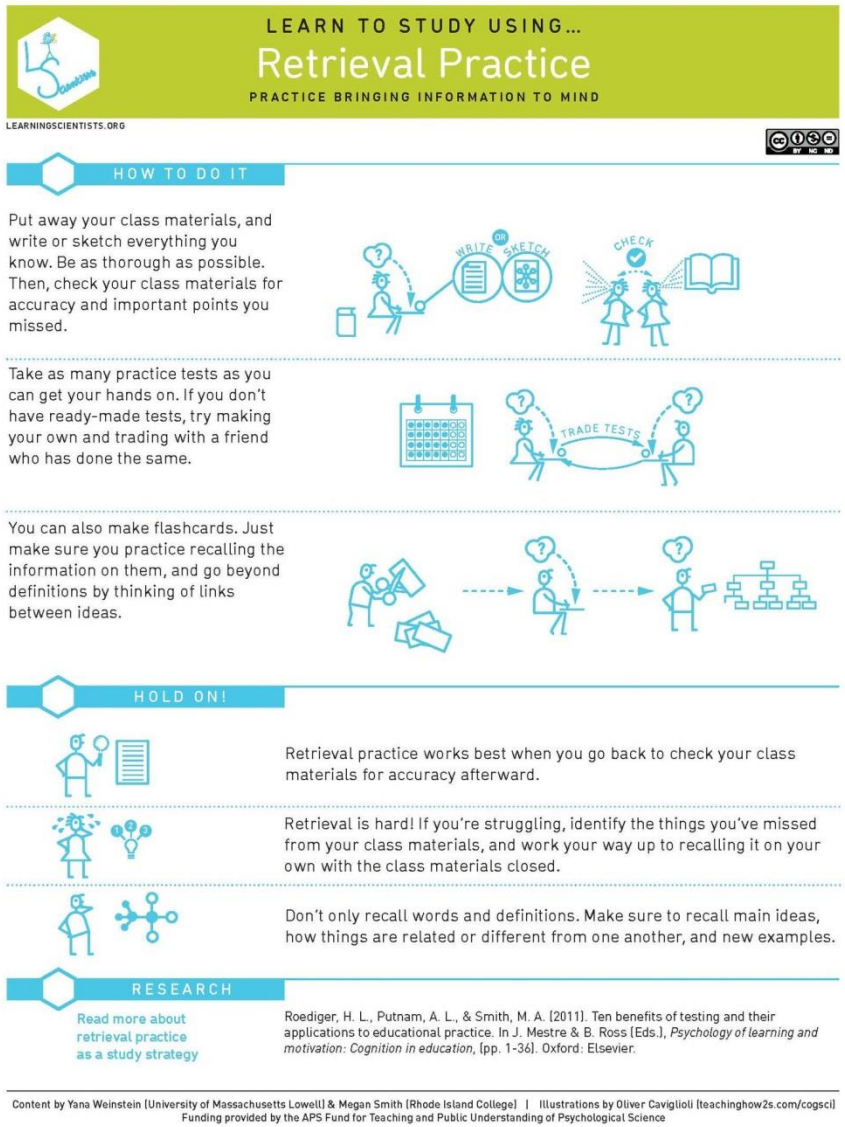
- Improvements in students applying metacognitive learning strategies have been correlated with improved learning, improved test scores, etc.
- Metacognitive practices increase students' abilities to transfer or adapt their learning to new contexts and tasks (National Research Council, 2000, p. 12; Palincsar & Brown, 1984; Scardamalia et al., 1984; Schoenfeld, 1983, 1985, 1991).

Effective Principles for Learning		Low-performing Practices for Learning
Retrieval	**Metacognition**	
Retrieval	Calibration	Highlighting
Spaced Retrieval	Reflection	Rereading
Interleaved Retrieval	Self-explanation	Summarization
Generative Practice	Planning, Monitoring, Evaluating, Revising	Imagery Use for Text Learning
Elaboration		Keyword Mnemonic

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest, 14*(1), 4-58. https://doi.org/10.1177/1529100612453266

Retrieval Practice

- Learning is most effectively promoted by efforts to retrieve information under conditions that resemble those in which learning will be tested.
- **Example:** Start with a blank sheet and write or draw everything that you can remember about a topic, a lecture, chapter, a section, etc.
- **Not:** Note-taking while reading, highlighting, etc.



Generate at least five ideas for incorporating retrieval practice into your approach to teaching.

