What Works with Designing Effective Multimedia Instruction

Richard E. Mayer

Department of Psychological and Brain Sciences

University of California, Santa Barbara

Santa Barbara, CA 93106

USA

mayer@ucsb.edu

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Greetings from the University of California, Santa Barbara

What Works with Multimedia Instruction

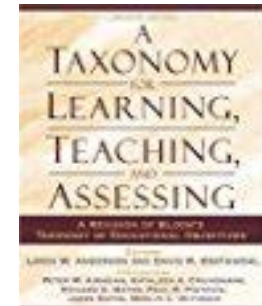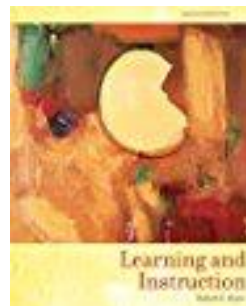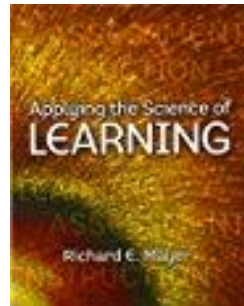→ **Introduction**

Understanding How Meaningful Learning Works

Evidence-Based Principles for Designing Effective Instructional Video

My General Domain:
Applying the Science of Learning to Education

Science of learning – How people learn

Science of instruction – How to help people learn

Science of assessment – How to determine what people learned

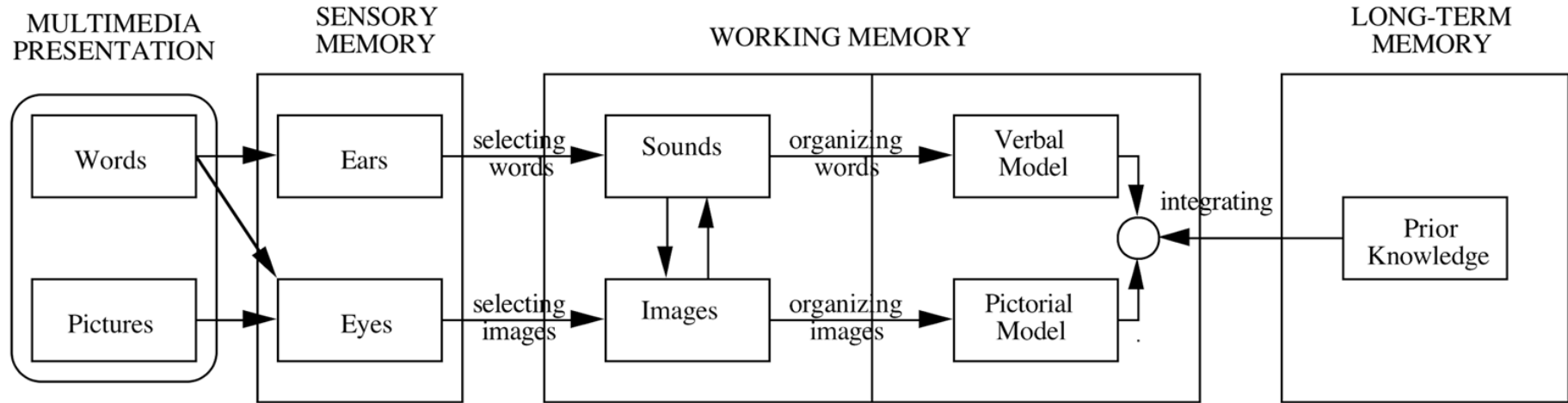**What Works with Multimedia Instruction**

Introduction

➡ **Understanding How Meaningful Learning Works**

Evidence-Based Principles for Designing Effective Instruction

How Does Meaningful Learning Work?
A Cognitive Theory of Multimedia Learning

How Does Instruction Work?
Three Demands on Learners During Multimedia Instruction

Extraneous: Wasted cognitive processing that does not support the objective of the lesson. Caused by poor instructional design.

Essential: Basic cognitive processing required to mentally represent the presented material. Caused by the inherent complexity of the material.

Generative: Deep cognitive processing required to make sense of the presented material. Caused by the learner's motivation to exert effort to learn.

How Can We Help People Learn?
Three Top-Level Goals for the Design of Effective Instruction

___

1. Reduce extraneous processing

2. Manage essential processing

3. Foster generative processing

___

cognitive >=   extraneous + essential   + generative
capacity   processing   processing   processing

___

Using Effect Size to Gauge Instructional Effectiveness: Compare Base Version of Lesson to Same Lesson with One Feature Added
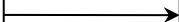
Compare base version vs. enhanced version

Measure learning outcome: Mean (M) & Standard Deviation (SD) on transfer

Compute effect size (d)
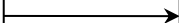
Base group
| Study base version | → | Take transfer test |

M = 10
SD = 5

Enhanced group
| Study enhanced version | → | Take Transfer test |

M = 12
SD = 5

$d = (12 - 10)/5 = 0.40$

What Works with Multimedia Instruction

Introduction

Understanding How Meaningful Learning Works

→ **Evidence-Based Principles for Designing Effective Instruction**

My Search for Evidence-Based Principles of Instructional Design

Conduct 200+ experiments.

Compare learning outcomes and learning processes of students who receive the base version of a lesson versus the same lesson with one feature added.

Yield 14 evidence-based principles.

Foster Generative Processing
Problem: Insufficient Generative Processing
Although Cognitive Capacity is Available
Solution: Foster Generative Processing

→ 1. **Personalization principle**
   2. Embodiment principle
   3. Voice principle
   4. Positivity principle
   5. Emotional design principle
   6. Generative activity principle

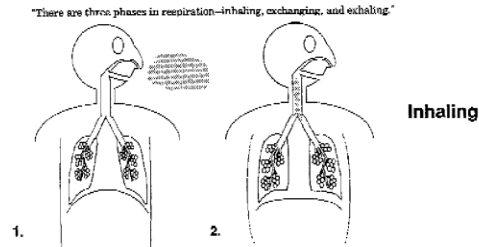# Which Wording Style Leads to Better Learning in a Narrated Animation?

