HILT | Harvard Initiative for Learning & Teaching

Research-Based Principles for Multimedia Learning

Richard E. Mayer
Department of Psychological and Brain Sciences
University of California, Santa Barbara
Santa Barbara, CA 93106

mayer@psych.ucsb.edu

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Collaborators

Robert K. Atkinson
Richard B. Anderson
Julie Campbell
Paul Chandler
Dorothy Chun
Gayle Dow
Joan Gallini
Stefan Hagmann
Shannon Harp
Julie Heiser
Joshua Jackson
Lewis Johnson
James Lester
Steve Lonn
Amanda Mathias
Patricia Mautone
Sarah Mayer
Roxana Moreno
Harold O'Neil
Jan Plass
William Prothero
Valerie Sims
Hiller Spires

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0. Examples

1. Introduction
    - The Science of Learning
    - The Science of Instruction
    - The Case for Applying the Science of Learning

2. Principles of Multimedia Instruction
    - Five Principles for Reducing Extraneous Processing
    - Three Principles for Managing Essential Processing
    - Two Principles for Fostering Generative Processing

3. Conclusion

Objectives

Describe how learning works based on the science of learning.

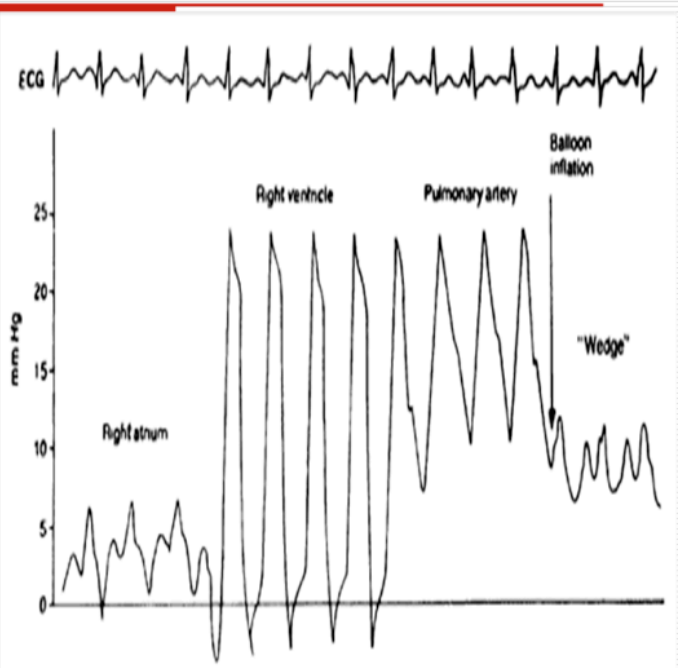
Describe how instruction works based on the science of instruction.

Define and exemplify five principles for reducing extraneous processing.

Define and exemplify three principles for managing essential processing.

Define and exemplify two principles for fostering generative processing.

Swan-Ganz (PAC) insertion is like 'Surfing through Blood Stream'



1. Mouth

When food is chewed, saliva starts digesting carbohydrates.

2. Esophagus

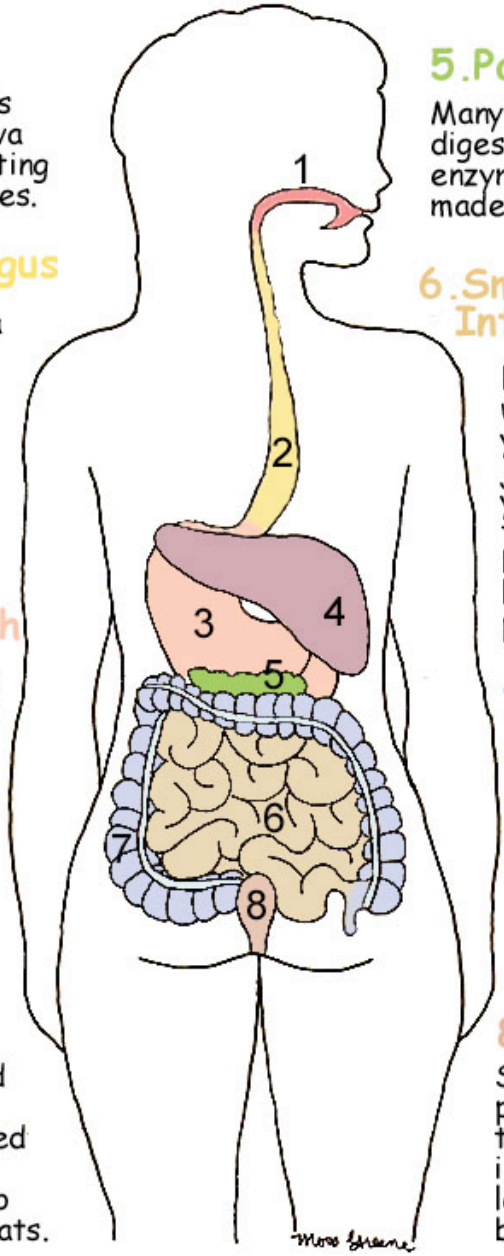
Muscles, in a process called peristalsis, push the food down into your stomach.

3. Stomach

Everything is blended with digestive juices. Hydrochloric Acid kills bacteria. Enzymes break down proteins.

4. Liver

A green liquid called bile, which is stored in your liver, is secreted to break down fats.



5. Pancreas

Many kinds of digestive enzymes are made here.

6. Small Intestine

Food is mixed with bile from your liver and juices from your pancreas to be sent back to your liver for more processing.

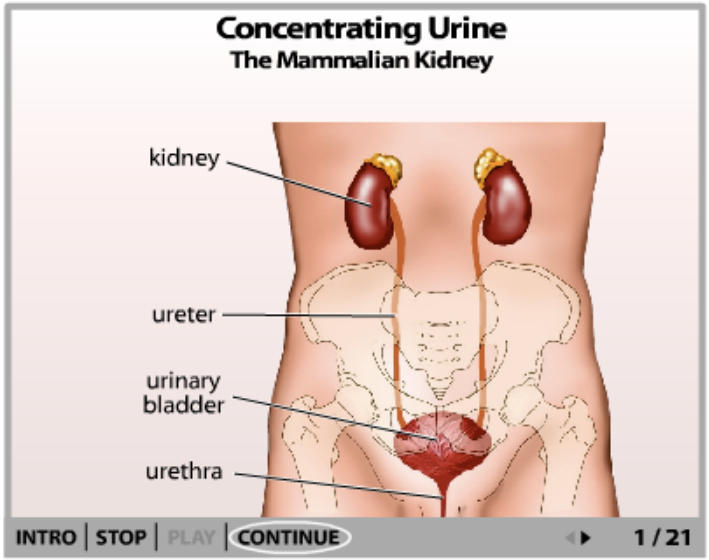
7. Large Intestine

Indigestible food and water are processed, stored and dispersed.

