Fostering Higher-Order Learning in STEM Education: A Role for Science of Learning

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Acknowledgments

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• Special thanks to Catherine Overson, Lauren Kordonowy, Elizabeth Tappin, Roy Richardson, Danney Rasco, and Michael Melville.

Linking *Kind of Knowledge*, *Learning Processes*, and *Instructional Method*
Pulling it Together
# Learning, Instruction, & Activity

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Numerous Studies on Fact Learning


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Interleaving: Revisiting the Past

Course: Statistical Reasoning

Overson, Stiegler-Balfour, Tappin, Melville, Rasco, & Benassi, 2016
WHAT WE DID
Study Background: Sequence of Instruction and Quizzing

- **Statistical test is covered**
  - Reading and instruction by teacher

- **Completion of online module on the statistical test**
  - Review of Material on statistical test, including conditions to be met to use the test

- **Quiz**
  - **Non-Interleaving**: Quiz on the current statistical test only
  - **Interleaving**: Quiz on both the current statistical test and on previous tests

- Repeat until all statistical tests addressed
Eight Statistical Tests

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<tr>
<td>z test</td>
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<tr>
<td>Single sample t</td>
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<tr>
<td>Correlated-groups t</td>
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<tr>
<td>Between-groups t</td>
</tr>
<tr>
<td>ANOVA</td>
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<td>Chi Square</td>
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<tr>
<td>Correlation</td>
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Experimental Manipulation Within Course

Statistical Reasoning (Rasco)

N = 38
Comparing Question Conditions

RESULTS
Mean Proportion Correct on Final Exam on Choosing the Appropriate Statistical Test

one sided $p < .03$

Error bars: 95% CI
How might you incorporate this principle into your courses?
The Power of Examples in Improving Classification of Concepts

Study Design

In three lab experiments, under a variety of conditions,

- College students studied declarative concepts, followed by either examples of the concepts or by additional study of the concepts.
- On a later classification task, students were shown examples and were asked to identify which concept the example represented.
Study Design

• In three lab experiments, under a variety of conditions,
  1. Definition only
  2. Definition then Example
  3. Example then Definition

• On a later classification task, students were shown examples and were asked to identify which concept the example represented.
Refer to Rawson, et al., 2015, Figures 1A and 1B
How might you incorporate this principle into your courses?
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Self-Explanation:
Making sense and meaning of new information

Course: Biological Science
N = 148

Overson, Kordonowy, Benassi, Richardson, 2017
Self-explanation

• Self-monitoring of evolving understanding
  – Review new material
  – Relate information to prior knowledge
  – Generate questions based on new understanding

• Mechanism
  – Identification of gaps in learning
  – Helps modify flawed, existing mental models
WHAT WE DID
Student Learning Activity

• Read assigned material
• Responded to prompts after each reading section
  1. What information is new?
  2. How do the new ideas work with what you already know?
  3. List two “I wonder (if, whether, why, how, which, where, who, etc.) ...” questions that you have as a result of reading this section
Research Design

• Random assignment to one of two groups
  – Self-explanation group
  – Summary group
Comparing Question Conditions

RESULTS
Summarize versus Self-explain Reading Activities
Summarize versus Self-explain Reading Activities

Error Bars: 95% CI
Does background ability matter?
How might you incorporate this principle into your courses?
Guiding Questions

Attending to relevant, related information

Guiding Questions

• Transfer-Appropriate Processing in a Psychology of Consciousness Course
• N = 39
• Completed Gates McGinity Reading Test
• Completed reading assignments
• Guiding questions for some assignments, not for others.
• Essay exam on all material. Focused on integration of concepts from readings.
Guiding Questions Examples

Encouraged students to think about relationships among concepts from the readings:

“What potential problems are there with the idea that consciousness causes our actions?”

“What kinds of evidence suggest a dissociation between vasomotor control and visual perception?”
Learning Outcomes
Mean performance on essay portion of exams for skilled and less-skilled readers when they completed the guiding questions versus when they did not.
How might you incorporate this principle into your courses?
Conclusions and Recommendations

• Do your courses already incorporate the kinds of principles I have discussed today?
• You can incorporate evidence-based principles, informed by science of learning, into your courses.
• You can expect to observe strong learning outcomes among your students.
Conclusions and Recommendations

• We have just scratched the service.

• Here are some sources:
Some User-Friendly websites

- *Retrieval Practice*
  
  http://www.retrievalpractice.org
  
  Pooja Argarwal

- *The Learning Scientists*
  
  http://www.learningscientists.org
  
  Megan Smith and Yana Weinstein
Some Accessible Videos

• Deep Learning (M. Chi)
  https://www.youtube.com/watch?v=uC-9lViDGL0

• How People Learn (H. Roedinger)
  https://www.youtube.com/watch?v=4tz8gVPHhFE

• Teaching, Learning, and Technology: A Role for Science of Learning (V. Benassi)
  https://www.youtube.com/watch?v=NG439BzFh7I
Thank you