Formal Wording

"During inhaling, the diaphragm moves down creating more space for the lungs, air enters through the nose or mouth, moves down through the throat and bronchial tubes to tiny air sacs in the lungs…"

"There are three phases in respiration—inhaling, exchanging, and exhaling."
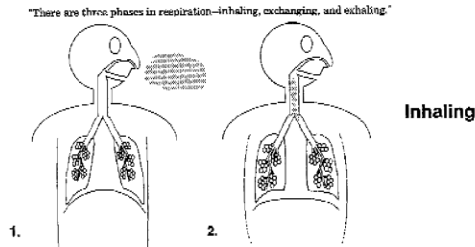
1.   2.   Inhaling

Conversational Wording

"During inhaling, your diaphragm moves down creating more space for your lungs, air enters through your nose or mouth, moves down through your throat and bronchial tubes to tiny air sacs in your lungs…"

"There are three phases in respiration—inhaling, exchanging, and exhaling."

1.   2.   Inhaling

Adapted from Mayer, Fennell, Farmer, & Campbell (2004)

Personalization Principle

People learn more deeply when words are
in conversational style rather than formal style.

Confirmed in: 13 of 15 tests

Median effect size: 1.00

Boundary conditions: May not apply to higher achieving
learners

Foster Generative Processing

Problem: Insufficient Generative Processing
Although Cognitive Capacity is Available
Solution: Foster Generative Processing

1. Personalization principle
→ **2. Embodiment principle**
3. Voice principle
4. Positivity principle
5. Emotional design principle
6. Generative activity principle

Which Perspective Leads to Better Learning in an Instructional Video?
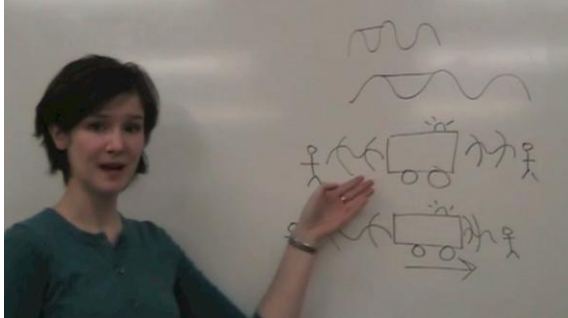
Third-person Perspective

First-person Perspective

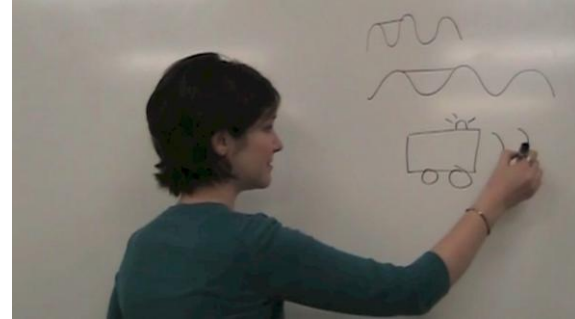Fiorella, L., Hoogerheide, V., van Gog, T., & Mayer, R. E. (2017)
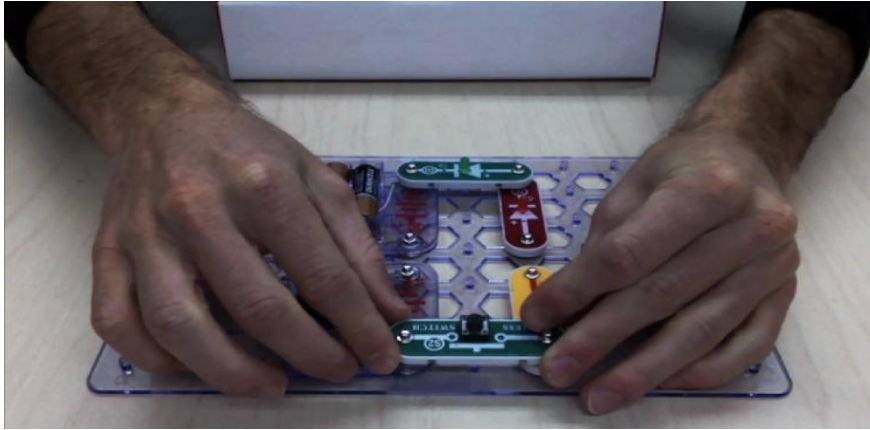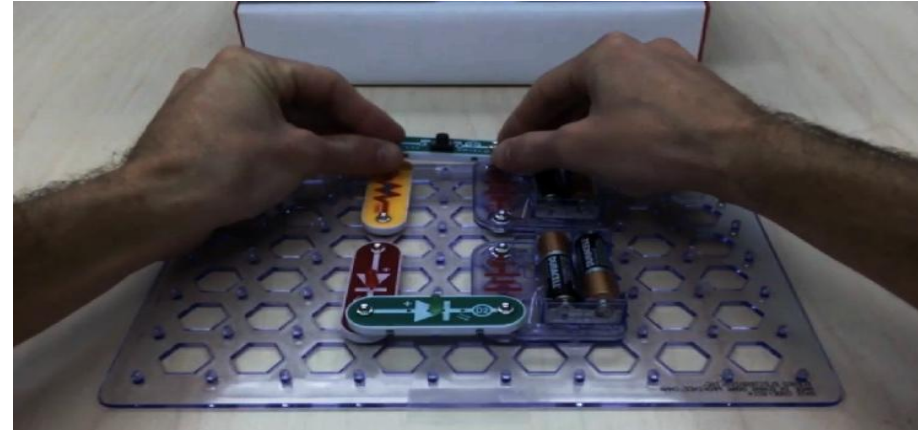
Which Method Leads to Better Learning from a Video Lecture?