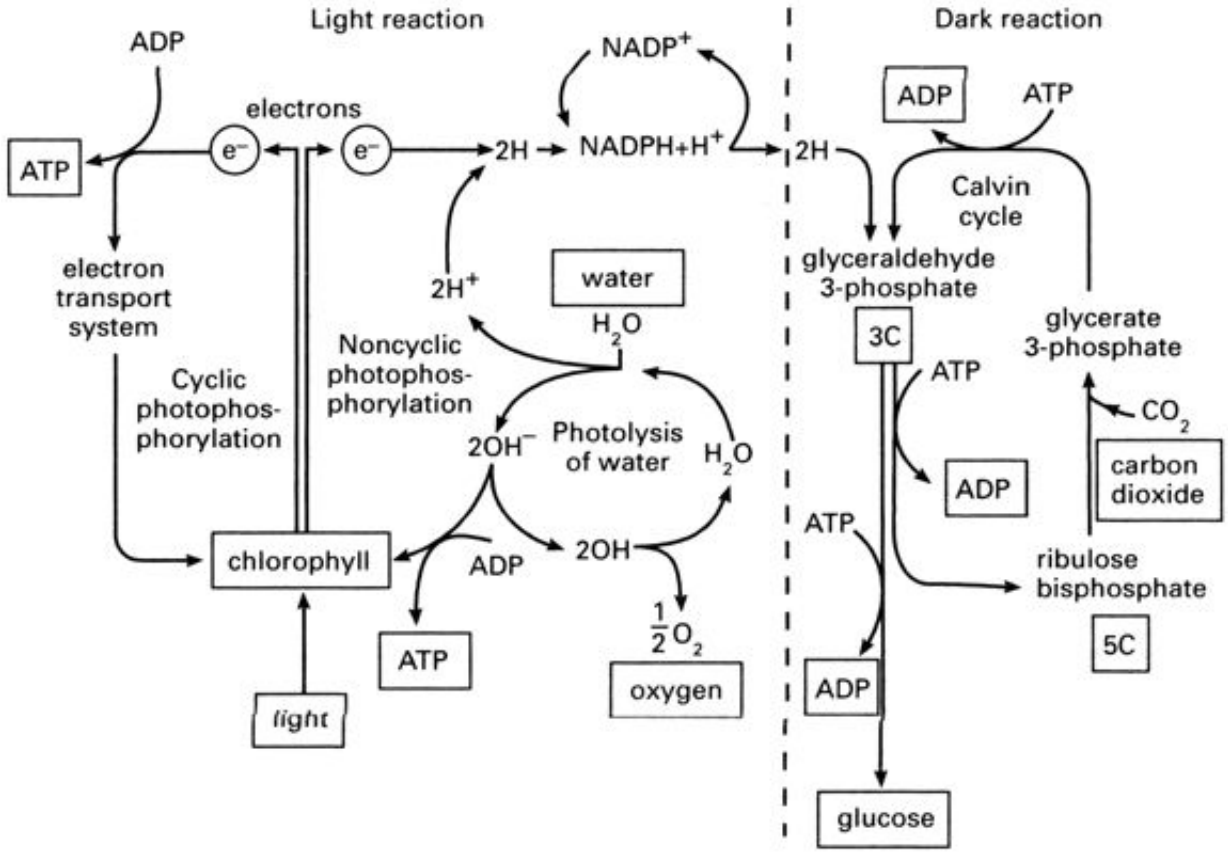
8. Anus

Solid waste passes from the rectum in order to leave your body.

[Note: The actual lesson contains 21 slides; when you press the play button, a voice describes the slide using the same words as in the caption; when you press stop, the presentation pauses; when you press continue, the presentation continues.]



The major excretory organ of mammals is the kidney. Humans have two kidneys located in the upper rear region of the abdominal cavity. The urine they produce is conducted to the urinary bladder through the ureters. The urethra drains the bladder.


Light reaction
Dark reaction
ADP
ATP
electrons
e⁻
e⁻
2H
NADP⁺
NADPH+H⁺
2H
ADP
ATP
Calvin cycle
electron transport system
2H⁺
water
H₂O
glyceraldehyde 3-phosphate
3C
glycerate 3-phosphate
Noncyclic photophos-phorylation
Cyclic photophos-phorylation
2OH⁻
Photolysis of water
H₂O
ATP
CO₂
ADP
carbon dioxide
chlorophyll
ADP
2OH
ATP
ribulose bisphosphate
5C
light
ATP
½O₂
oxygen
ADP
glucose

RESPIRATORY

SYSTEM

The Science of Learning

What is learning?

What is multimedia learning?

How do people learn?

How does multimedia learning work?

What is learning?

Learning is a change in knowledge attributable to experience.

Learning:

1. is a change
2. in what the learner knows (inferred from a change in behavior)
3. caused by the learner's experience.

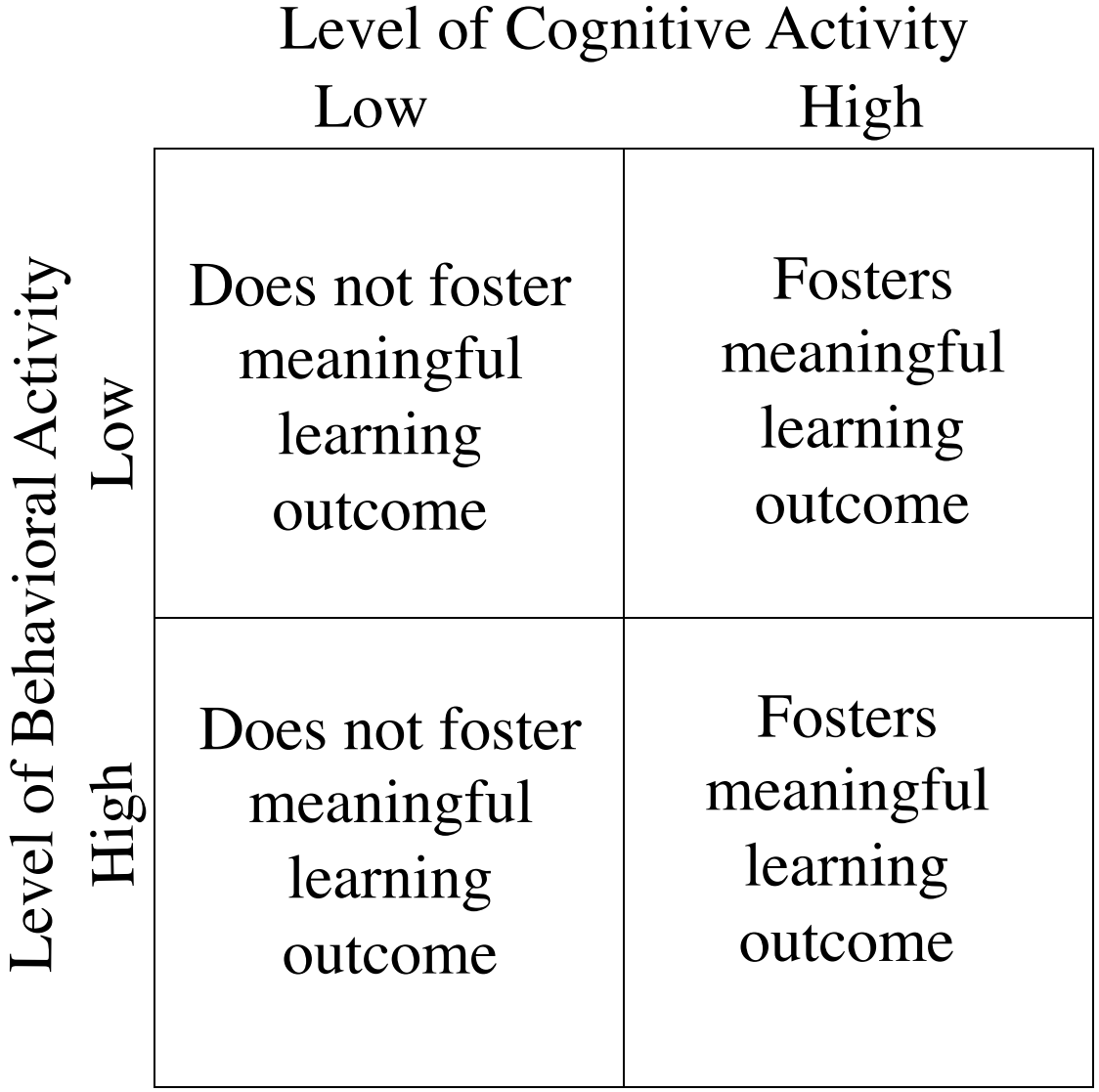
What is multimedia learning?

Multimedia learning is learning from words (e.g., printed or spoken text) and pictures (e.g., animation, video, illustrations, or photos).

