Welcome

Before we begin, please make sure:
Your microphone is muted.

Your Display Name is your first and last name. You can change this by hovering on your image block and clicking on the ... symbol at the top right corner of your picture and selecting Display Name.

We will be recording this session.

Chat protocol:
Please send questions during the session to xxxx.

The setting to send a chat to everyone will be available so presenters can utilize it during their session for engagement. Please do not post questions to everyone unless otherwise prompted.
THE APPLICATION OF COGNITIVE PSYCHOLOGY TO IMPROVE TEACHING AND LEARNING
Zoom Fatigue

• Try speaker view
• Avoid other distractions
• Realize it’s ok to zone out a bit
• Take quality breaks
OVERVIEW

Cognitive Psychology Applied to Education

Strategies for Effective Teaching: Planning
- Spacing
- Interleaving

Strategies for Effective Teaching: Development of Learning
- Elaboration
- Concrete examples
- Dual coding

Strategies for Effective Teaching: Reinforcement of Learning
- Retrieval practice

Resources
Cognitive psychology applied to education
The Goal of our Research is to...

Help instructors

...help students learn more effectively.
Cognitive psychology applied to education

- Memory
- Attention
- Perception
- Learning strategy
- Teaching strategy
The lab to classroom model

**Basic Laboratory**

*In the lab with simple materials*  
(e.g., word lists, nonsense syllables)

**Applied Laboratory**

*In the lab with relevant materials*  
(e.g., textbook chapters, video lectures)

**Applied Classroom**

*In the classroom with relevant materials*  
(e.g., teachers altering their instruction)
Warnings

• We can’t predict students’ grades

• We can’t guarantee success
What we can do

We can try to build on what we know:

- Memory
- Attention
- Perception
- Learning strategy
- Teaching strategy
What we can do

We can try to come up with flexible guiding principles
What we can do

Try to ask why:
What we can do

We can ask instructors what research questions we should pursue
Why we need more cross-communication:

% of teacher training textbooks that cover evidence-based strategies for effective learning

- Spaced Practice: 22%
- Retrieval Practice: 0%
- Elaboration: 41%
- Interleaving: 0%
- Concrete...: 25%
- Dual Coding: 13%

Learning About Learning Report (2016)
Blog post: [We Need to Rewrite the Textbook on How to Teach Teachers](https://example.com/blog/rewrite-textbook)
Planning

Spaced Practice
Main idea – Spacing

Study — Re-Study — Test

Study — Re-Study — Test

😊

😊
Spacing – An All-rounder

Vocabulary learning (e.g., Bahrick et al., 1993; Kornell, 2009; Bloom & Shuell, 1981)

Fact learning (e.g., DeRemer & D’Agostino, 1974)

Text passages (e.g., Gordon, 1925; Rawson & Kintsch, 2005; Verkoeijen et al., 2008)

Problem solving (e.g., Cook, 1934; Grote, 1995)

Motor skills (e.g., Baddeley & Longman, 1978; Shea et al., 2000; Goedert & Miller, 2008)

Musical instrument learning (e.g., Simmons, 2007)

Works in many domains
Evidence from the Laboratory
Rawson & Kintsch (2005)

- Participants studied a lengthy science text
Evidence from the Laboratory
Rawson & Kintsch (2005)
Evidence from the Laboratory
Rawson & Kintsch (2005)
Massed Teaching

Spaced Teaching

Image from Class Teaching blog, Durrington School, UK
### Spacing Plan

<table>
<thead>
<tr>
<th>Topic</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>JUNE!!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Topic 2</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 3</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 4</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 5</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 6</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 7</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 8</td>
<td>Taught</td>
<td>Lag Hwk</td>
<td>SL 1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Image from *Mr Benney, Penyrheol Comprehensive School, UK*
Interleaved Practice
Main idea – interleaving

