Metacognition and Transfer - What Faculty Members Expect Their Students to Learn, but Never Teach

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Workshop Ground Rules

• Purpose: Participant Learning
  – The purpose is participant learning, not content coverage

• Questions
  – Please ask whenever you have a question

• PowerPoint Presentation
  – A copy of the presentation will be made available to Dr. Kamel at the conclusion of the workshop
  – Please contact Dr. Kamel for a copy
## Overview: Five Days

<table>
<thead>
<tr>
<th>Date</th>
<th>Workshop Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday, 14 January 2018</td>
<td>Setting Expectations for Learning in a Course</td>
</tr>
<tr>
<td>Monday, 15 January 2018</td>
<td>Applying Research-based Instructional Approaches in Courses You Teach</td>
</tr>
<tr>
<td>Tuesday, 16 January 2018</td>
<td>Designing Course-based Assessment Approaches</td>
</tr>
<tr>
<td>Wednesday, 17 January 2018</td>
<td>Metacognition and Transfer - What Faculty Members Expect Their Students to Learn, but Never Teach</td>
</tr>
<tr>
<td>Thursday, 18 January 2018</td>
<td>Research-based Course Design – Putting It All Together</td>
</tr>
</tbody>
</table>
What is metacognition?

\[ \int \frac{x}{x^2 - 9} \, dx \]

During office hours, Josephina expresses that she was happy the exam was on a Monday, because she had a lot of time to prepare the previous weekend. She shares that she started studying after work on Saturday evening and did not go out with friends that night. When queried, she also shares that she reread all of the assigned textbook material and made flashcards of the bold words in the text. She feels that she should have done well on the test, because she studied all Saturday night and all day on Sunday. She feels that she did everything she could do to prepare. That said, she is worried about what her grade will be, and she wants you to know that she studied really hard, so she should get a good grade on the exam.

Maya

Later in the week, Maya visits your office. When asked how she prepared for the first exam, she explains that she has regularly reviewed the PowerPoint slides each evening after class since the beginning of the term 4 weeks ago. She also read the assigned textbook pages weekly, but expresses that she spent most of her time comparing the ideas in the PowerPoint slides with the information in the textbook to see how they were similar and different. She found several places in which things seemed not to agree, which confused her. She kept a running list of these confusions each week. When you ask what she did with these confusions, she shares that she brought them to her weekly study group with peers from her course lab section. There, she says, she got most of her questions answered and lots of her confusions cleared up. She has come to office hours to ask you about a couple of things that she did not figure out before the exam that she thinks she probably missed. She is not too worried about her score on the exam, because most of the material related to problems and concepts that she felt had been thinking about a lot.

Workshop Learning Outcomes

- Describe metacognition
- Describe transfer of learning
- Explain importance of metacognition
- Promote development of metacognitive skills
- Promote development of skills associated with transfer of learning
What is metacognition?

• Elements
  – Self-assessment, monitoring, corrective action
  – Task identification
  – Planning, strategy selection
  – Organization of what you know
• Closely related to self-regulated learning
• Closely related to reflection
Improvements in metacognitive abilities make significant differences in student achievements.

- Enhancement of metacognitive abilities strengthens learning skills and improves academic success.
- Students with good self-regulated learning skills are more likely to achieve academic success and a high GPA.
- Students with good self-regulated learning skills are more knowledgeable and responsible for their cognition and accomplish cognitive actions more successfully.
- Self-evaluation ability is essential in science, technology, engineering, and mathematics.
References

If a faculty member wants to promote student development with respect to metacognition, what three tasks must be completed?

1) ?
2) ?
3) ?
What is transfer of learning?

• Transfer of learning occurs when a learner transfers their learning in one context to another context.
  – Near transfer – between two closely related contexts
  – Far transfer – between very dissimilar contexts
If a faculty member wants to promote student development with respect to transfer of learning, what three tasks must be completed?