How Do People Learn?
Three Metaphors of Learning

Name	Definition	Learner's role	Teacher's role
Response strengthening	Strengthening or weakening of an association	Passive recipient of rewards and punishments	Dispenser of rewards and punishments
Information acquisition	Adding information to memory	Passive recipient of information	Dispenser of information
Knowledge construction	Building cognitive representations	Active sense maker	Cognitive guide

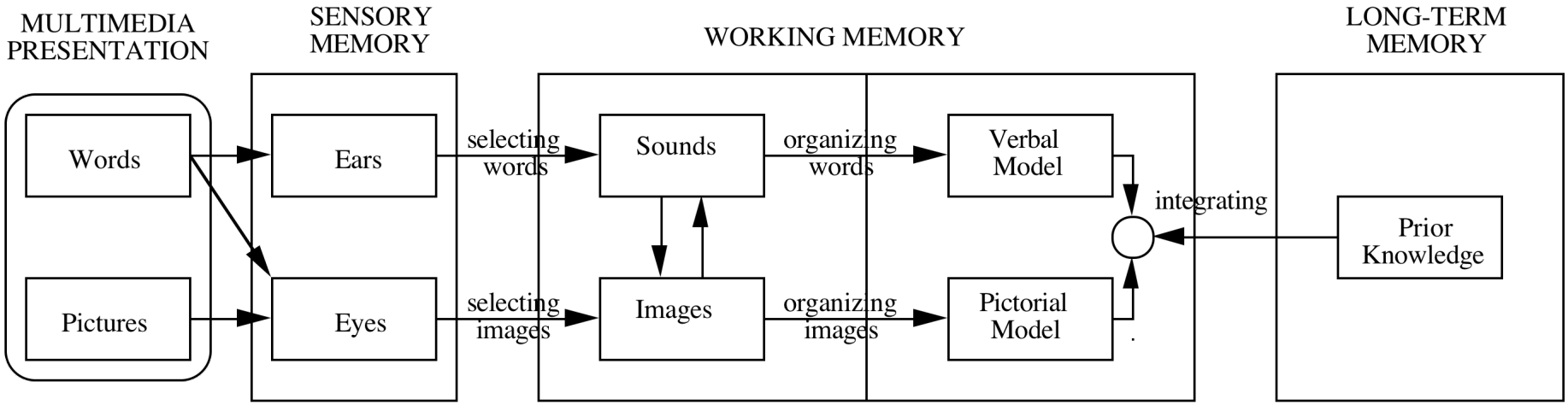
How Do People Learn?
Two Kinds of Active Learning



How Does Multimedia Learning Work?
Three Principles from the Learning Sciences

Name	Definition
Dual channels	People have separate channels for processing verbal and visual material
Limited capacity	People can process only small amounts of material in each channel at any one time
Active processing	Meaningful learning occurs when learners engage in appropriate cognitive processing during learning (e.g., attending to relevant material, organizing it into a coherent representation, and integrating it with relevant prior knowledge)

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



How Does Multimedia Learning Work?
Three Cognitive Processes Required for Meaningful Learning

Process	Description	Location
Selecting	Paying attention to relevant words and pictures	Transfer information from sensory memory to working memory
Organizing	Organizing selected words and pictures into coherent mental representations	Manipulate information in working memory
Integrating	Connecting verbal and pictorial representations with each other and with prior knowledge	Transfer knowledge from long term memory to working memory

The Science of Instruction

What is instruction?

What is a learning objective?

What is a learning outcome?

How does multimedia instruction work?

What is an evidence-based approach?

What is instruction?

Instruction is the instructor's manipulation of the learner's environment in order to foster learning.

Instruction is:

1. manipulating what the learner experiences
2. with the intention to cause learning.

What is multimedia instruction?

Multimedia instruction is instruction that uses words and pictures.

What is a learning objective?

A learning objective is a description of the intended change in the learner's knowledge.

What Is a Learning Objective?
Five Kinds of Knowledge

Name	Definition	Example
Facts	Factual knowledge the world	Boston is in Massachusetts.
Concepts	Categories, schemas, models, principles	In the number 65, 6 refers to the number of tens.
Procedures	A step-by-step process	Multiplication of 252 x 12.
Strategies	A general method	Breaking a problem into parts.
Beliefs	Thoughts about learning	Thinking “I am not good at statistics.”

Two Ways to Measure Learning Outcomes

Type of test	Goal of test	Definition	Example
Retention	Remembering	Recall or recognize the presented material	Please write down all you remember about the device described in the lesson.
Transfer	Understanding	Evaluate or use the material in a new situation	How would improve the device you just learned about to make it more effective?

Three Kinds of Learning Outcomes

Learning outcome	Cognitive description	Retention test score	Transfer test score
No learning	No knowledge	Poor	Poor
Rote learning	Fragmented knowledge	Good	Poor
Meaningful learning	Integrated knowledge	Good	Good

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

Extraneous processing

Cognitive processing that does not support the objective of the lesson; caused by poor instructional design.

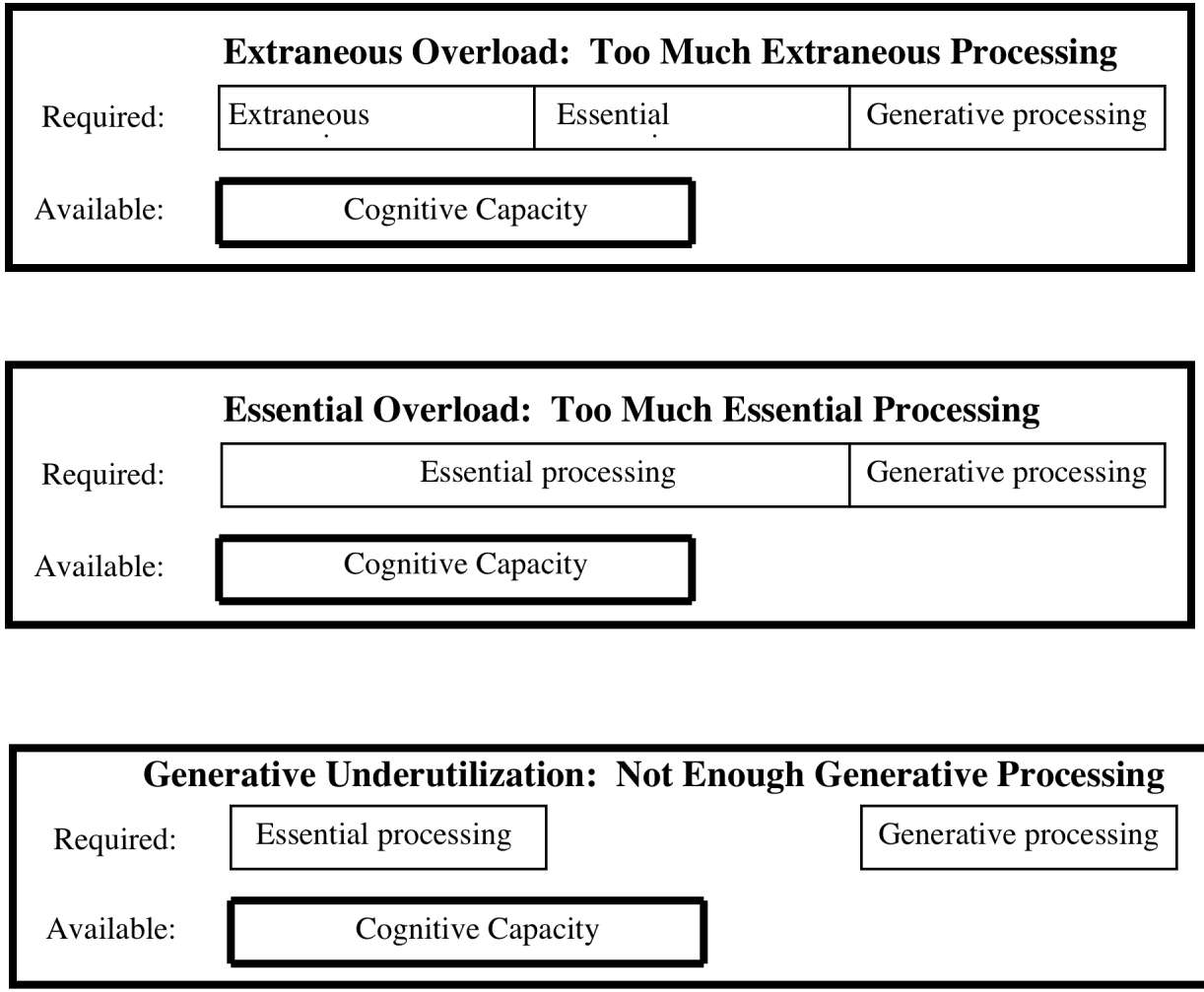
Essential processing

Basic cognitive processing required to mentally represent the presented material; caused by the inherent complexity of the material.