TOPICS
A B C

STUDY SESSION 1

TOPICS
C B A

STUDY SESSION 2

TOPICS
A C B

STUDY SESSION 3
Interleaving in math learning
Taylor & Rohrer (2010)

- Children (age ~ 10.5)
- Learned 4 different formulas

- Interleaved Practice:
  ABCD CADB DCBA BDAC

- Blocked Practice:
  AAAA BBBB CCCC DDDD

- Tested 1 day later
Interleaving in math learning
Taylor & Rohrer (2010)
Interleaving in math learning
Taylor & Rohrer (2010)
Interleaving in math learning
Taylor & Rohrer (2010)
### Easy way to implement interleaving

<table>
<thead>
<tr>
<th>Practice makes perfect 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) $2^3 = 64$</td>
</tr>
<tr>
<td>2) $3^2 \times 2^3$</td>
</tr>
<tr>
<td>3) What time is 14 45?</td>
</tr>
<tr>
<td>4) Reflect the shape</td>
</tr>
<tr>
<td>5) Can you have two obtuse angles in a triangle?</td>
</tr>
<tr>
<td>6) $\begin{array}{c} \times 2 + 3 \ 5 \ 27 \ 33 \end{array}$</td>
</tr>
<tr>
<td>7) Write $\frac{3}{8}$ as a percentage</td>
</tr>
<tr>
<td>8) Cube root of 1000?</td>
</tr>
<tr>
<td>9) Solve $\frac{n}{3} = 14$</td>
</tr>
<tr>
<td>10) $3 + \frac{1}{2}$</td>
</tr>
<tr>
<td>11) Coordinates?</td>
</tr>
<tr>
<td>12) Area?</td>
</tr>
<tr>
<td>13) 5% of 90</td>
</tr>
<tr>
<td>14) Use $+/\div\times+/-$ to make 30</td>
</tr>
<tr>
<td>15) $0.25 \times 22$</td>
</tr>
<tr>
<td>16) Does 2157 divide by 3?</td>
</tr>
<tr>
<td>17) $3.6 \times 1000$</td>
</tr>
<tr>
<td>18) Chance of fog = 0.6 chance not foggy?</td>
</tr>
<tr>
<td>19) £5 – £2.31</td>
</tr>
<tr>
<td>20) Surface area?</td>
</tr>
<tr>
<td>21) 8 pens cost £2; 6 pens cost?</td>
</tr>
<tr>
<td>22) Why is $20% = \frac{1}{5}$?</td>
</tr>
<tr>
<td>23) 1 2 3 4 5 6 7 8 9</td>
</tr>
<tr>
<td>Mode = range =</td>
</tr>
<tr>
<td>24) Square d + 3</td>
</tr>
<tr>
<td>Perimeter?</td>
</tr>
</tbody>
</table>
More complex way to implement interleaving
### Topic and Quiz Spacing Spreadsheet: A Planning Tool for Teachers

#### Output Will Start Here

<table>
<thead>
<tr>
<th>Class 1 Topic(s) to Teach</th>
<th>Class 2 Topic(s) to Teach</th>
<th>Class 3 Topic(s) to Teach</th>
<th>Class 4 Topic(s) to Teach</th>
<th>Class 5 Topic(s) to Teach</th>
<th>Class 6 Topic(s) to Teach</th>
</tr>
</thead>
</table>

#### Class 1 Quiz Questions

1. Question: Topic1 Quiz Question 1
2. Question: Topic1 Quiz Question 2
3. Question: Topic1 Quiz Question 3
4. Question: Topic1 Quiz Question 4
5. Question: Topic1 Quiz Question 5
6. Question: Topic1 Quiz Question 6
7. Question: Topic1 Quiz Question 7
8. Question: Topic1 Quiz Question 8

#### Class 2 Quiz Questions

1. Question: Topic2 Quiz Question 1
2. Question: Topic2 Quiz Question 2
3. Question: Topic2 Quiz Question 3
4. Question: Topic2 Quiz Question 4
5. Question: Topic2 Quiz Question 5
6. Question: Topic2 Quiz Question 6
7. Question: Topic2 Quiz Question 7
8. Question: Topic2 Quiz Question 8