Explain Already Drawn Graphics
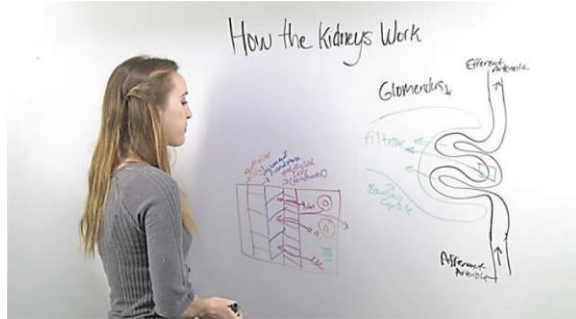

Draw Graphics as You Explain

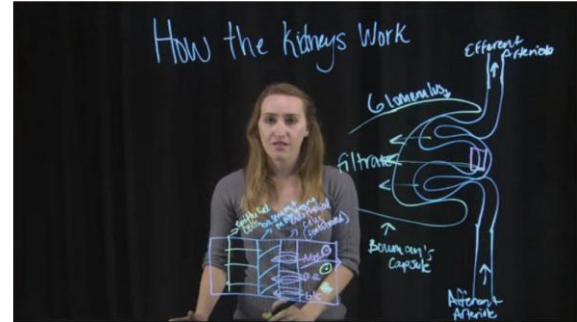Adapted from: Fiorella, L. & Mayer, R. E. (2016)

Do Students Learn Better When the Instructor Makes Eye Contact While Lecturing?

On-screen Instructor Never Makes Eye Contact
(Facing a Traditional Whiteboard)

On-screen Instructor Makes Eye Contact
(Facing Audience Through a Transparent Board)

Adapted from Fiorella, Stull, Kuhlmann, & Mayer (2019)

Embodiment Principle

People learn more deeply from multimedia presentations when an onscreen instructor moves from a first-person perspective, draws while explaining, maintains eye contact while lecturing, and gestures appropriately while lecturing.

Confirmed in: 16 of 17 tests

Median effect size: 0.58

Foster Generative Processing
Problem: Insufficient Generative Processing
Although Cognitive Capacity is Available
Solution: Foster Generative Processing

1. Personalization principle
2. Embodiment principle
→ **3. Voice principle**
4. Positivity principle
5. Emotional design principle
6. Generative activity principle

Do Students Learn Better from a Narrated Lesson When the Narrator's Voice Is Appealing?

Unappealing Voice

😖 "Cool moist air moves over a warmer surface and becomes heated."

Appealing Voice

🙂 "Cool moist air moves over a warmer surface and becomes heated."

Adapted from Mayer, Sobko, & Mautone (2003)

Voice Principle

People learn more deeply when the narration is spoken in a pleasant human voice than a machine voice.

Confirmed in: 5 of 6 tests

Median effect size: 0.74

Foster Generative Processing
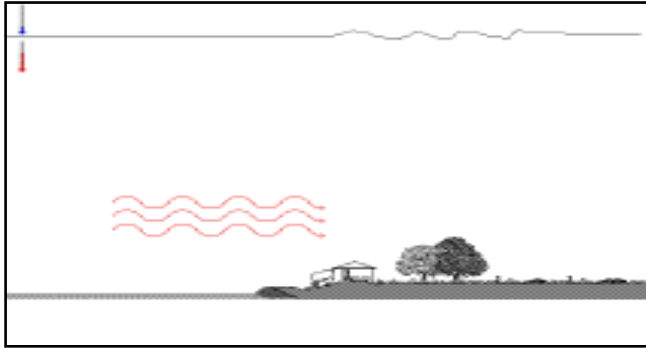Problem: Insufficient Generative Processing
Although Cognitive Capacity is Available
Solution: Foster Generative Processing

1. Personalization principle
2. Embodiment principle
3. Voice principle
→ **4. Positivity principle**
5. Emotional design principle
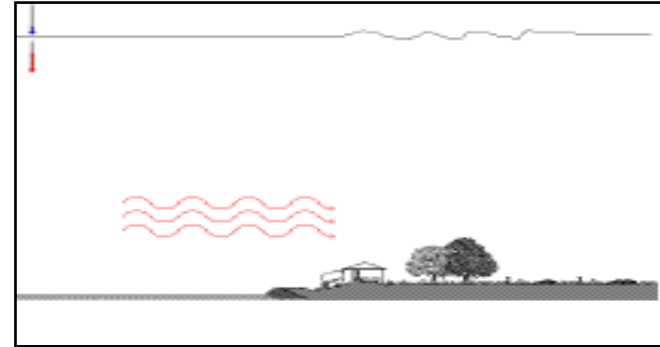6. Generative activity principle

Do Students Learn Better When Instructors Display Positive Gestures and Facial Expression in Instructional Videos?

Negative Instructor

Positive Instructor

Adapted from Lawson, Mayer, Adamo, Benes, Lei, & Cheng (2021)

Positivity Principle

People learn more deeply when the instructor displays positive emotional tone through gesture, facial expression, body stance, and voice.

Confirmed in: 3 out of 4 tests
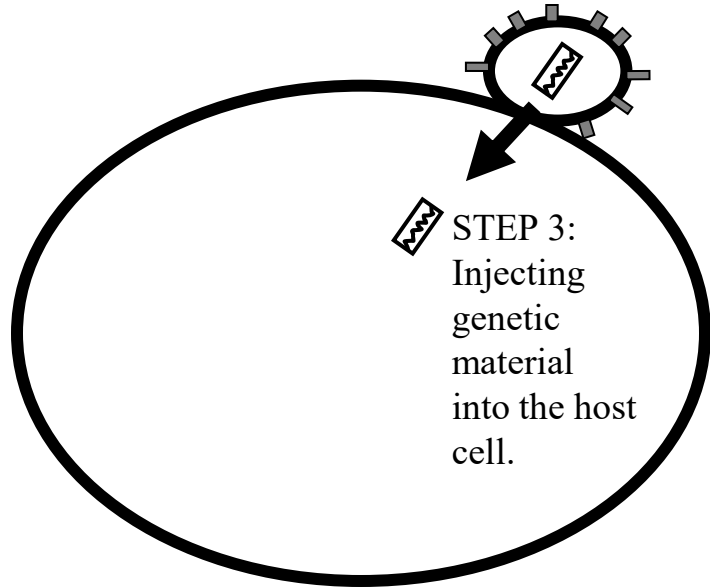
Median effect size: .34