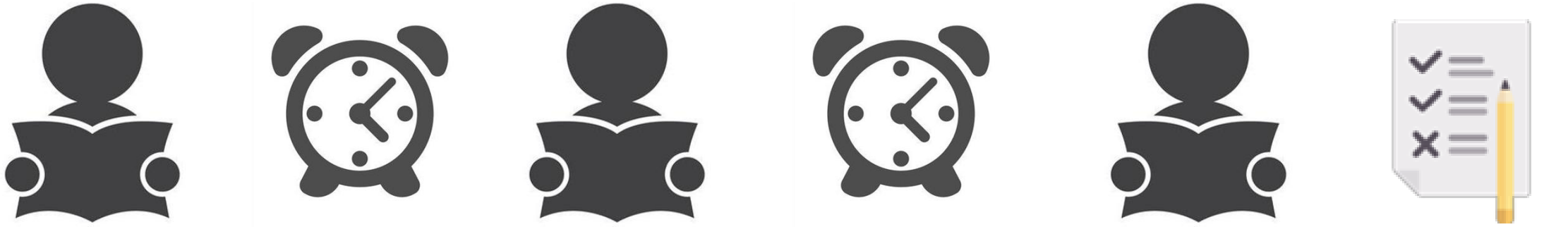
Please write down your questions individually

Retrieval Practice: What can teachers do?

- Use retrieval exercises/activities in class, e.g., peer instruction, concept questions
- Bookend lectures naturally incorporate retrieval exercises/activities
- Talk to your students about retrieval practice and learning, especially after the first test
- Use blank sheet exercises in class
- Use sheets with prompts to complete or some of the main ideas already filled in
- Ask students to explain the concept / example / etc. just presented to themselves

Spaced Retrieval Practice

How does it work?



Practice | **Time between** | **Practice** | **Time between** | **Practice** | **Calibration**

Example Study: 38 surgical residents; microsurgery: how to reattach tiny vessels https://dx.doi.org/10.1097/01.sla.0000234808.85789.6a

http://www.learningscientists.org/learning-scientists-podcast/2018/3/7/episode-14-how-students-can-use-spacing-and-retrieval-practice

Generate at least five ideas for incorporating spaced retrieval practice into your approach to teaching.

Please write down your questions individually

Spaced Retrieval Practice: What can teachers do?

- Spread content and examples on a single topic over several lecture periods instead of covering all of the content on a topic in a single lecture.
- Ask students about content in retrieval exercises/activities overall several lecture periods
- Use some processing activities in bookend lectures to refer to material presented in earlier lecture periods
- Talk to your students about spaced retrieval practice and learning, especially after the first test

Interleaved Retrieval Practice

How does it work?

Example Study: College students learning obscure geometric solids

http://www.learningscientists.org/learning-scientists-podcast/2017/12/6/episode-8-interleaving

Generate at least five ideas for incorporating interleaved retrieval practice into your approach to teaching.

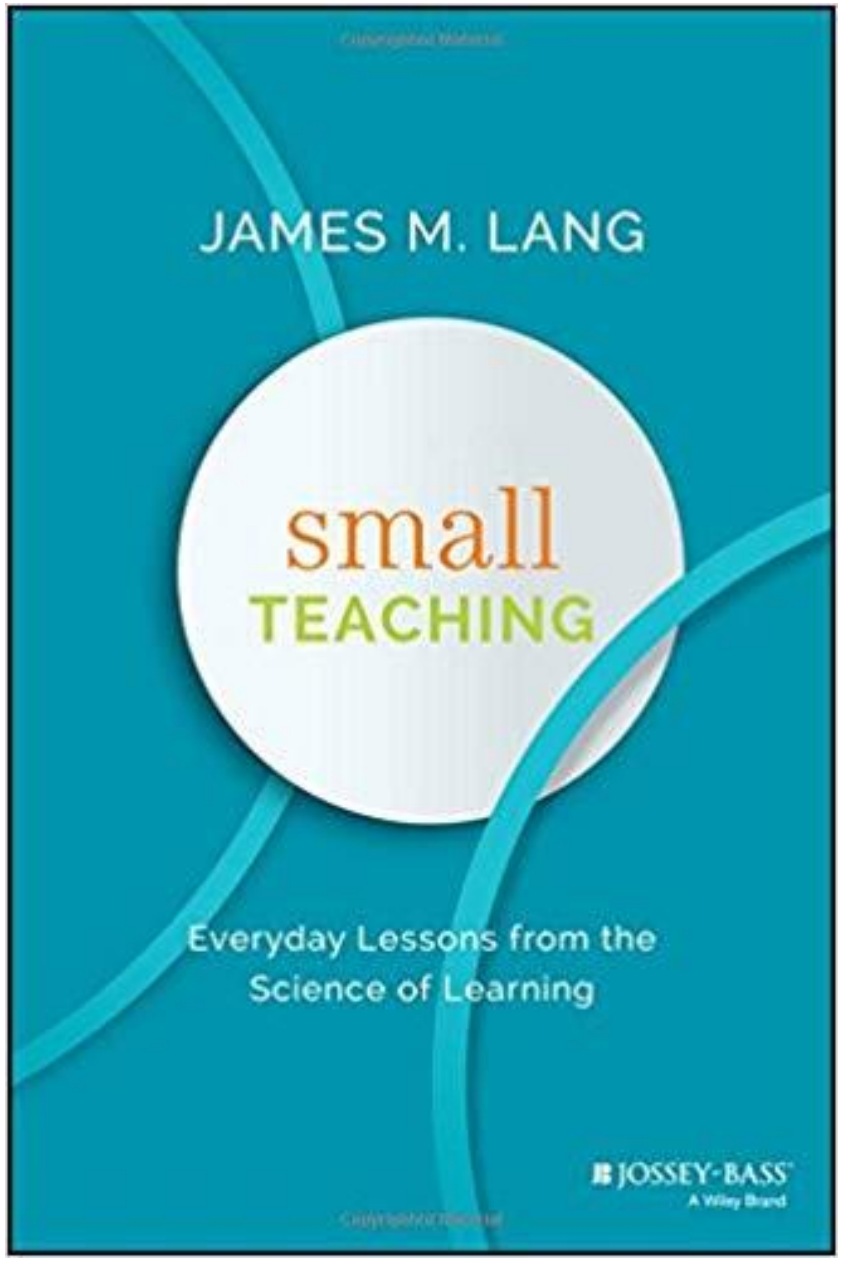
Please write down your questions individually