#### Class 3 Quiz Questions

1. Question: Topic3 Quiz Question 1
2. Question: Topic3 Quiz Question 2
3. Question: Topic3 Quiz Question 3
4. Question: Topic3 Quiz Question 4
5. Question: Topic3 Quiz Question 5
6. Question: Topic3 Quiz Question 6
7. Question: Topic3 Quiz Question 7
8. Question: Topic3 Quiz Question 8

#### Class 4 Quiz Questions

1. Question: Topic4 Quiz Question 1
2. Question: Topic4 Quiz Question 2
3. Question: Topic4 Quiz Question 3
4. Question: Topic4 Quiz Question 4
5. Question: Topic4 Quiz Question 5
6. Question: Topic4 Quiz Question 6
7. Question: Topic4 Quiz Question 7
8. Question: Topic4 Quiz Question 8

#### Class 5 Quiz Questions

1. Question: Topic5 Quiz Question 1
2. Question: Topic5 Quiz Question 2
3. Question: Topic5 Quiz Question 3
4. Question: Topic5 Quiz Question 4
5. Question: Topic5 Quiz Question 5
6. Question: Topic5 Quiz Question 6
7. Question: Topic5 Quiz Question 7
8. Question: Topic5 Quiz Question 8

#### Class 6 Quiz Questions

1. Question: Topic6 Quiz Question 1
2. Question: Topic6 Quiz Question 2
3. Question: Topic6 Quiz Question 3
4. Question: Topic6 Quiz Question 4
5. Question: Topic6 Quiz Question 5
6. Question: Topic6 Quiz Question 6
7. Question: Topic6 Quiz Question 7
8. Question: Topic6 Quiz Question 8

Development of Learning

Elaboration
Many definitions...

“...additions to nominal input” (Postman, 1976)

“A conscious, intentional process that associates to-be-remembered information with other information in memory.”
(Hirschman, 2001)

“One of the most potent manipulations that can be performed in terms of increasing a subject’s memory for material”
(Anderson, 1983)
Elaboration increases depth of processing

- A simple demonstration
- If your last name starts with N-Z: close your eyes!
In this task I would like you to imagine that you are stranded in the grasslands of a foreign land, without any basic survival materials. Over the next few months, you’ll need to find steady supplies of food and water and protect yourself from predators. I am going to show you a list of words, and I would like you to rate how relevant each of these words would be for you in this survival situation. Some of the words may be relevant and others may not – it’s up to you to decide.

In your head, please rate each word using a 5-point scale from 1 = totally irrelevant to 5 = extremely relevant
In this task I would like you to look at each word and count the number of vowels that it contains. For example, the word “baseball” contains 3 vowels. Some of the words will contain few vowels, and others will contain many – it’s up to you to count them.

In your head, please count the number of vowels in each of the words that you see.
READY?
TOMB
CONTRACT
SUNSET
OPIUM
Write down as many words as you can remember.
Check to make sure any words you wrote down are on this list

| Bacteria    | Journal   |
| Body        | Magazine  |
| Contract    | Opium     |
| Hostage     | Sunset    |
| Institute   | Tomb      |
Report your results!

- https://forms.gle/Lk46XUZRTJBJW4NSG9
Elaboration: levels of processing (Craik & Lockhart, 1972)

Materials can be processed at different levels

- Surface: orthography/case/length
- Phonemic: sounds/rhyme
- Semantic: meaning/associations
Elaboration: levels of processing (Craik & Lockhart, 1972)

Materials can be processed at different levels

- Surface: How many vowels does it have?
- Semantic: Is it relevant to survival?
Elaboration: levels of processing (Craik & Lockhart, 1972)

Example: Bear

Yes, it might kill me

Semantic

Surface

2 vowels
Depth of processing effect on memory (Craik & Tulving, 1975)
Elaboration increases organization