1) ?
2) ?
3) ?
Exercise: Generate metacognitive activities

• Think – Pair – Share
• Assume a team of students are working on an engineering design problem. As they are working on the problem, generate metacognitive activities in which the team could/should be engaged.

• ?
Exercise: Generate metacognitive activities

- Are we generating different types of prototypes?
- Where are we on our conceptual map?
- Are we clear on our strategy?
- Intentionally using different research methods?
- Brainstorming to generate different potential solutions
- Alternative evaluation
- Identify limitations of process and potential solution
- Acknowledge our constraints: time, resources, etc.
- Remember that versatility will be important
Exercise: How do you promote student metacognitive development?

• Think – Pair – Share

• Generate a list of strategies to promote student metacognitive development

• ?
Exercise: How do you promote student metacognitive development?

- Jigsaw
- Assign multidiscipline mini-project, see challenge from multiple perspectives
- Read and critique a controversial issue
- Create study groups focused on metacognition
- Give a variety of examples for addressing a project
- Problem-based learning with different scenarios
- Assign students limited resources and ask for solution with these limited resources
- Break a challenge into much smaller challenges
- Have a plan for project management and monitor progress against the plan.
How do you promote student metacognitive development?

- Strategy 1: Develop metacognitive learning outcomes
- Strategy 2: Know research-based strategies for learning
- Strategy 3: Help your students know and apply research-based strategies for learning
- Strategy 4: Work with your students to assess their development with respect to metacognitive learning outcomes?
Exercise: Generate learning outcomes for student metacognitive development

• Think – Pair – Share
• Generate a list learning outcomes for student metacognitive development
• ?
Exercise: Generate learning outcomes for student metacognitive development?

• Evaluate effectiveness of a selected approach toward learning
• Generate alternative strategies for approaching an assignment in a course
Exercise: Generate learning outcomes for student metacognitive development at the Remembering level of the revised Bloom’s taxonomy

• Think – Pair – Share
• Generate a list learning outcomes for student metacognitive development at the Remembering level of the revised Bloom’s taxonomy
• Verbs: ?
Exercise: Generate learning outcomes for student metacognitive development at the Remembering level of the revised Bloom’s taxonomy

• List advantages of metacognition
• List possible methods to learn a certain topic
• List the prompts you will use to remind yourself to consider alternative approaches
• List the prompts you will use to remind yourself of the different applicable physics principles
• List the prompts you will use to remind yourself to consider different ways to open a speech
Exercise: Generate learning outcomes for student metacognitive development at the Remembering level of the revised Bloom’s taxonomy

• Identify strategies for retaining information.
• List strategies for monitoring learning
• Identify strategies for self-assessment
• List prompts to use of self-assessment
• ...

## Example: Metacognitive Learning Outcomes for Project Management

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Introductory</th>
<th>Milestone</th>
<th>Capstone</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>Identifies and reflects upon project goals</td>
<td>Develops and implements a feasible plan to meet project goals</td>
<td>Evaluates the effectiveness of a project plan or strategy</td>
<td>Proposes an improved process for future projects</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Experiments with new strategies.</td>
</tr>
<tr>
<td>Self evaluation</td>
<td>Identifies and reflects upon prior knowledge and skills</td>
<td>Pursues resources to improve knowledge and skills</td>
<td>Determines degree of improvement in knowledge and skills</td>
<td>Develops life-long learning skills in response to ongoing self-monitoring</td>
</tr>
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Research-based Strategies for Learning

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Research-based Strategies for Learning

<table>
<thead>
<tr>
<th>Practice</th>
<th>Description</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieval Practice</td>
<td>Practice retrieving newly learned material from memory (for example, self quizzing)</td>
<td>Strengthens the memory (literally via strengthening neural pathways), tells you what you do and don’t know, and interrupts forgetting</td>
</tr>
<tr>
<td>Spaced Practice</td>
<td>Leaving time between retrieval practice sessions</td>
<td>Arrests forgetting, strengthens retrieval routes, and is essential for holding onto the knowledge you want to gain, but feels more difficult than massed practice</td>
</tr>
</tbody>
</table>