Interleaved Retrieval Practice: What can teachers do?

- Spread content and examples on a single topic over several lecture periods instead of covering all of the content on a topic in a single lecture.
- Ask students about content in retrieval exercises/activities overall several lecture periods
- Use some processing activities in bookend lectures to refer to material presented in earlier lecture periods
- Talk to your students about spaced retrieval practice and learning, especially after the first test

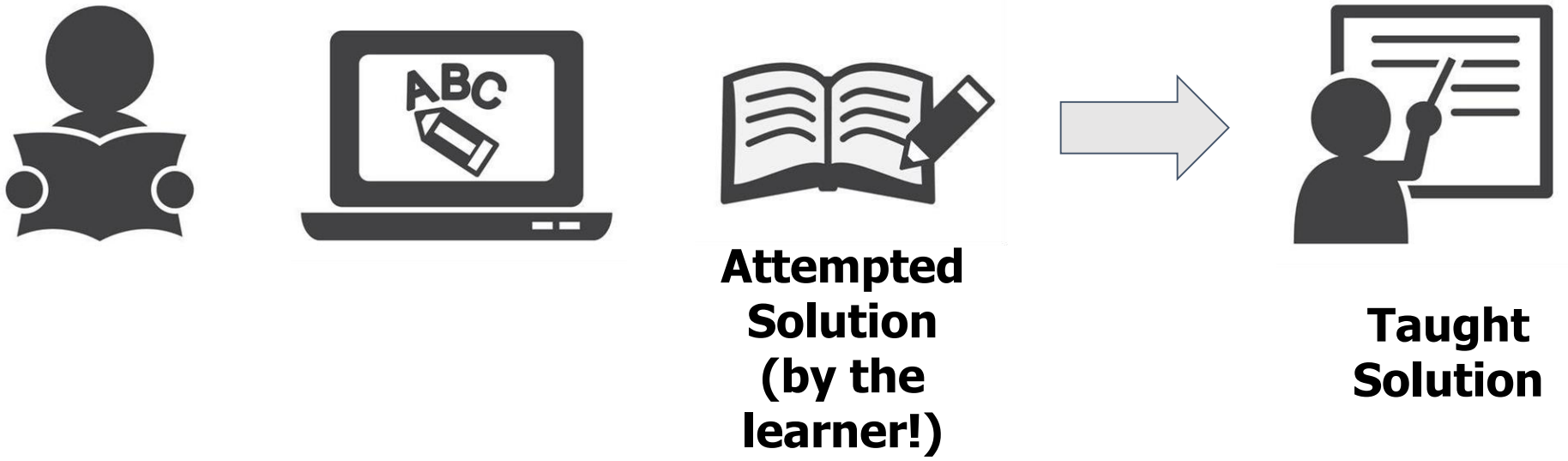
Learning Names

- Coffee barista story



Generative Retrieval Practice

How does it work?



Working on answering a question, solving a problem, summarizing content, drawing a concept map, etc., even before being shown the answer, solution, summary, concept map, etc.

Generate at least five ideas for incorporating generative retrieval practice into your approach to teaching.