Generative processing

Deep cognitive processing required to make sense of the presented material; caused by learner's motivation to make an effort to learn.

Three Instructional Scenarios



Three Top-Level Goals for the Design of Multimedia Instruction

1. Reduce extraneous processing

2. Manage essential processing

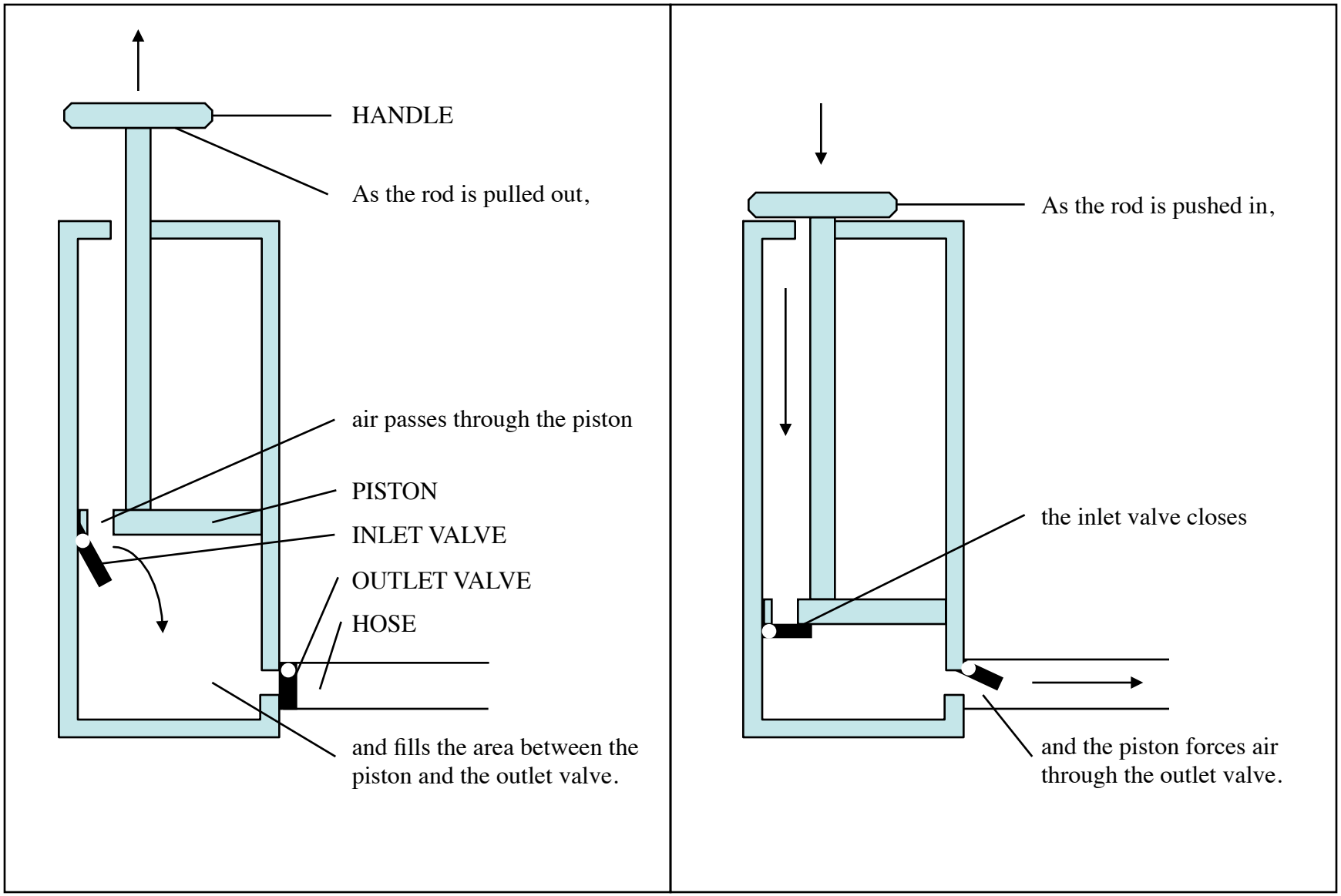
3. Foster generative processing

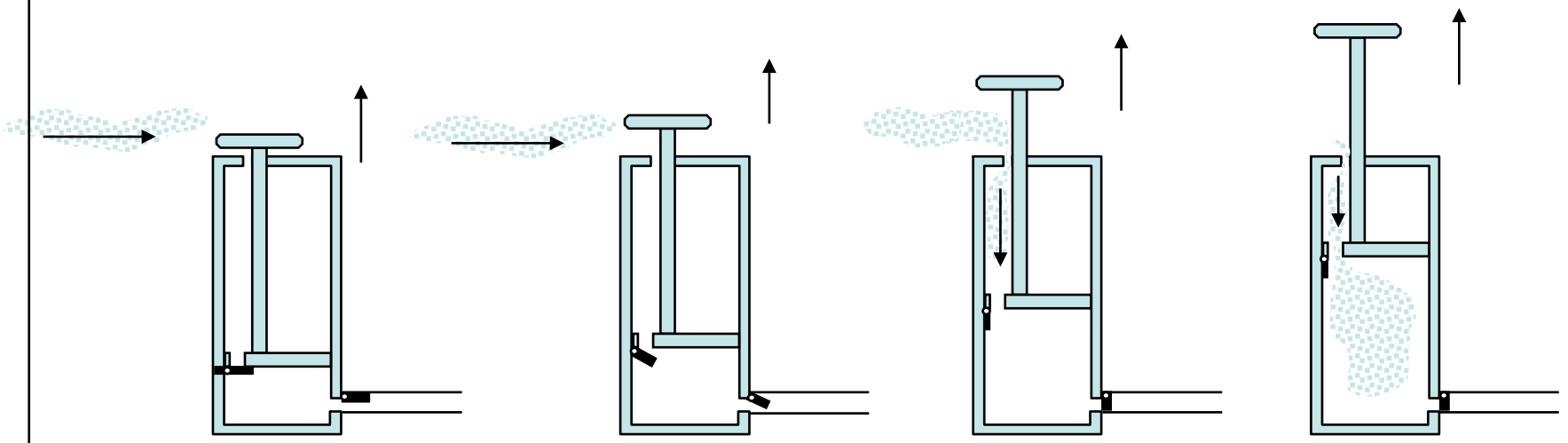
cognitive capacity	>=	extraneous processing	+	essential processing	+	generative processing

What is evidence-based instruction?
Evidence-based instruction refers to determining which instructional methods are effective for teaching which kinds of material to which kinds of learners.