Foster Generative Processing
Problem: Insufficient Generative Processing
Although Cognitive Capacity is Available
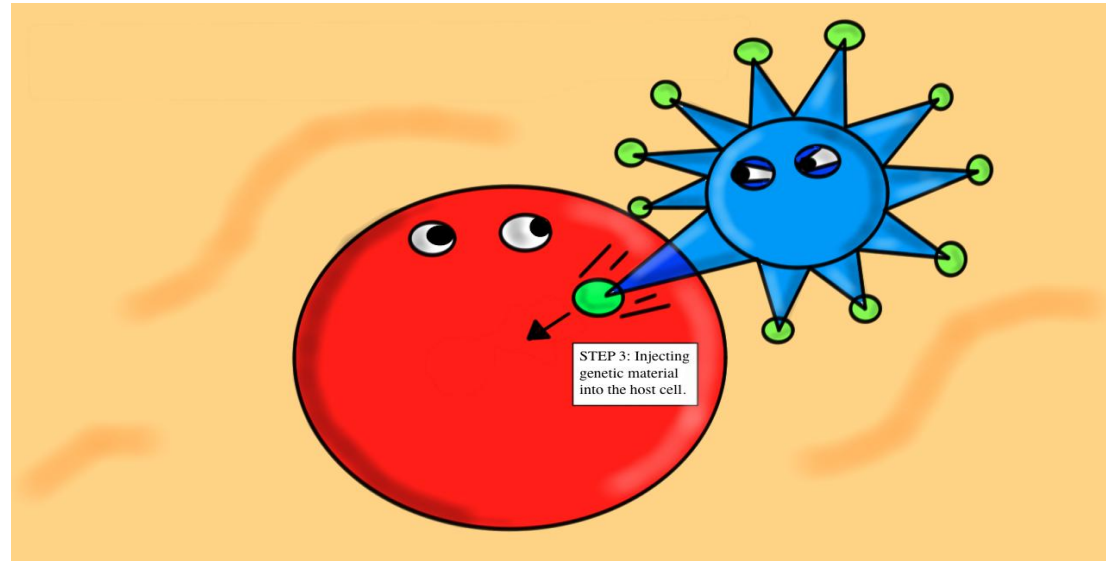Solution: Foster Generative Processing

1. Personalization principle
2. Embodiment principle
3. Voice principle
4. Positivity principle
➡ **5. Emotional design principle**
6. Generative activity principle

Which Kind of Graphic Leads to Better Learning in Online Lessons?

Black and White Line Drawings

STEP 3: Injecting genetic material into the host cell.

Color Graphics with Facial Expressions

STEP 3: Injecting genetic material into the host cell.

Adapted from Mayer & Estrella (2014)

Which Kind of Graphic Leads to Better Learning on Online Lessons?

Line Drawings with Minimal Color

"Cool moist air moves over a warmer surface and becomes heated."

Key Elements Rendered as Cartoon Characters with Facial Expression in Color

"Cool moist air moves over a warmer surface and becomes heated."

Adapted from Zhao & Mayer (2023)
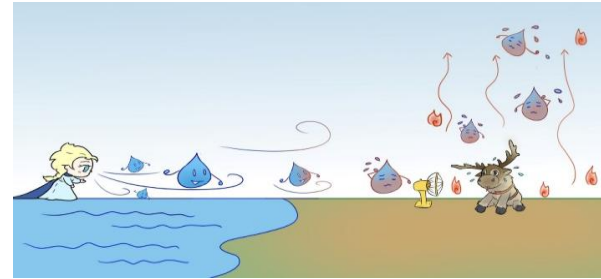
Emotional Design Principle

People learn more deeply when key elements in the graphic are rendered with facial expressions and warm colors.

Confirmed in: 4 out of 4 tests

Median effect size: .57

Foster Generative Processing
Problem: Insufficient Generative Processing
Although Cognitive Capacity is Available
Solution: Foster Generative Processing

1. Personalization principle
2. Embodiment principle
3. Voice principle
4. Positivity principle
5. Emotional design principle
➔ 6. **Generative activity principle**

Do People Learn Better When They Are Asked to Write Brief Explanations During Pauses in a Multimedia Lesson?

No Prompts to Explain
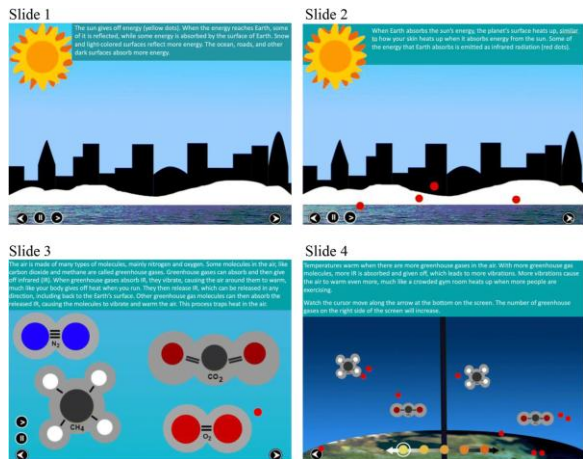
Prompts to Explain After Each Segment
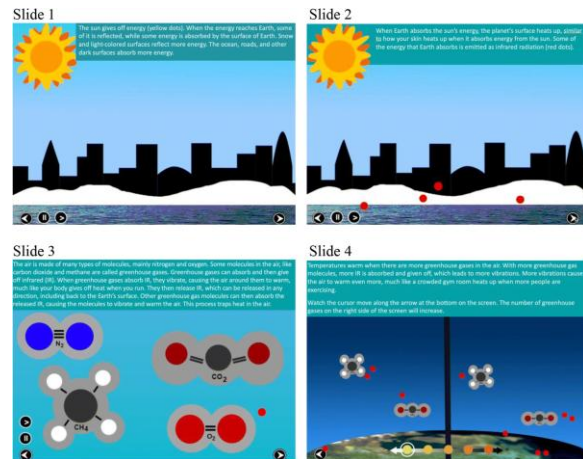
After each segment (prompt and textbox):
Please explain what you learned in the last clip.