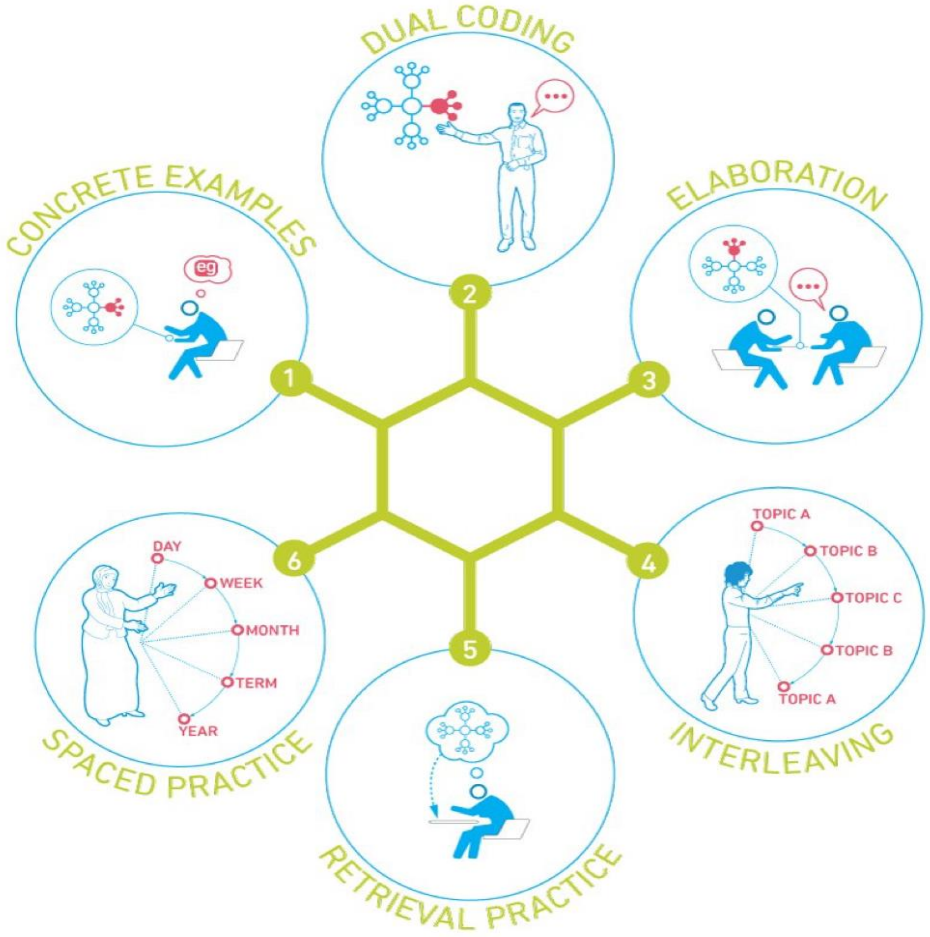
Please write down your questions individually

Generative Retrieval Practice: What can teachers do?

- Use some advance organizers in lecture sessions to ask students to write down what they know about the lecture topics for the day (e.g., blank sheet, concept map, concept map with some concepts included, applications of the lecture topics)
- Give students a problem and ask how they would start before giving them the worked example

Elaboration and Retrieval Practice

- Prompts: Interrogative Elaboration
  - Why did this happen?
  - Why does this work?
  - Related new content to already known material
- Concrete Examples: Find your own and/or instructor offers
- Dual Coding



Concrete Examples

- **Learning Principle:** When learning, turn ideas you're learning into concrete examples. Linking an idea you're studying to a vivid, concrete example can help the lesson stick better.
- Applying Concrete Example Principle in Teaching Practice
  - Given concrete/specific examples of concepts in class
  - Ask students to generate concrete/specific examples of applying a concept
  - Worked examples (see next slide)

Worked Examples as Concrete Examples

- Undergraduate engineering courses teach a considerable number of procedures for computing values
- Exams for these courses have multiple problems in which students are expected to compute values for specific configurations.
- Faculty give concrete examples of these procedures as they work examples in class

Worked Examples as Concrete Examples

Literature on Worked Examples / Example-based Learning

- **Approach 1 - Problem Solving:** Give students problems and let them worked on them
- **Approach 2 - Worked Examples:** Give students examples in which problems have been solved and let them review.
- **Approach 3 - Worked Examples with Fading:** Give students examples in which problems have been solved, but with steps missing, and let them review and fill in the missing steps
- **Approach 4 - Instructional Examples:** Faculty member shows the students step-by-step how to solve the examples.