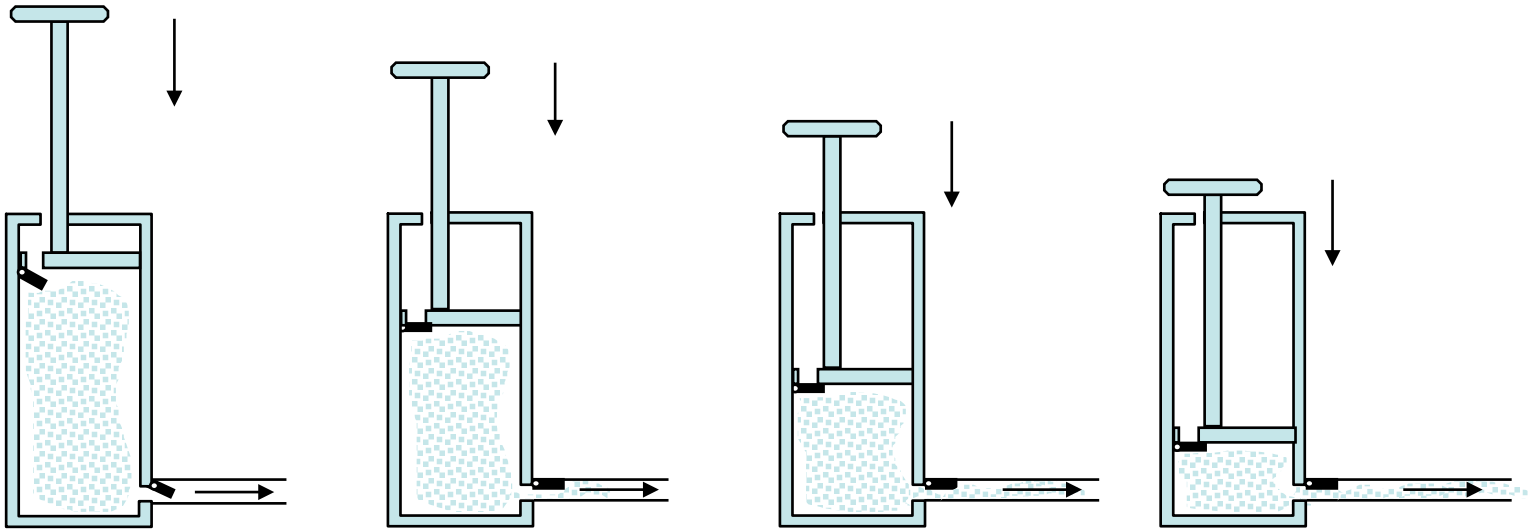
What is research on instructional methods?
Control group learns with standard training.
Treatment group learns with instructional technique added.
Both groups take a transfer test.

What is effect size?
Effect size = mean score of treatment group minus mean score of control group divided by pooled standard deviation.


HANDLE
As the rod is pulled out,
air passes through the piston
PISTON
INLET VALVE
OUTLET VALVE
HOSE
and fills the area between the piston and the outlet valve.
As the rod is pushed in,
the inlet valve closes
and the piston forces air through the outlet valve.



"When the handle is pulled up, the piston moves up, the inlet valve opens, the outlet valve closes, and air enters the lower part of the cylinder."



"When the handle is pushed down, the piston moves down, the inlet valve closes, the outlet valve opens, and air moves out through the hose."

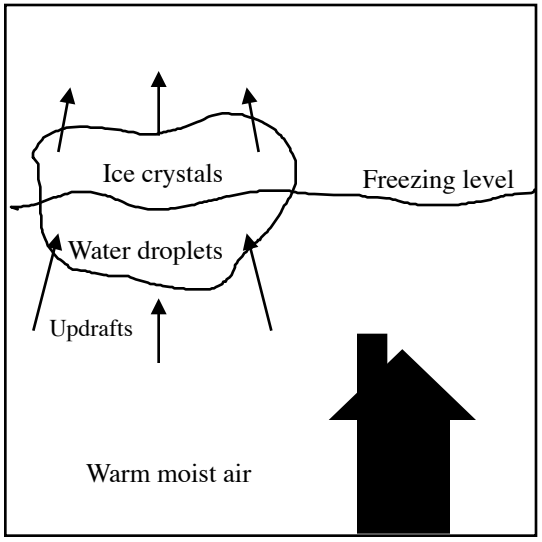
Retention and Transfer Questions for the Pump Lesson

Retention Test

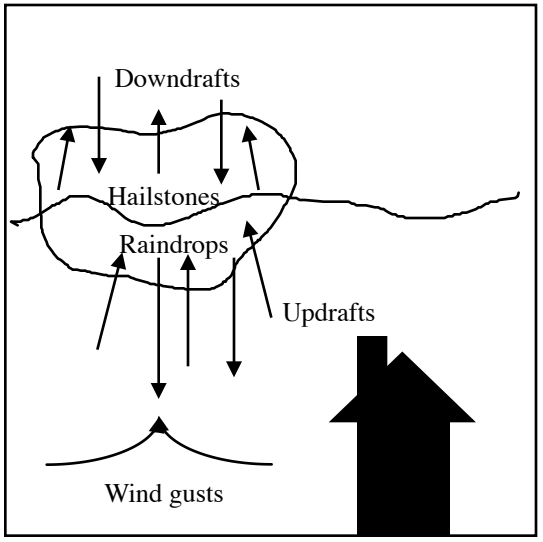
Please write down all you can remember about how a bicycle tire pump works.

Transfer Test

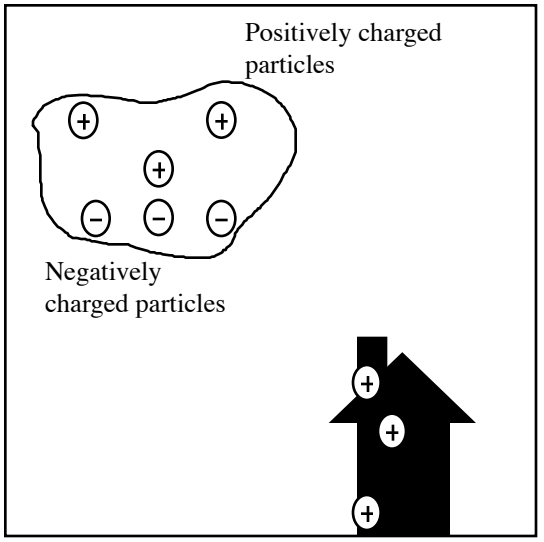
1. What could be done to make a pump more reliable--that is, to make sure it would not fail?
2. What could be done to make a pump more effective--that is, to make it move more air more rapidly?
3. Suppose you push down and pull up the handle of a pump several times but no air comes out. What could have gone wrong?
4. Why does air enter a pump? Why does air exit from a pump?



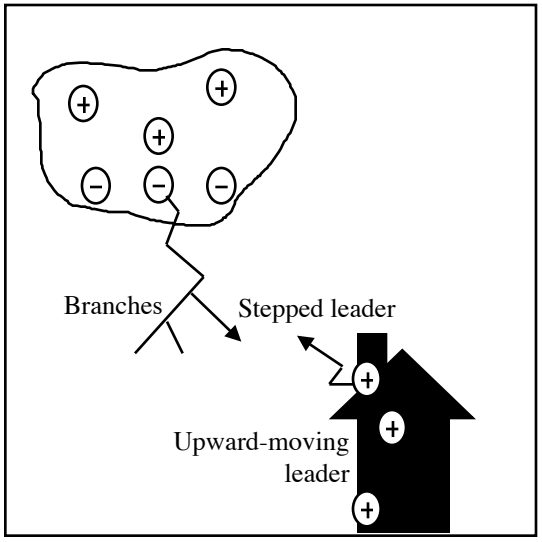
1. Warm moist air rises, water vapor condenses and forms a cloud.



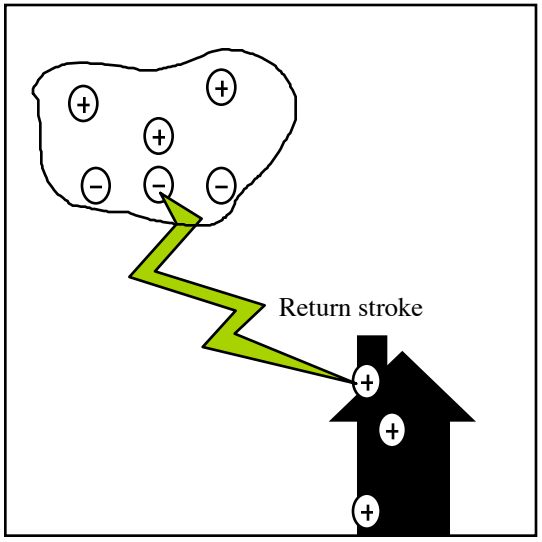
2. Raindrops and ice crystals drag air downward.