# Research-based Strategies for Learning

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</thead>
<tbody>
<tr>
<td>Interleave Practice</td>
<td>When you practice, mix up (interleave) the different types of problems you are trying to solve or characteristics you are trying to identify</td>
<td>Improves discrimination and identification abilities; improves success in a later test or in real world settings where you need to discern the type of problem you are trying to solve. Blocked practice may feel more productive, but research shows that in the long run this feeling is not correct</td>
</tr>
</tbody>
</table>

Interleave Practice

- Hitting a curveball
- Transfer of learning
# Research-based Strategies for Learning

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<tbody>
<tr>
<td>Elaboration</td>
<td>Finding additional layers of meaning in new material, such as relating the material to what you already know, explaining it to others in your own words, or explaining how it relates to your life outside the classroom (that is, expanding to a larger context).</td>
<td>Increases the strength of the newly learned material and the number of connections between the newly learned material and prior knowledge, helping you to remember it later.</td>
</tr>
<tr>
<td>Generation</td>
<td>Attempt to answer a question or solve a problem before being shown the answer or solution, (for example, experiential learning).</td>
<td>Makes the mind more receptive to new learning.</td>
</tr>
</tbody>
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# Research-based Strategies for Learning

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<tbody>
<tr>
<td>Reflection</td>
<td>Intentional act of taking a few minutes to review what has been observed and learned and asking yourself questions about it. A combination of retrieval practice and elaboration</td>
<td>Involves several cognitive activities that lead to stronger learning, for example, retrieving from memory, connecting to new experiences, and visualizing and mentally rehearsing what you might do differently next time (that is, make adjustments)</td>
</tr>
<tr>
<td>Calibration</td>
<td>The act of using an objective instrument, such as a quiz or test, to clear away illusions and adjust your judgments to better reflect reality</td>
<td>Develops sound metacognitive skills, being able to determine if your sense of what you know and can do is accurate or not</td>
</tr>
</tbody>
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### Research-based Strategies for Learning

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<tbody>
<tr>
<td>Mnemonic Devices</td>
<td>Useful way to store information, not a learning tool per se; mnemonic is from the Greek word memory</td>
<td>Act as mental file cabinets to help organize, store, and retrieve information when you need it</td>
</tr>
</tbody>
</table>

Retrieval Practice – Testing Effect

Spaced Retrieval vs. Massed Retrieval

Interleaved vs. Blocked Practice

Elaboration


Generation: References


• “The Physics Department at Washington University in St. Louis now requires students to work problems before class. Some students take umbrage, arguing it’s the professor’s job to teach the solutions, but the professors understand that when students wrestle with content beforehand, classroom learning is stronger.” (Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2014). *Make it stick.* Harvard University Press, p. 209)
Reflection

Calibration


• Dinsmore, D. L., & Parkinson, M. M. (2013). What are confidence judgments made of? Students' explanations for their confidence ratings and what that means for calibration. Learning and Instruction, 24, 4-14. doi: 10.1016/j.learninstruc.2012.06.001

• Dunlosky, J., & Thiede, K. W. (2013). Four cornerstones of calibration research: Why understanding students' judgments can improve their achievement. Learning and Instruction, 24, 58-61. doi: 10.1016/j.learninstruc.2012.05.002

Mnemonic Devices & Increase Your Abilities

  - Marshmallow study: delayed gratification
  - James Paterson and mnemonic devices
  - Neuroplasticity
  - Mutability of IQ
  - Growth mindset, Carol Dweck
  - Deliberate practice, Anders Ericsson
  - Memory cues, memory palace
Development of Adaptive Expertise: What is the Most Time-efficient Path?