Worked Examples as Concrete Examples

Combinations of approaches (2), (3), and (1) have been shown to be most effective

- **Approach 1 - Problem Solving**
- **Approach 2 - Worked Examples**
- **Approach 3 - Worked Examples with Fading**
- **Approach 4 - Instructional Examples**

Generate at least five ideas for incorporating research on worked examples to help you students learn problem solving.

Please write down your questions individually

Effective Principles for Learning		Low-performing Practices for Learning
Retrieval	**Metacognition**	
Retrieval	Calibration	Highlighting
Spaced Retrieval	Reflection	Rereading
Interleaved Retrieval	Self-explanation	Summarization
Generative Practice	Planning, Monitoring, Evaluating, Revising	Imagery Use for Text Learning
Elaboration		Keyword Mnemonic

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest, 14*(1), 4-58. https://doi.org/10.1177/1529100612453266

Activity 6: Calculus Test – Problem 1

Suppose you were taking a calculus test and the first problem on the test was the problem on the following slide.

What are questions that you should be asking yourself and/or items that you should be considering before and as you work on the problem?

Activity 6: Calculus Test – Problem 1

$$\int \frac{x}{x^2 - 9} dx$$

Schoenfeld, A. H. (1987). What's all the fuss about metacognition. in *Cognitive science and mathematics education*, A. H. Schoenfeld (ed.), Hillsdale, NJ, USA: Lawrence Erlbaum Associates, Publishers 189-216.

Activity 6: Calculus Test – Problem 1

Suppose you were taking a calculus test and the first problem on the test was the problem on the following slide.

What are questions that you should be asking yourself and/or items that you should be considering before and as you work on the problem?

Most of the responses are metacognitive knowledge or use of metacognitive skills

Calibration: What is it?

- Calibration is the degree of fit between a person's judgment of performance and his or her actual performance

- Calibration reflects a metacognitive monitoring process that provides information about the status of one's knowledge or strategies at a cognitive level

- Based on this information, control at a metacognitive level can be exerted to regulate one's knowledge or strategies. Therefore, greater accuracy in a person's judgments of performance (i.e., being well calibrated) creates greater potential for self-regulation

Bol, L. & Hacker, D. J. (2012). Calibration research: where do we go from here? *Frontiers in Psychology, 3*(229), 1-6. doi:10.3389/fpsyg.2012.00229

Calibration: Why Should You Care?

Theoretical Argument

Accurate metacognitive monitoring is essential to self-regulated learning. (inadequate empirical research support)

Finding:
Monitoring can positively impact decisions about what to study

Finding: There is a positive relation between calibration accuracy and achievement level

Finding: Students who participated in interventions to increase calibration accuracy realized higher gains in achievement than students who did not participate in them. (questions raised about validity of results of studies)

Finding:
Overconfidence produces underachievement. Inaccurate self-evaluations undermine students' learning and retention. (more research needed)

Bol, L. & Hacker, D. J. (2012). Calibration research: where do we go from here? Frontiers in Psychology, 3(229), 1-6. doi:10.3389/fpsyg.2012.00229

Calibration: Challenges

Overconfidence Effect: (a) overestimation of one's actual performance, (b) overplacement of one's performance relative to others, and (c) excessive precision in one's beliefs (Moore & Healy, 2008)

Dunning-Kruger Effect: Across a wide range of tasks, poor performers greatly overestimate their ability, whereas top performers make more accurate self-assessments (Kruger & Dunning, 1999)