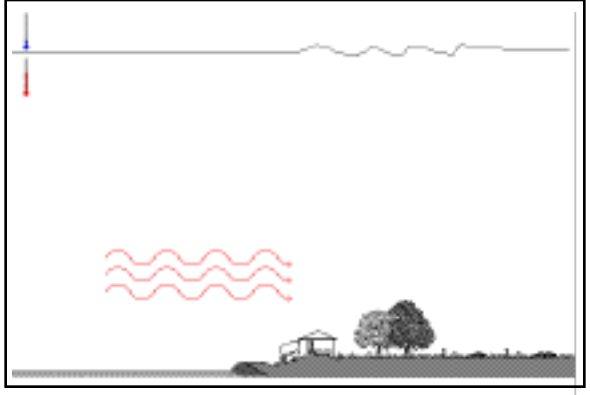
3. Negatively charged particles fall to the bottom of the cloud.



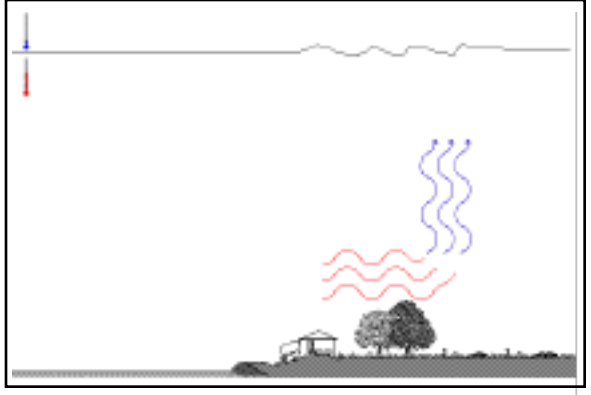
4. Two leaders meet, negatively charged particles rush from the cloud to the ground.



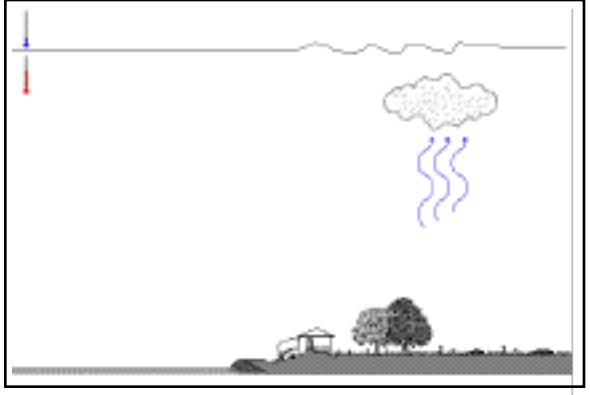
5. Positively charged particles from the ground rush upward along the same path.



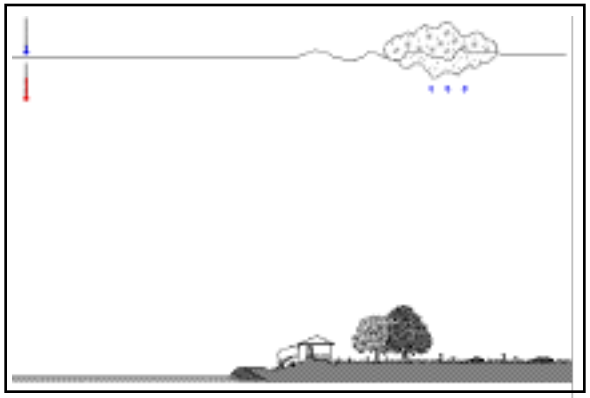
"Cool moist air moves over a warmer surface and becomes heated."



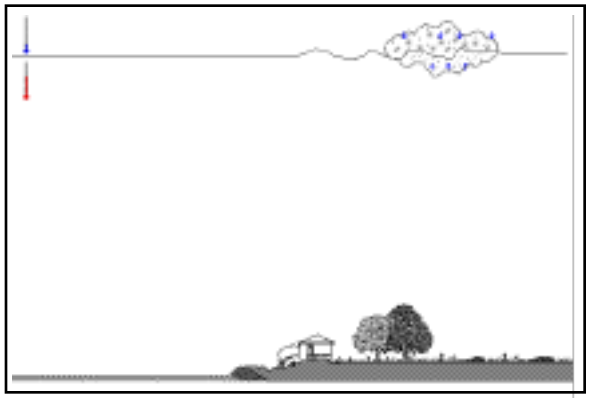
"Warmed moist air near the earth's surface rises rapidly."



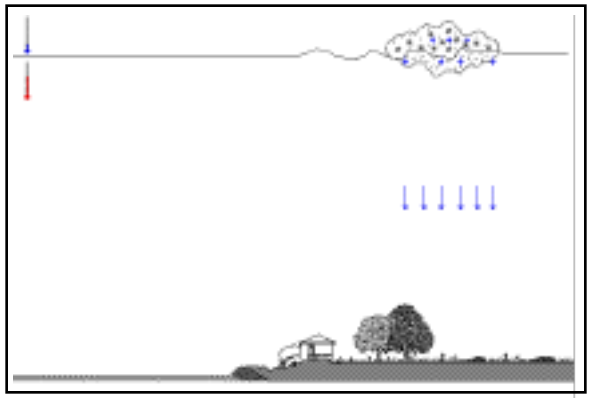
"As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud."



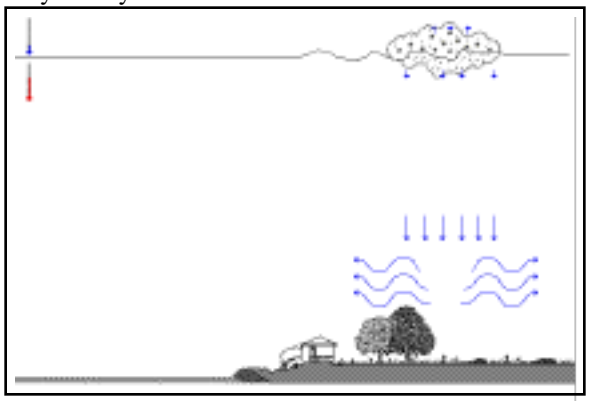
"The cloud's top extends above the freezing level, so the upper portion of the cloud is composed of tiny ice crystals."



"Eventually, the water droplets and ice crystals become too large to be suspended by the updrafts."



"As raindrops and ice crystals fall through the cloud, they drag some of the air in the cloud downward, producing downdrafts."



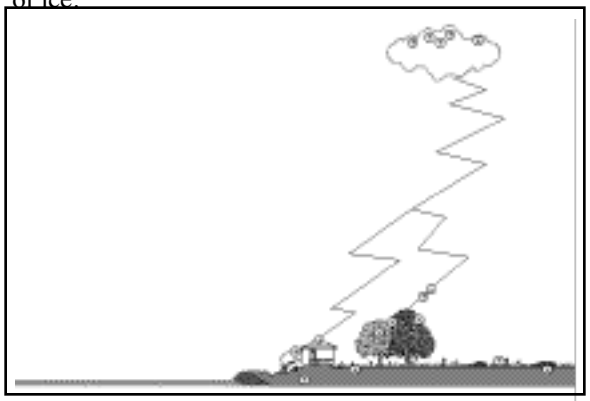
"When downdrafts strike the ground, they spread out in all directions, producing the gusts of cool wind people feel just before the start of the rain."

"Within the cloud, the rising and falling air currents cause electrical charges to build."

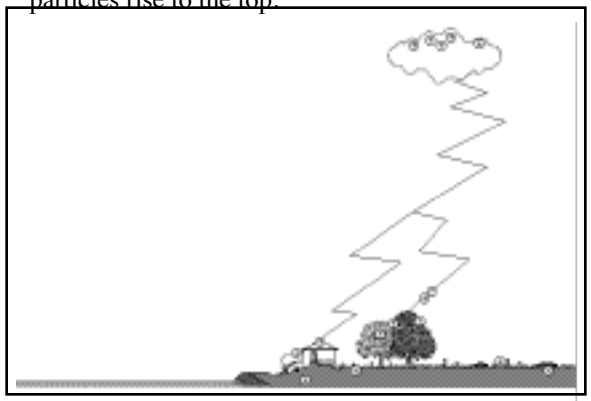
"The charge results from the collision of the cloud's rising water droplets against heavier, falling pieces of ice."