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<table>
<thead>
<tr>
<th>Content</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>(High Content, Low Process)</td>
<td>(High Content, High Process)</td>
</tr>
<tr>
<td>Low Content, Low Process</td>
<td>Low Content, High Process</td>
</tr>
<tr>
<td>Content</td>
<td>Process</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>(High Content, Low Process)</td>
<td>Encyclopedists</td>
</tr>
<tr>
<td>(Low Content, Low Process)</td>
<td>Unengaged</td>
</tr>
<tr>
<td>(High Content, High Process)</td>
<td>Experts</td>
</tr>
<tr>
<td>(Low Content, High Process)</td>
<td>Intellectual Amnesiacs</td>
</tr>
</tbody>
</table>

Content Emphasis
First

Typical University Education

Process Emphasis First

Content

Process
<table>
<thead>
<tr>
<th>Efficiency</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(High Efficiency, Low Innovation)</td>
</tr>
<tr>
<td>Routine Expert</td>
<td><strong>Adaptive Expert</strong></td>
</tr>
<tr>
<td>(Low Efficiency, Low Innovation)</td>
<td>(Low Efficiency, High Innovation)</td>
</tr>
<tr>
<td>Novice</td>
<td>Rudderless &amp; Overwhelmed</td>
</tr>
</tbody>
</table>

<table>
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<th>Efficiency</th>
<th>Innovation</th>
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<td>Novice</td>
</tr>
<tr>
<td>(High Efficiency, High Innovation)</td>
<td>Adaptive Expert</td>
</tr>
<tr>
<td>(Low Efficiency, High Innovation)</td>
<td>Intelligent Novices (Bruer)</td>
</tr>
</tbody>
</table>

Describe an experiment to test whether innovation-first or efficiency-first learning experience moves students to adaptive expertise more rapidly.

First create two sets of students:

• Content Emphasis First
• Process Emphasis First
• **Tell-and-practice Set (Content Emphasis First)**
  • Teacher talked about grading on a curve and gave students a procedure for marking deviation regions on a histogram to compare grades.
  • Students practiced on a new data set for comparing grades.

• **Invention Set (Process Emphasis First)**
  • Students (in small groups) tried to invent a way to determine whether a long jump or pole vault competitor had broken their sport’s prior world record by a greater relative amount.
  • There were no class presentations, no sharing of solutions, and the students did not receive any feedback on their inventions.
From the two sets, create four sets:

- Two subsets, one from the tell-and-practice-set and one from the invention set, took a post-test with a worked example related to the subject of the post test.
- Two other subsets, one from the tell-and-practice-set and one from the invention set, took the post-test with no resource.
“Of the four different [subsets] with results from the post-test, only one [subset] demonstrated significantly improved performance:

• The group that received the invention intervention and the worked example.
• That is, “the students who invented their own methods for standardizing data learned from a worked example embedded in the test and spontaneously transferred this learning to solve a novel problem, even more so than students who had been told and had practiced a specific visual technique for standardizing data”
Activities to Promote Metacognition

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Four Activities to Promote Metacognition

• **Pre-assessments**—Encouraging Students to Examine Their Current Thinking: “What do I already know about this topic that could guide my learning?”

• **The Muddiest Point**—Giving Students Practice in Identifying Confusions: “What was most confusing to me about the material explored in class today?”

• **Retrospective Post-assessments**—Pushing Students to Recognize Conceptual Change: “Before this course, I thought evolution was... Now I think that evolution is ....” or “How is my thinking changing (or not changing) over time?”

• **Reflective Journals**—Providing a Forum in Which Students Monitor Their Own Thinking: “What about my exam preparation worked well that I should remember to do next time? What did not work so well that I should not do next time or that I should change?”

https://cft.vanderbilt.edu/guides-sub-pages/metacognition/

7 Strategies that Improve Metacognition

1) Teach students how their brains are wired for growth.
2) Give students practice recognizing what they don't understand. (Generative Practice)
3) Provide opportunities to reflect on coursework.
4) Have students keep learning journals.
5) Use a "wrapper" to increase students' monitoring skills.
6) Consider essay vs. multiple-choice exams.
7) Facilitate reflexive thinking. Reflexivity is the metacognitive process of becoming aware of our biases -- prejudices that get in the way of healthy development.