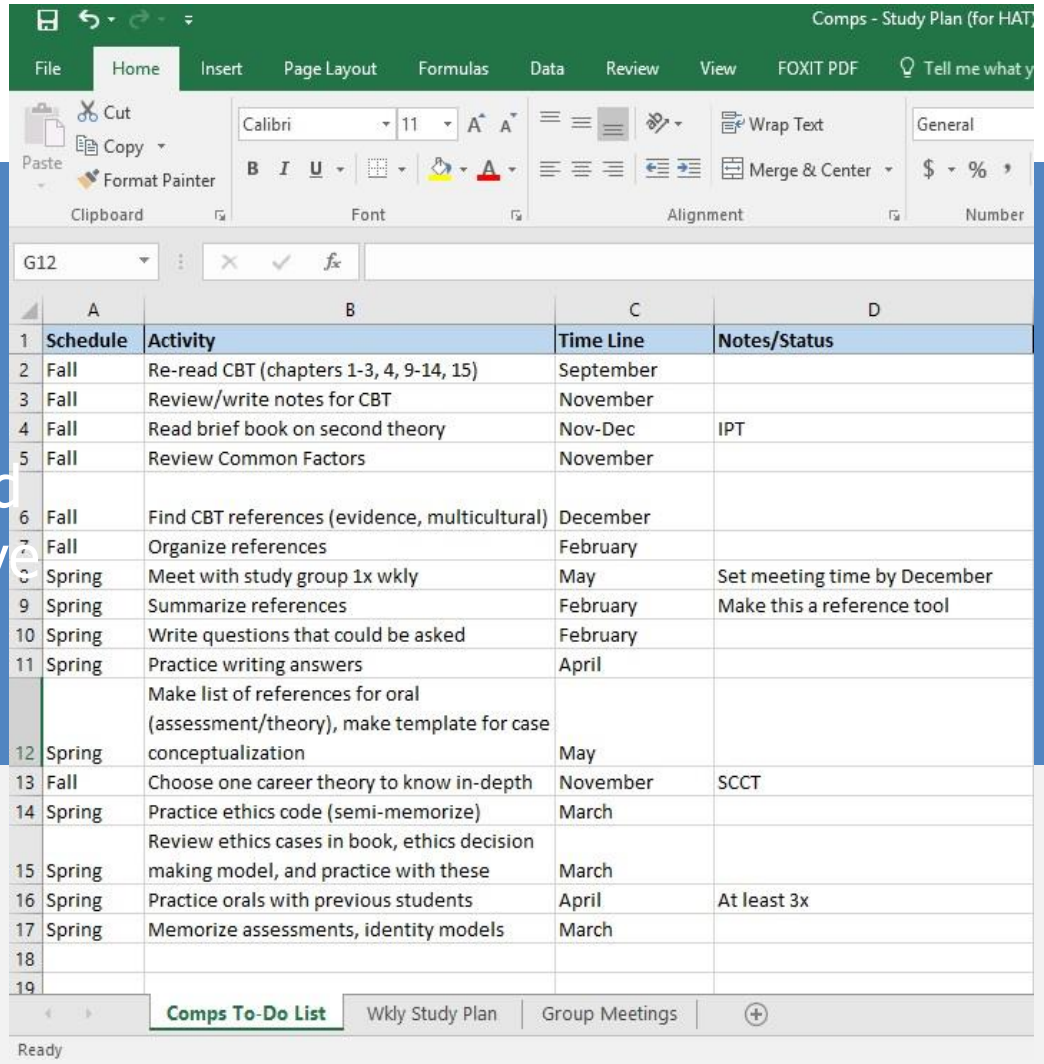
Hard-Easy Effect: People tend to be more accurate but underconfident on easy items and less accurate but overconfident on difficult items (Juslin, Winman, & Olsson, 2000)

Underconfidence-with-practice (UWP): People initially show overconfident calibration when making judgments of learning (JOLs) but subsequently become underconfident after their second study trial (Koriat, et al., 2002)

Calibration: Learner Interventions

Mike Hart

GUEST POST:
Making Three Years of Learning Stick or: How I Learned to Stop Worrying and Prepare for My Comprehensiv Exam



	A	B	C	D
1	Schedule	Activity	Time Line	Notes/Status
2	Fall	Re-read CBT (chapters 1-3, 4, 9-14, 15)	September	
3	Fall	Review/write notes for CBT	November	
4	Fall	Read brief book on second theory	Nov-Dec	IPT
5	Fall	Review Common Factors	November	
6	Fall	Find CBT references (evidence, multicultural)	December	
7	Fall	Organize references	February	
8	Spring	Meet with study group 1x wkly	May	Set meeting time by December
9	Spring	Summarize references	February	Make this a reference tool
10	Spring	Write questions that could be asked	February	
11	Spring	Practice writing answers	April	
12	Spring	Make list of references for oral (assessment/theory), make template for case conceptualization	May	
13	Fall	Choose one career theory to know in-depth	November	SCCT
14	Spring	Practice ethics code (semi-memorize)	March	
15	Spring	Review ethics cases in book, ethics decision making model, and practice with these	March	
16	Spring	Practice orals with previous students	April	At least 3x
17	Spring	Memorize assessments, identity models	March	
18				
19				

http://www.learningscientists.org/blog/2018/9/25-1

Calibration: Learner Interventions

Make a plan that allocates time for retrieval (i.e., self-quizzing), practice, feedback, reflection, etc.

Understand and distrust cognitive illusions (pilot's sense of flying level versus instrument readings, Make It Stick, pp. 210-11)

Practice, low-stakes calibration exercises, i.e., frequent quizzes

Study partner (feedback, belonging, multiple perspectives, accountability, motivation)

Strategy	For Each Strategy
Retrieval	What does this mean for me?
Spaced retrieval	
Interleaved retrieval	How do you use it?
Elaboration	What your intuition tells you to do?
Generative retrieval	
Reflection	What the strategy is more effective?
Calibration	

Calibration: Classroom Interventions

- Teach cognitive illusions, e.g., the illusion of knowing
- Encourage students to find and use external measures of their learning, e.g., self-testing, study partners, etc.
- Provide students with an objective measure of their learning, e.g., frequent, low-stakes quizzes [Examples: Peer Instruction, Team-based Learning, Classroom Response Systems]
- Use rubrics for grading complex work products, e.g., design reports, laboratory reports, etc.