Adapted from Lawson & Mayer (2021)

Generative Activity Principle

People learn more deeply when they are asked to carry out generative learning activities during pauses in a lesson (such as writing a brief explanation, creating a knowledge map, making a drawing, trying to recall the material, or teaching the material to others).

Confirmed in: 37 out of 44 tests

Median effect size: d = .71

Reduce Extraneous Processing

Problem: Extraneous Processing + Intrinsic Processing +
Generative Processing Exceeds Cognitive Capacity
Solution: Reduce Extraneous Processing

→ 1. **Coherence principle**
   2. Signaling principle
   3. Redundancy principle
   4. Spatial contiguity principle
   5. Temporal contiguity
      principle

Do Students Learn Better When We Add Interesting But Irrelevant Details?

Presentation with Seductive Details

Step 5: Breaking Free from the Host Cell
The new parts are packaged into new virus within the host cell. The new viruses break free from the host cell. In some cases, they break the host cell open, destroying the host cell in the process, which is called lysis. In other cases, they punch out of he cell membrane surrounding them, which is called budding. A study conducted by researchers at Wilkes University in Wilkes-Barre, Pennsylvania, reveals that people who make love once or twice a week are more immune to colds than folks who abstain from sex. Researchers believe that the bedroom activity somehow stimulates an immune-boosting antibody called IgA.
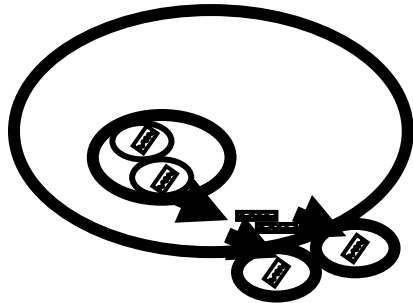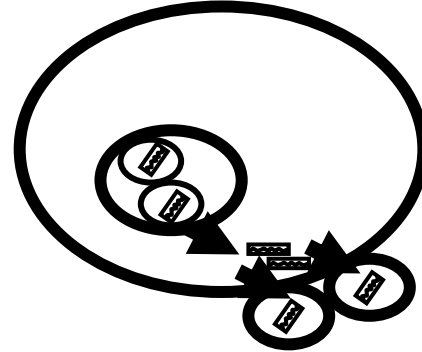

STEP 5: Breaking free from the host cell.

Presentation Without Seductive Details

Step 5: Breaking Free from the Host Cell
The new parts are packaged into new virus within the host cell. The new viruses break free from the host cell. In some cases, they break the host cell open, destroying the host cell in the process, which is called lysis. In other cases, they punch out of he cell membrane surrounding them, which is called budding.

STEP 5: Breaking free from the host cell.

Adapted from Mayer, Griffin, Naftaly & Rothman (2008)

Coherence Principle

People learn more deeply when extraneous material is excluded rather than included.

Confirmed in: 18 of 19 tests
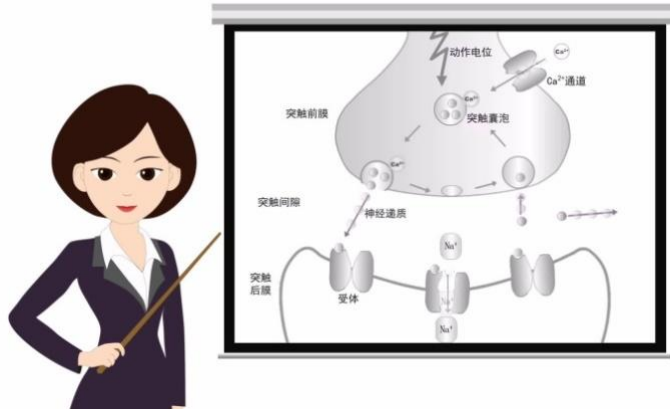
Median effect size: 0.86

Reduce Extraneous Processing

Problem: Extraneous Processing + Intrinsic Processing +
Generative Processing Exceeds Cognitive Capacity
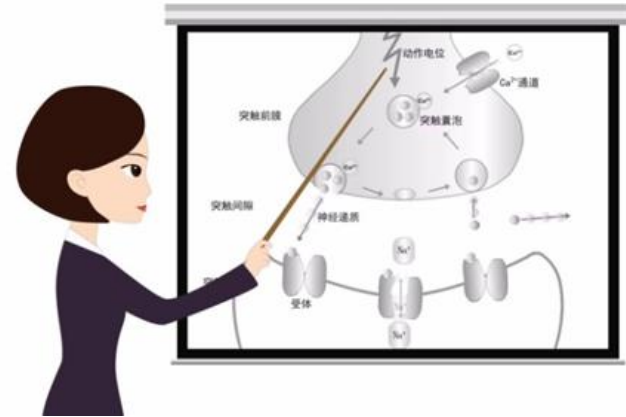Solution: Reduce Extraneous Processing

1. Coherence principle
→ 2. **Signaling principle**
3. Redundancy principle
4. Spatial contiguity principle
5. Temporal contiguity principle

Do Students Learn Better When the Instructor Points to the Part of the Graphic She Is Talking About?

Non-signaled Presentation:
Instructor Stands Still as She Speaks

Signaled Presentation:
Instructor Points as She Speaks

Adapted from Li, Wang, Mayer, & Liu (2019)

Signaling Principle

People learn more deeply when cues are added that highlight the main ideas and organization of the material.