### Prompts for Metacognitive Development

<table>
<thead>
<tr>
<th>Activity</th>
<th>Planning</th>
<th>Monitoring</th>
<th>Evaluating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class session</td>
<td>• What are the goals of the class session going to be?</td>
<td>• What insights am I having as I experience this class session? What confusions?</td>
<td>• What was today's class session about?</td>
</tr>
<tr>
<td></td>
<td>• What do I already know about this topic?</td>
<td>• What questions are arising for me during the class session? Am I writing</td>
<td>• What did I hear today that is in conflict with my prior understanding?</td>
</tr>
<tr>
<td></td>
<td>• How could I best prepare for the class session?</td>
<td>them down somewhere?</td>
<td>• How did the ideas of today's class session relate to previous class</td>
</tr>
<tr>
<td></td>
<td>• Where should I sit and what should I be doing (or not doing) to best</td>
<td>• Do I find this interesting? Why or why not? How could I make this material</td>
<td>sessions?</td>
</tr>
<tr>
<td></td>
<td>support my learning during class?</td>
<td>personally relevant</td>
<td>• What do I need to actively go and do now to get my questions answered</td>
</tr>
<tr>
<td></td>
<td>• What questions do I already have about this topic that I want to find</td>
<td>• Can I distinguish important information from details? If not, how will I</td>
<td>and my confusions clarified?</td>
</tr>
<tr>
<td></td>
<td>out more about?</td>
<td>figure this out?</td>
<td>• What did I find most interesting about class today?</td>
</tr>
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</table>

Physics Post-exam Reflection
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/
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Three Metacognitive Assessment Activities

1) Focused listing
2) Directed paraphrasing
3) Application cards

Focused Listing

Near the end of a classroom session, students write at the top of an index card a key concept, which will be one of the foci of the next classroom session.

Briefly—usually no more than one or two minutes—students write down everything they remember about this concept. This activity lets students know how much they recall—right or wrong—about a given concept.

Faculty members collect the cards and review them to determine students’ overall level of knowledge, plus their misconceptions. They summarize results at the next classroom session.

Directed Paraphrasing

Near the end of a classroom session, students write at the top of an index card a key concept, which will be one of the foci of the next classroom session.

Briefly—usually no more than one or two minutes—students explain or define it in their own words for a specific audience or purpose.

Faculty members collect the cards and review them to determine students’ overall level of knowledge, plus their misconceptions. They summarize results at the next classroom session.

Application Cards

Near the end of a classroom session, students write at the top of an index card a key concept, which will be one of the foci of the next classroom session.

Briefly—usually no more than one or two minutes—students offer real-world applications or personal examples for important concepts, theories, or procedures.

Faculty members collect the cards and review them to determine students’ overall level of knowledge, plus their misconceptions. They summarize results at the next classroom session.

Minute Paper for Papers/Projects

Students, on a separate sheet of paper, respond to various questions or to prompts about their submission. Typical questions and prompts might be:

• What parts of the paper or project were the most effective?/I’m most satisfied with...
• When were you least satisfied with this paper or project?/I’m least satisfied with...
• What problems arose as you wrote?/I’m having problems with...
• What skills do you feel you improved?/Writing this paper or completing this project lead to improvement in skills such as...
• In writing this essay or completing this project, what did you learn that surprised you?/I was surprised by...
• When editing your paper or project, what were you uncertain about?/When editing, I was most uncertain about...
• What changes would you make to this assignment?/Given two more weeks, I would change...
• How does this assignment contribute to your growth as a professional in X discipline?/This lesson/assignment is important to my role as a professional in [X discipline] because...

Minute Paper

• If I were doing another workshop on metacognition and transfer, what instructional practices should I:
  – Continue to do
  – Start doing
  – Stop doing
References