"The negatively charged particles fall to the bottom of the cloud, and most of the positively charged particles rise to the top."

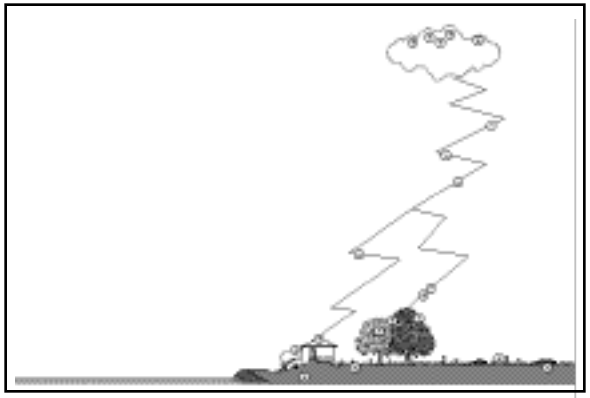
"A stepped leader of negative charges moves downward in a series of steps. It nears the ground."



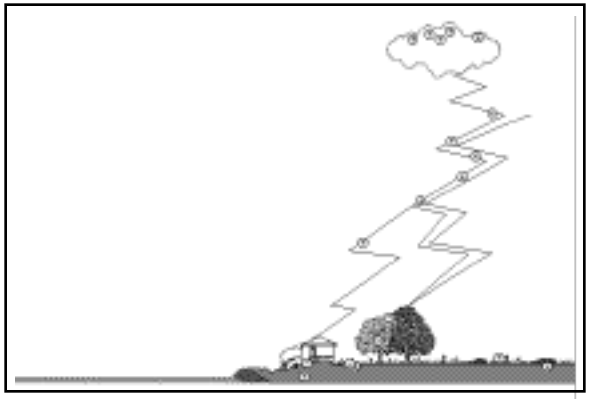
"A positively charged leader travels up from such objects as trees and buildings."



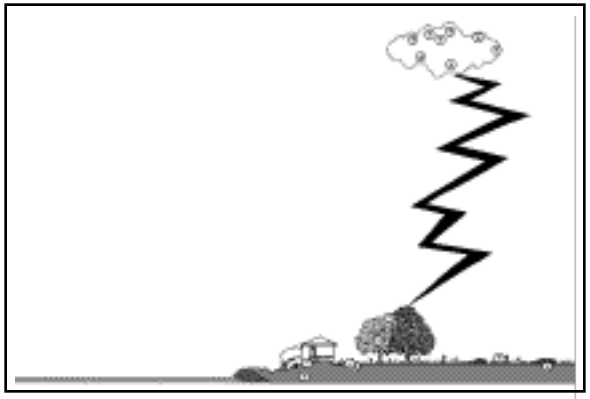
"The two leaders generally meet about 165-feet above the ground."



"Negatively charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright."



"As the leader stroke nears the ground, it induces an opposite charge, so positively charged particles from the ground rush upward along the same path."



"This upward motion of the current is the return stroke. It produces the bright light that people notice as a flash of lightning."

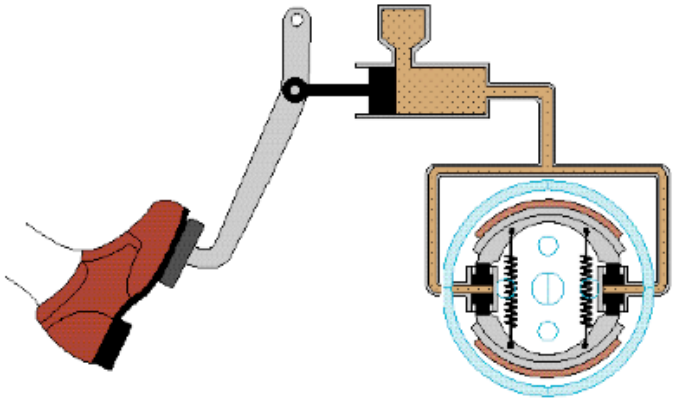
Retention and Transfer Questions for the Lightning Lesson

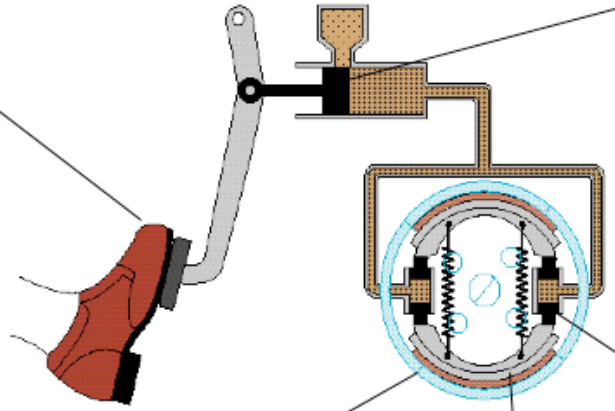
Retention Test

Please write down all you can remember about how lightning works.

Transfer Test

1. What could you do to reduce the intensity of lightning?
2. Suppose you see clouds in the sky but no lightning. Why not?
3. What does air temperature have to do with lightning?
4. What causes lightning?





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.

Retention and Transfer Questions for the Brakes Lesson

Retention Test

Please write down all you can remember about how a car's braking system works.

Transfer Test

1. Why do brakes get hot?
2. What could be done to make brakes more reliable--that is, to make sure they would not fail?
3. What could be done to make brakes more effective--that is, to reduce the distance needed bring a car to a stop?
4. Suppose you press on the brake pedal in your car but the brakes don't work. What could have gone wrong?
5. What happens when you pump the brakes (i.e., press the pedal and release the pedal repeatedly and rapidly)?

Rationale for Using Words and Pictures

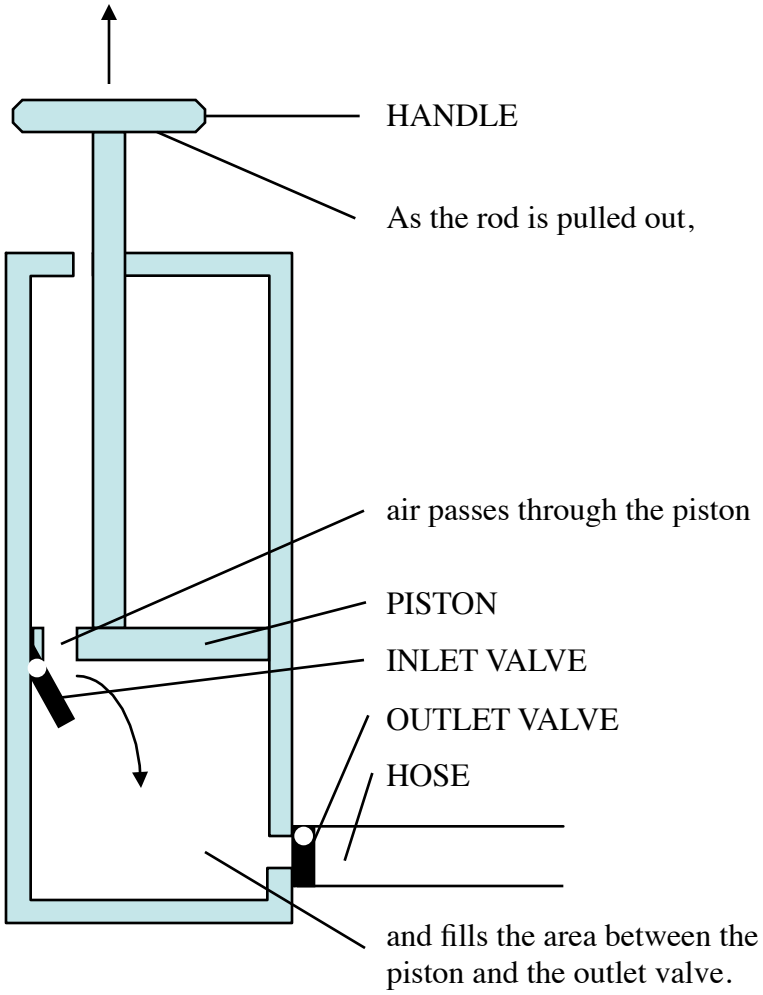
Multimedia principle: People learn better from words and pictures than from words alone.