Confirmed in: 26 of 28 tests
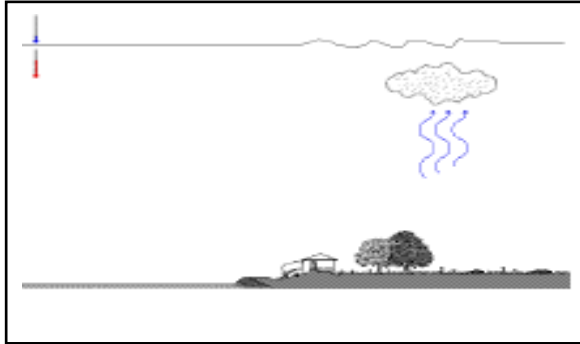
Median effect size: 0.70

Reduce Extraneous Processing

Problem: Extraneous Processing + Intrinsic Processing + Generative Processing Exceeds Cognitive Capacity

Solution: Reduce Extraneous Processing

1. Coherence principle
2. Signaling principle
→ **3. Redundancy principle**
4. Spatial contiguity principle
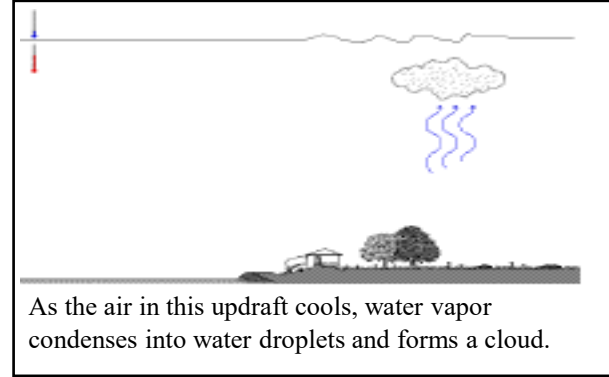5. Temporal contiguity principle

Do Students Learn Better When On-Screen Text Is Added that Contains the Same Words that Instructor Is Speaking?

Non-Redundant Presentation: Animation and Narration

"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud".

Redundant Presentation: Animation, Narration, and On-Screen Text

As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.

"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud".

Adapted from Mayer, Heiser, & Lonn (2001)

Redundancy Principle

People do not learn more deeply from graphics, narration and on-screen text than from graphics and narration.

Confirmed in: 8 of 12 tests

Median effect size: 0.10 (favoring redundant presentation)

Boundary conditions: learning in a second language, technical jargon, shortened printed text

Reduce Extraneous Processing

Problem: Extraneous Processing + Intrinsic Processing +
Generative Processing Exceeds Cognitive Capacity
Solution: Reduce Extraneous Processing

1. Coherence principle
2. Signaling principle
3. Redundancy principle
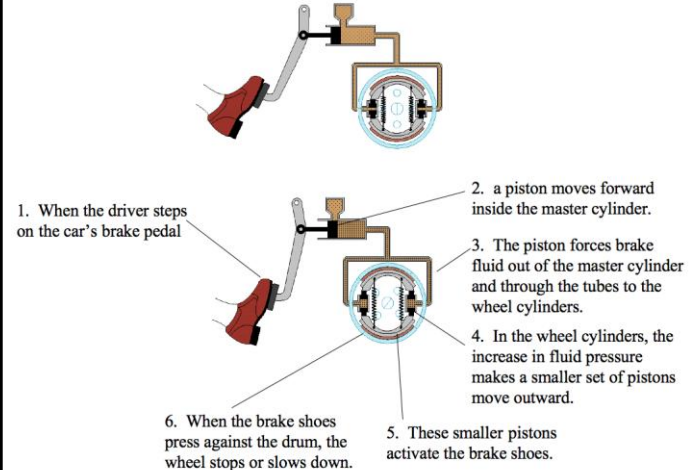→ **4. Spatial contiguity principle**
5. Temporal contiguity
   principle

Do Students Learn Better When Printed Text Is Placed Near the Corresponding Parts of the Graphic?

Separated Presentation: Place Text as a Caption Under the Illustration
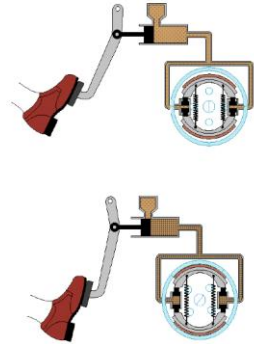
When the driver steps on the car's brake pedal, a piston moves forward inside the master cylinder. The piston forces brake fluid out of the master cylinder and through the tubes to the wheel cylinders. In the wheel cylinders, the increase in fluid pressure makes a smaller set of pistons move outward. These smaller pistons activate the brake shoes. When the brake shoes press against the drum, the wheel stops or slows down.

Integrated Presentation: Place Text Next to the Corresponding Parts of the Illustration

1. When the driver steps on the car's brake pedal

2. a piston moves forward inside the master cylinder.

3. The piston forces brake fluid out of the master cylinder and through the tubes to the wheel cylinders.

4. In the wheel cylinders, the increase in fluid pressure makes a smaller set of pistons move outward.

5. These smaller pistons activate the brake shoes.

6. When the brake shoes press against the drum, the wheel stops or slows down.

Adapted from Johnson & Mayer (2012)

Spatial Contiguity Principle

People learn more deeply when corresponding printed words and graphics are placed near rather than far from each other on the page or screen.

