Designing Instruction and Practice to Benefit Students’ Performance in STEM

Catherine Overson
Director, Teaching, Learning, and Research Services, CEITL, and Affiliate Associate Professor of College Teaching

Victor Benassi
Director CEITL and Professor of Psychology

Fostering Academic Success in STEM
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• Special thanks to the faculty and graduate students who have worked with us on the projects described in this presentation.
How do we improve student learning in STEM?

It depends . . .
It Depends?

What kind of knowledge do you want your students to attain?
- Facts?
- Concepts?
- Principles?

What kind of learning processes is required for your learning objective?
- Memory and fluency?
- Induction and refinement?
- Understanding and sense-making?

What kind of instruction will you provide to promote learning your objectives?
- Quizzing?
- Schema development?
- Self-explanation?
Taxonomies of Knowledge-Learning-Instruction (KLI)

Koedinger, Corbett, & Perfetti, 2012
Taxonomies of Knowledge

- Association
- Fact
- Category
- Concept
- Schema
- Rule
- Principle
Taxonomies of Learning

Memory & fluency-building processes (non-verbal)
- Compiling knowledge
- Producing “automatic” knowledge

Induction & refinement processes (non-verbal)
- Improving accuracy of knowledge
- Categorization/schema development/causal induction

Understanding and sense-making processes (verbal)
- Discovery
- Reasoning
KLI Framework
Dependencies

- Kinds of Knowledge
- Learning Processes
- Instructional method
Taxonomies of Instruction

- **Memory & fluency enhancing instruction**
  - Spacing practice
  - Retrieval practice

- **Induction & refinement enhancing instruction**
  - Feature focusing to facilitate schema development

- **Understanding & sense-making enhancing instruction**
  - Prompted self-explanation
Pulling it All Together

Matching Knowledge Components, Learning Processes, and Instructional Principles
## Taxonomies of Knowledge, Learning, & Instruction

<table>
<thead>
<tr>
<th>Knowledge Component</th>
<th>Learning Process</th>
<th>Instructional Principle</th>
<th>Learning Activity</th>
</tr>
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<tbody>
<tr>
<td>Facts</td>
<td>Memory &amp; Fluency</td>
<td>Spacing and Retrieval</td>
<td>Flashcards prior to exam</td>
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</table>
Spacing: Distributing Study Practice

Based on Kornell, 2009, *Applied Cognitive Psychology. Study 3*

Course: Introductory Biology

N = 176

Overson, Benassi, Kordonowy, Pyburn, & Hall, 2017

In preparation
Spacing vs. Massing
Introductory Biology Course

• 176 Students who completed all FC 4 study days
• Within-subjects design
• 32 items to be studied randomly assigned to a condition
  – Spacing/Massing
  – Massing questions randomized to Study Day
    ➢ (1, 2, 3, or 4)
• Students completed study sessions on 4 consecutive days leading up to the exam
Flashcard Sequence

32 items

First 16 items (Spaced)
- Every item studied twice each of the 4 days
- Every item studied a total of 8 times

Second 16 items (Massed)
- Four blocks, each comprising 4 unique items per block
- Each block of items studied on a different day
- Every item on each block studied 8 times on that day
FINDINGS
Mean Exam Transfer Scores For Flashcard Days Completed

Mean Percent Correct on Exam 3 Transfer Questions

< 4 Days

4 days

Difference

Error Bars: 95% CI
Massed Versus Spaced Practice Overall

<table>
<thead>
<tr>
<th>Study Condition</th>
<th>Mean Percent Correct</th>
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<tr>
<td>Massed Overall</td>
<td></td>
</tr>
<tr>
<td>Spaced</td>
<td></td>
</tr>
<tr>
<td>Diff</td>
<td></td>
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Mean Difference

Error Bars: 95% CI
Does background ability matter?
Massed Versus Spaced Conditions

Mean Percent Correct Delayed Exam

<table>
<thead>
<tr>
<th>Day</th>
<th>Massed Study</th>
<th>Spaced</th>
</tr>
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<tbody>
<tr>
<td>Day1</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Day2</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>Day3</td>
<td>60</td>
<td>90</td>
</tr>
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<td>Day4</td>
<td>80</td>
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Error Bars: 95% CI
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<td>Induction &amp; Refinement</td>
<td>Skill Schema development</td>
<td>Guiding questions for integration of relevant elements</td>
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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?”
FINDINGS
Mean performance on essay portion of exams for skilled and less-skilled readers when they completed the guiding questions versus when they did not.
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<td>Principle Model</td>
<td>Understanding &amp; Making Sense</td>
<td>Self-Explanation</td>
<td>Self-explanation prompts for each section in textbook chapter</td>
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Self-Explanation: Making sense and meaning of new information

Course: Introductory Biology
N = 148

Overson, Benassi, Kordonowy, & Richardson 2017
In Preparation
Self-explanation

- Constructive learning strategy
- 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
Student Learning Activity

• Read textbook chapter
• Responded to prompts after each chapter section
• Random assignment to one of two groups
  – Self-explanation group
  – Summary group
Does background ability matter?
Thank you

Questions?