Reflection: What is it?

Reflection <u>for</u> action

Thinking about future actions with the intention of improving or changing a practice

Reflection <u>in</u> action

Thinking about actions while you are carrying out the activity

Reflection <u>on</u> action

Thinking about how practice can be developed, changed or improved after the event has occurred

Olteanu, C. (2017). Reflection-for-action and the choice or design of examples in the teaching of mathematics. Mathematics Education Research Journal, 29(3), 349–367. doi:10.1007/s13394-017-0211-9

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books, Inc..

Reflection and Metacognition

Metacognition (learner-oriented)	Reflection (practitioner-oriented)
Planning	Reflection for action
Monitoring	Reflection in action
?	Reflection on action

Reflection: Guided and Unguided

Guided Reflection

Use of specific prompts

Encourage Focus

Facilitate development of reflection

Unguided Reflection

Reflection without prompts

Matheson, A., Wood, L., Hane, E., & Franklin, S. (2017, July 26-27). *Guided and unguided student reflections*. Paper presented at Physics Education Research Conference 2017, Cincinnati, OH. doi:10.1119/perc.2017.pr.061

Self-explanation: What is it?

Self-explanation: Explaining to oneself how the one is making sense of instructional input

Related to reflection, especially reflection in action, but focused on making sense of instructional input

Sometimes classified as a metacognitive skill

Knowledge, Connection, and Application Assessments

- Start of Class: Students had about 10 minutes to complete a 5-item open-book and open-notes assessment
- First five minutes, students answer the five questions from memory (closed-book) in the left column.
- Second five minutes, students answer the five questions using open-book, open-notes resources
- Grading: scale of 0 (absence) to 1 (0 or 1 correct) to 2 (2 or 3 correct) to a maximum of 3 (4 or 5 correct).

Boosting Metacognition through In-Class Assessments: https://www.improvewithmetacognition.com/boosting-metacognition-through-in-class-assessments/

Traffic Lights as an Exit Ticket

Today my learning stopped because...

Today I considered a question, new idea or new perspective...

Today I understood and learned...

Strategies for teaching metacognition in classroom: https://www.brookings.edu/blog/education-plus-development/2017/11/15/strategies-for-teaching-metacognition-in-classrooms/

Physics Post-exam Reflection Wrapper

Marsha Lovett, Eberly Center, Carnegie Mellon University

As with the first exam, this activity is designed to give you a chance to reflect on your exam performance and, more importantly, on the effectiveness of your exam preparation. Again, please answer the questions sincerely. Your responses will be collected to inform the instructional team; they will have no impact on your grade.

1. Approximately how much time did you spend preparing for this exam? _____

2. What percentage of your test-preparation time was spent in each of these activities?

    a. Reading textbook section(s) for the first time _____

    b. Re-reading textbook section(s) _____

    c. Reviewing homework solutions _____

    d. Solving problems for practice _____

    e. Reviewing your own notes _____

    f. Reviewing materials from blackboard _____

        (What materials? _____)

    g. Other _____

        (Please specify: _____)

3. What aspect(s) of your preparation for this exam seemed different from your exam 1 preparation? Did these changes have any effect?

4. Now that you have looked over your graded exam, estimate the percentage of points you lost due to each of the following (make sure the percentages add up to 100):

    a. Trouble with vectors and vector notation _____

    b. Algebra or arithmetic errors _____

    c. Problem with force-body diagram _____

    d. Lack of understanding of the concept _____

    e. Not knowing how to approach the problem _____

    f. Careless mistakes _____

    g. Other _____

        (Please specify: _____)

5. Students sometimes have difficulty drawing appropriate force-body diagrams and applying Newton's second law appropriately. Was either of these a difficulty for you (check question 2 on the exam)? If so, try to self-assess your understanding: Identify what aspect of these skills are causing you difficulty and what you can do to improve your ability to solve problems using these skills.

Reference: https://www.cmu.edu/teaching/designteach/teach/examwrappers/

Physics Post-exam Reflection Wrapper

Marsha Lovett, Eberly Center, Carnegie Mellon University

As with the first exam, this activity is designed to give you a chance to reflect on your exam performance and, more importantly, on the effectiveness of your exam preparation. Again, please answer the questions sincerely. Your responses will be collected to inform the instructional team; they will have no impact on your grade.