Confirmed in: 9 of 9 tests

Median effect size: 0.82

Reduce Extraneous Processing
Problem: Extraneous Processing + Intrinsic Processing +
Generative Processing Exceeds Cognitive Capacity
Solution: Reduce Extraneous Processing

1. Coherence principle
2. Signaling principle
3. Redundancy principle
4. Spatial contiguity principle
→ **5. Temporal contiguity principle**

Do Students Learn Better When the Instructor's Spoken Words Are in Sync with the Graphics on the Screen?
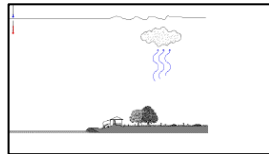
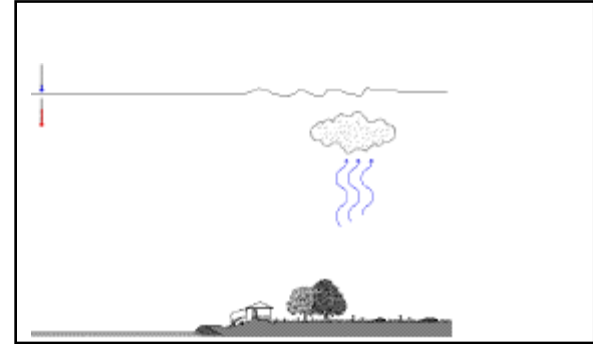## Successive Presentation:
View Slides Then Listen to Narration
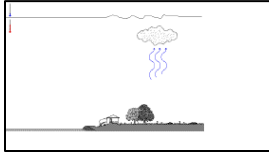
"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud".

Listen to Narration Then View Slides

"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud".

Simultaneous Presentation:
Receive Narrated Slides

"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud".

Adapted from Mayer, Moreno, Boire, & Vagge (1999)

Temporal Contiguity Principle

People learn more deeply when corresponding graphics and narration are presented simultaneously rather than successively.

Confirmed in: 8 of 8 tests

Median effect size: 1.31

Manage Essential Processing
Problem: Essential Processing + Generative Processing
Exceeds Cognitive Capacity
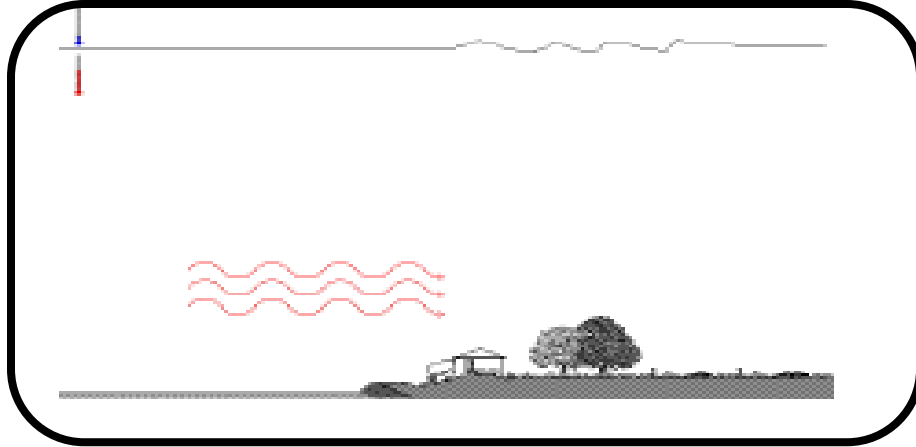Solution: Manage Essential Processing

→ 1. **Segmenting principle**
2. Pre-training principle
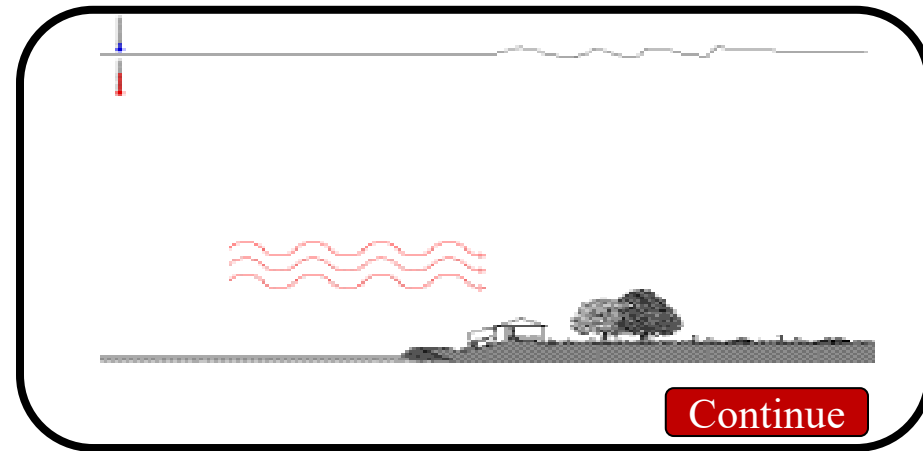3. Modality principle

Do Students Learn Better When a Continue Button Is Added After Each Segment of a Narrated Animation?

Continuous Presentation: Animation Runs Without Stopping

Segmented Presentation: Animation Pauses After Each Segment Until Learner Clicks on the Continue Button

"Cool moist air moves over a warmer surface and becomes heated."

"Cool moist air moves over a warmer surface and becomes heated."

Adapted from Mayer & Chandler (2001)

Do Students Learn Better When the Instructor Shows Each Slide All at Once or Segment by Segment?