(Bellezza, Cheesman, & Reddy, 1977; Mandler, 1979)
But, what is elaboration, and how do you do it?
Elaborative interrogation is the technique with the most evidence

- Students ask “how” and “why” questions
- Students then try to answer those questions
- This is compared to passive re-reading (McDaniel & Donnelly, 1996)

- The process of trying to figure out the answer can help learning (Overoye & Storm, 2015)
Example from physics

- How does a plane take off?
- Why does a plane need an engine?
- How does the upward force (lift) work?
- Why do the wings have a curved upper surface and a flat lower surface?
- Why is there a downwash behind the wings?
Elaborative interrogation may work better when knowledge is high

Woloshyn et al. (1992)
Practical Tips

Elaboration
In the classroom...

- Compare/contrast activities
- Groupwork
- “Connection” papers or discussion
- Exam questions that relate new concepts with prior ones
Development of Learning

Concrete Examples
Concrete information is easier to remember

- Concrete words are recalled better than abstract words (Gorman, 1961)
  - E.g. “button” vs. “bound”
  - This happens even when controlling for factors such as word frequency, length, and meaningfulness
Novices tend to remember surface features of examples (Chi et al., 1981)
Transfer of knowledge is very difficult (Gick & Holyoak, 1980, 1983)
Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. To operate on the patient is impossible, but unless the tumor is destroyed, the patient will die. A kind of ray, at a sufficiently high intensity, can destroy the tumor. Unfortunately, at this intensity, the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities, the rays are harmless to healthy tissue, but will not affect the tumor.

How can the rays be used to destroy the tumor without injuring healthy tissue?
Transfer of knowledge is very difficult (Gick & Holyoak, 1980, 1983)
Going from one example to another

- Students read and recall three stories, including the fortress story
- Students are presented with the tumor problem and asked to solve it
  - No hint
  - Hint:
    “In solving this problem, you may find that one of the stories you read before will give you a hint for a solution of this problem”

Gick & Holyoak (1980), *Cognitive Psychology*
Going from one example to another

Gick & Holyoak (1980), *Cognitive Psychology*
Going from one example to another

• What *doesn’t* work?
  • Having students summarize the solution
  • Providing a verbal description of the underlying structure
  • Providing a diagram

• What *does (seem to)* work?
  • Provide multiple examples esp. with different surface details
  • Having students explain how the examples are similar (i.e., extracting the underlying structure)
Practical Tips

Concrete Examples
In the classroom...

- Highlight links between examples
- Have students create examples
  - But correct wrong examples
- Use multiple, varied examples
Development of Learning

Dual Coding
Main idea – Dual coding

Alan Paivio’s dual-coding theory

Water moves around the earth. Each day, water moves from the ocean and the land through the air. This movement is called the water cycle.

The water cycle works because of energy. Evaporation brings water into the air from surface bodies of water like lakes, oceans, and rivers. Transpiration can move from underground to vapor from their leaves. Eventually, it evaporates into the sky and then condenses.
Pictures can help students understand texts (Jalilehvand, 2012)

<table>
<thead>
<tr>
<th>NO PICTURE</th>
<th>PICTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LONG TEXT</strong></td>
<td>Water moves around the earth. This movement is called the water cycle. The water cycle works because of time. Evaporation brings water into the air from surface bodies of water like lakes, or from land, or even underground. Heat evaporation. Transpiration is related to evaporation that can move from underground into the air vapor from their leaves. Water travels the Eventually it evaporates from the leaves.</td>
</tr>
<tr>
<td><strong>SHORT TEXT</strong></td>
<td>Water moves around the earth. This movement is called the water cycle. The water cycle works because of time. Evaporation brings water into the air from surface bodies of water like lakes, or from land, or even underground. Heat evaporation. Transpiration is related to evaporation that can move from underground into the air vapor from their leaves. Water travels the Eventually it evaporates from the leaves.</td>
</tr>
</tbody>
</table>
Pictures can help students understand texts (Jalilehvand, 2012)
BE CAREFUL: Dual Coding vs. Learning Styles

DUAL CODING

• EVERYONE will learn better if verbal info is combined with visuals.