1. Approximately how much time did you spend preparing for this exam? _____

2. What percentage of your test-preparation time was spent in each of these activities?

    a. Reading textbook section(s) for the first time _____

    b. Re-reading textbook section(s) _____

    c. Reviewing homework solutions _____

    d. Solving problems for practice _____

    e. Reviewing your own notes _____

    f. Reviewing materials from blackboard _____

        (What materials? _____)

    g. Other _____

        (Please specify: _____)

Reference: https://www.cmu.edu/teaching/designteach/teach/examwrappers/

Physics Post-exam Reflection Wrapper

Marsha Lovett, Eberly Center, Carnegie Mellon University

3. What aspect(s) of your preparation for this exam seemed different from your exam 1 preparation? Did these changes have any effect?

4. Now that you have looked over your graded exam, estimate the percentage of points you lost due to each of the following (make sure the percentages add up to 100):

a. Trouble with vectors and vector notation _____

b. Algebra or arithmetic errors _____

c. Problem with force-body diagram _____

d. Lack of understanding of the concept _____

e. Not knowing how to approach the problem _____

f. Careless mistakes _____

g. Other _____

(Please specify: _____)

5. Students sometimes have difficulty drawing appropriate force-body diagrams and applying Newton's second law appropriately. Was either of these a difficulty for you (check question 2 on the exam)? If so, try to self-assess your understanding: Identify what aspect of these skills are causing you difficulty and what you can do to improve your ability to solve problems using these skills.

Reference: https://www.cmu.edu/teaching/designteach/teach/examwrappers/

Course Design: Student Metacognitive Development

- You are teaching a required undergraduate engineering course, which is taken by students (according to the course catalog) in the second year of their four-year curriculum. What are some of the instructional elements you would incorporate to promote self-directed learning, while ensuring that students are prepared for their subsequent courses?
- Please write down your answers.

Minute Paper

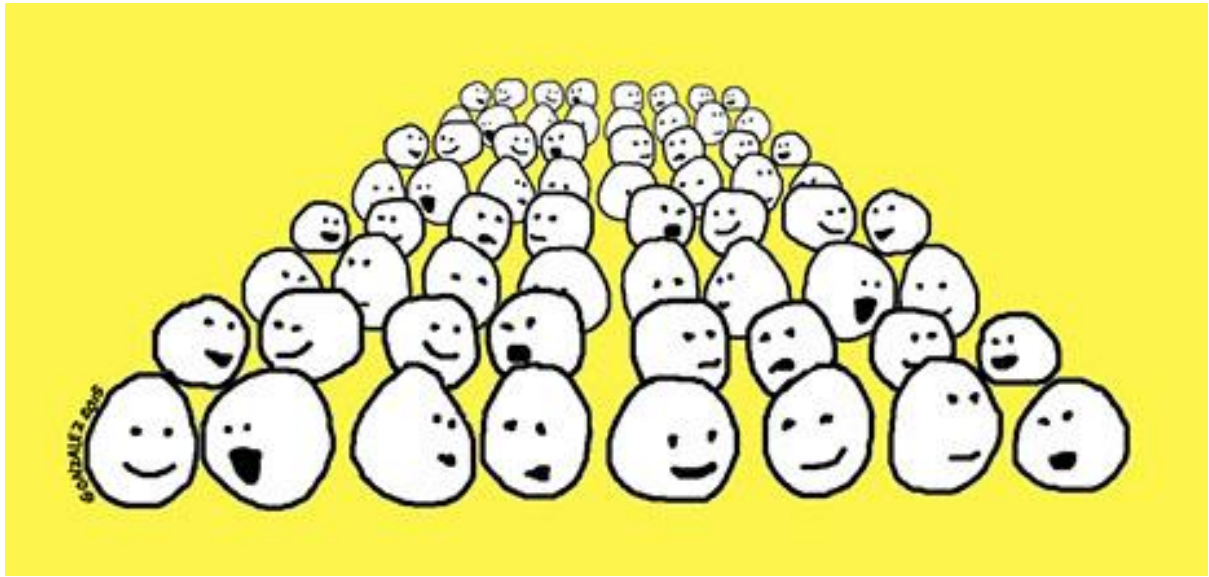
- Write brief answers to the following questions:
  - What is most valuable or helpful about metacognitive learning strategies?
  - What is the “muddiest or most confusing point” about research-based instructional strategies?

Describe how you would explain metacognitive learning strategies to your colleagues.

Please write down your questions individually

Describe how you would explain metacognitive learning strategies to your colleagues.

Please turn to your neighbor and exchange answers.



Describe how you would explain metacognitive learning strategies to your colleagues.

- Please share your answers with the group

Final Workshop Reflection

Questions?