Continuous Presentation:
Present Each Slide All at Once

Segmented Presentation:
Present Each Slide Segment by Segment

Adapted from Mayer, Wells, Parong, & Howarth (2019)
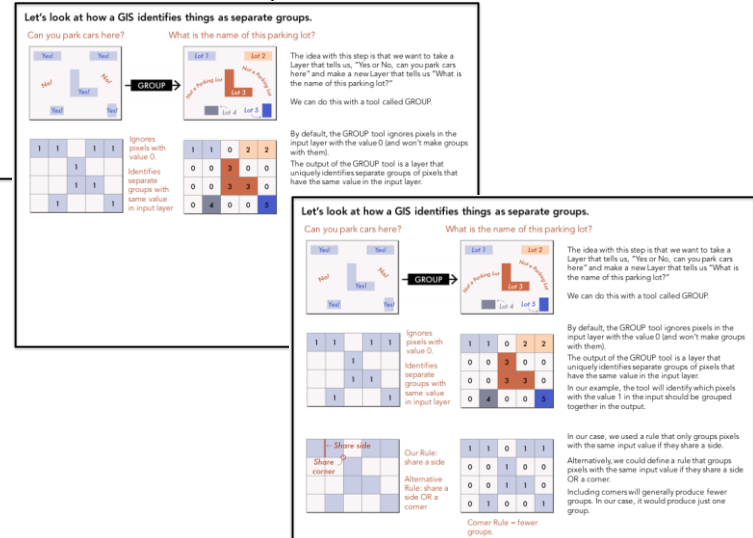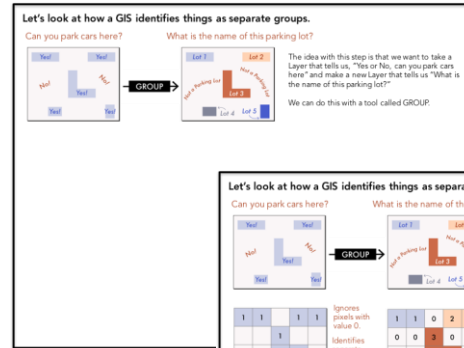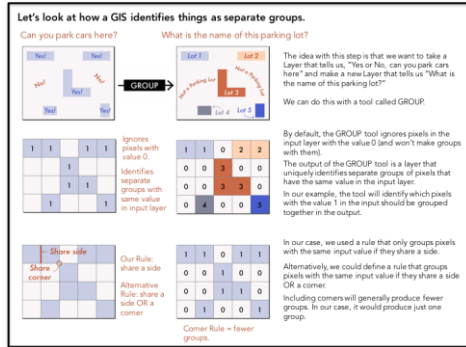
Segmenting Principle

People learn more deeply when a lesson is presented in learner-paced segments than as a continuous unit.

Confirmed in: 7 of 7 tests

Median effect size: 0.67
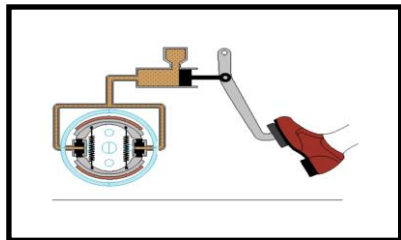
Manage Essential Processing

Problem: Essential Processing + Generative Processing
Exceeds Cognitive Capacity
Solution: Manage Essential Processing

1. Segmenting principle
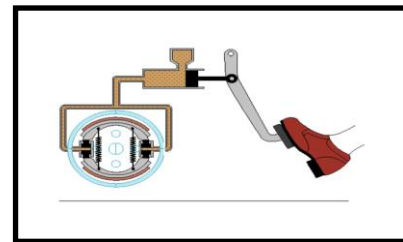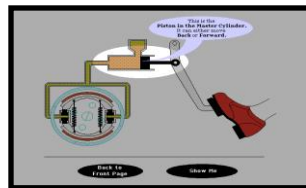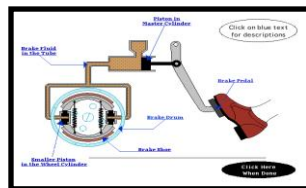→ **2. Pre-training principle**
3. Modality principle

Do Students Learn Better When They Receive Pretraining in the Names and Characteristics of Key Parts?

No Pretraining: View Narrated Animation on How Brakes Work

Pretraining: View Pretraining Before Narrated Animation on How Brakes Work

"When the driver steps on the brake petal…"

"When the driver steps on the brake petal…"

Adapted from Mayer, Mathias & Wetzell (2002)

Pre-training Principle

People learn more deeply from a narrated animation when they have had training in the names and characteristics of the main concepts. Confirmed in: 10 of 10 tests

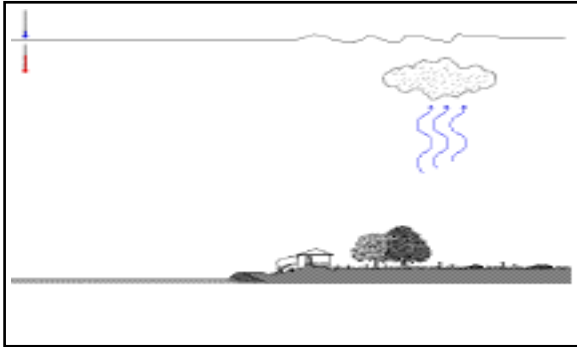Median effect size: 0.78

Manage Essential Processing

Problem: Essential Processing + Generative Processing
Exceeds Cognitive Capacity
Solution: Manage Essential Processing

1. Segmenting principle
2. Pre-training principle
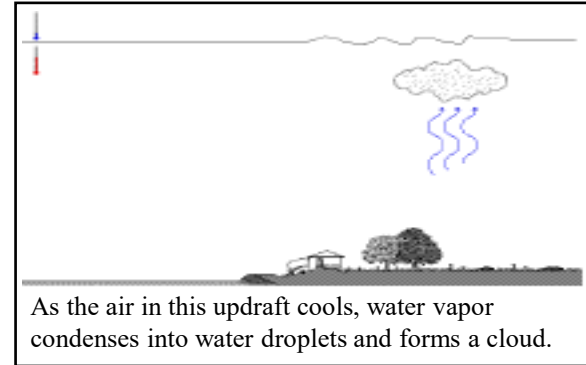→ **3. Modality principle**

Do Students Learn Better from an Animation When the Words Are Spoken or Printed?

Words as Narration

"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud."

Words as On-Screen Text

As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.

Adapted from Mayer & Moreno (1998, 1999)

Modality Principle

People learn more deeply from graphics and narration than from graphics and on-screen text.

Confirmed in: 18 of 19 tests

Median effect size: 1.00

Boundary conditions: May not apply when words are unfamiliar or in the learner's second language, or when the lesson is slow-paced or pace is controlled by the learner.

What Works with Designing Effective Multimedia Instruction

Thank you for being here today!

Additional Sources

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E-mail Address: mayer@ucsb.edu