• EMBRACES the human ability to appreciate and learn with both verbal and non-verbal representations.
BE CAREFUL: Dual Coding vs. Learning Styles

LEARNING STYLES

- People with CERTAIN learning preferences will benefit from one mode, but not the other.
- Restricts the human ability to one optimal way of presenting information.

"Verbal" Water moves around the earth. This movement is called the water cycle. The water cycle works because of evaporation. Evaporation brings water into the air from the surface of water like lakes, from soil, or even underground. Precipitation is related to evaporation. Precipitation is water that returns to the earth from the air. Precipitation can return to the earth as rain, snow, sleet, or hail. Water travels from the surface of water like lakes or oceans. Water travels from snow, sleet, or rain back to the earth as runoff. Water travels from rain, snow, or sleet back to the earth as runoff. Water travels by evaporation from the oceans.

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"Visual" Water moves around the earth. This movement is called the water cycle. The water cycle works because of evaporation. Evaporation brings water into the air from the surface of water like lakes, from soil, or even underground. Precipitation is related to evaporation. Precipitation is water that returns to the earth from the air. Precipitation can return to the earth as rain, snow, sleet, or hail. Water travels from the surface of water like lakes or oceans. Water travels from snow, sleet, or rain back to the earth as runoff. Water travels from rain, snow, or sleet back to the earth as runoff. Water travels by evaporation from the oceans.
Retrieval Practice
Effects on Learning

- Retrieval Practice
- Learning

Indirect Effects:
- Feedback
- Study allocation
- Motivation
Effects on Learning

Retrieval Practice → Learning

Direct Effect

Indirect Effects

Feedback
Study allocation
Motivation
Direct effects of retrieval practice

STUDY → RESTUDY → RESTUDY → RESTUDY → FINAL TEST

STUDY → RETRIEVAL → RETRIEVAL → RETRIEVAL → FINAL TEST
Do Students realize retrieval helps?
(Roediger & Karpicke, 2006, Exp 2)
Do Students realize retrieval helps?
(Roediger & Karpicke, 2006, Exp 2)
Do Students realize retrieval helps?
(Roediger & Karpicke, 2006, Exp 2)
Retrieval Practice with Vocabulary
(Karpicke, 2009)

Mashua-Boat
Mashua-
Mashua-Boat
Mashua-

Drop Condition
Retrieval Practice with Vocabulary (Karpicke, 2009)

Drop Condition

STUDY | PRACTICE TEST | STUDY | PRACTICE TEST
STUDY | PRACTICE TEST | STUDY | PRACTICE TEST | STUDY X 2
Retrieval Practice with Vocabulary (Karpicke, 2009)
Spaced retrieval practice

At the beginning of class:

Q1 – Q3 – retrieval of information from last class
Q4 – retrieval of information from last week
Q5 – retrieval of information from last month
Q6 – make link between information from last class & previously learned information

Example based on blog by MrTharby, UK Author and teacher
Free Resources

www.learningscientists.org
Resource digests

Learning Scientists and Guest posts
Six strategy posters
Powerpoints for teaching the 6 strategies

Retrieval Practice

**How to do it**

You can also make flashcards. Just make sure you practice recalling the information on them, and go beyond definitions by thinking of links between ideas.
Videos for teaching the 6 strategies

- Spaced Practice
- Retrieval Practice
- Elaboration
- Interleaving
Sketchnote Video: Summarizing the 6 strategies

https://www.youtube.com/watch?v=CPxSzxylRCI
The Learning Scientists Podcast
How to Make the Most of learningscientists.org as a Student

www.learningscientists.org/blog/2018/1/11-1