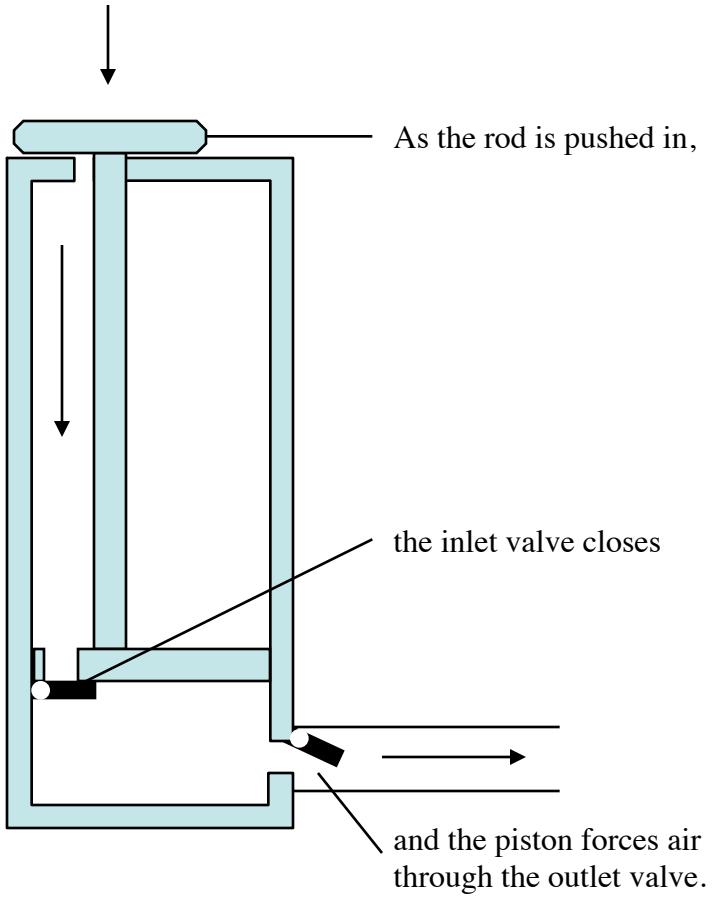
Text only:

Bicycle tire pumps vary in the number and location of the valves they have and in the way air enters the cylinder. Some simple tire pumps have the inlet valve on the piston and the outlet valve at the closed end of the cylinder. A bicycle tire pump has a piston that moves up and down. Air enters the pump near the point where the connecting rod passes through the cylinder. *As the rod is pulled out, air passes through the piston and fills the area between the piston and the outlet valve. As the rod is pushed in, the inlet valve closes and the piston forces air through the outlet valve.*

[italics added]

Text and illustrations:

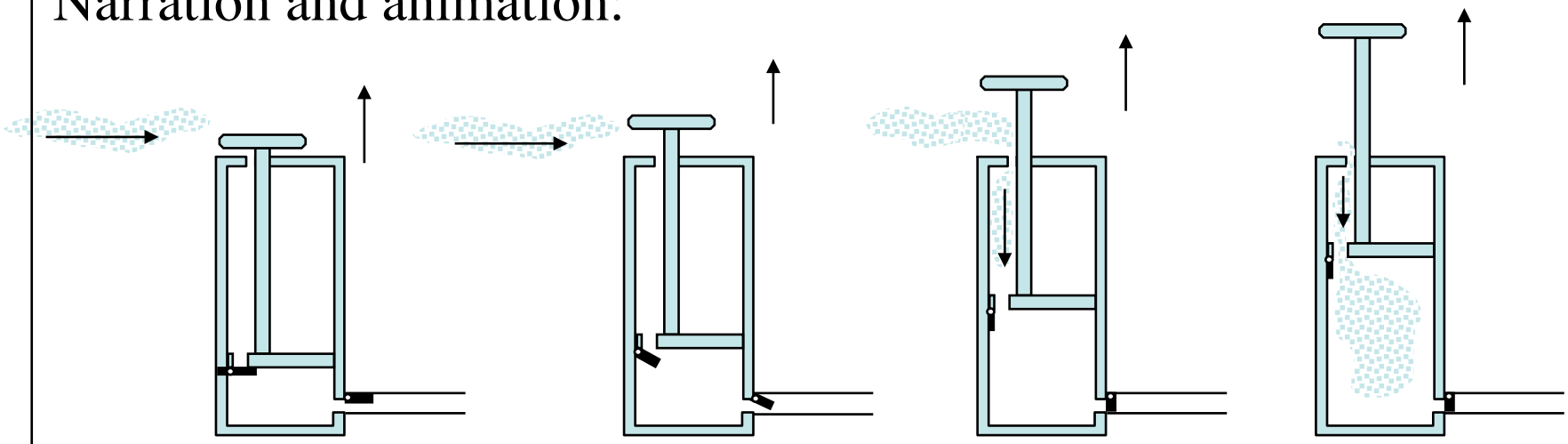




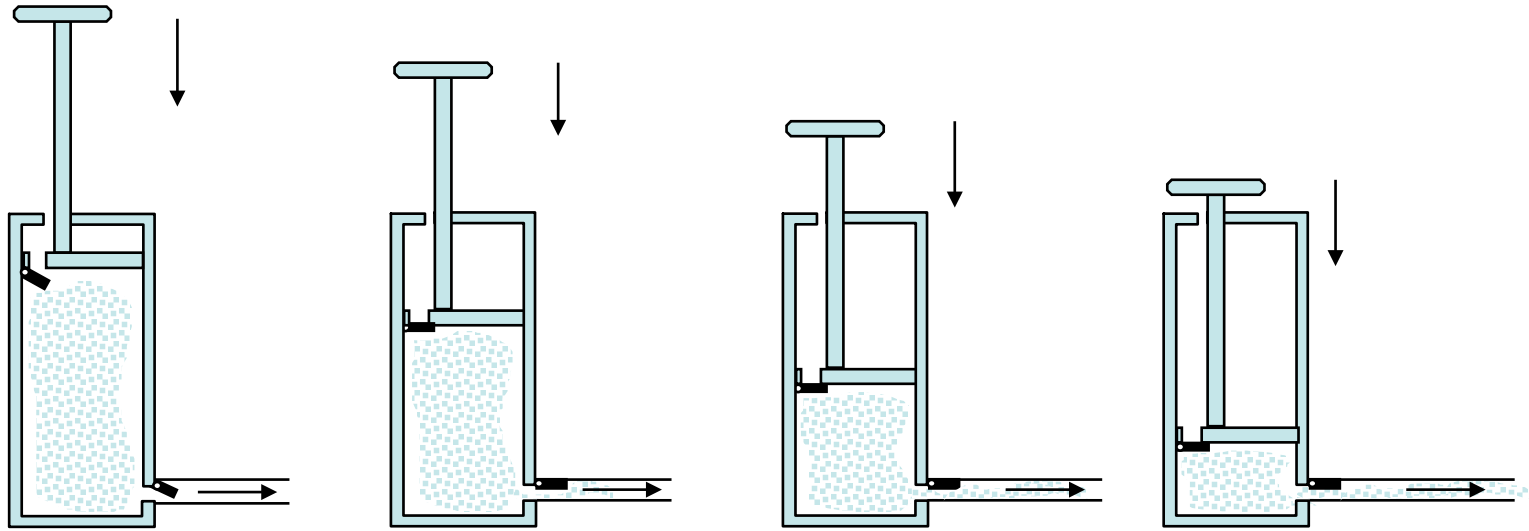
Narration only:

"When the handle is pulled up, the piston moves up, the inlet valve opens, the outlet valve closes and air enters the lower part of the cylinder. When the handle is pushed down, the piston moves down, the inlet valve closes, the outlet valve opens, and air moves out through the hose."

Narration and animation:



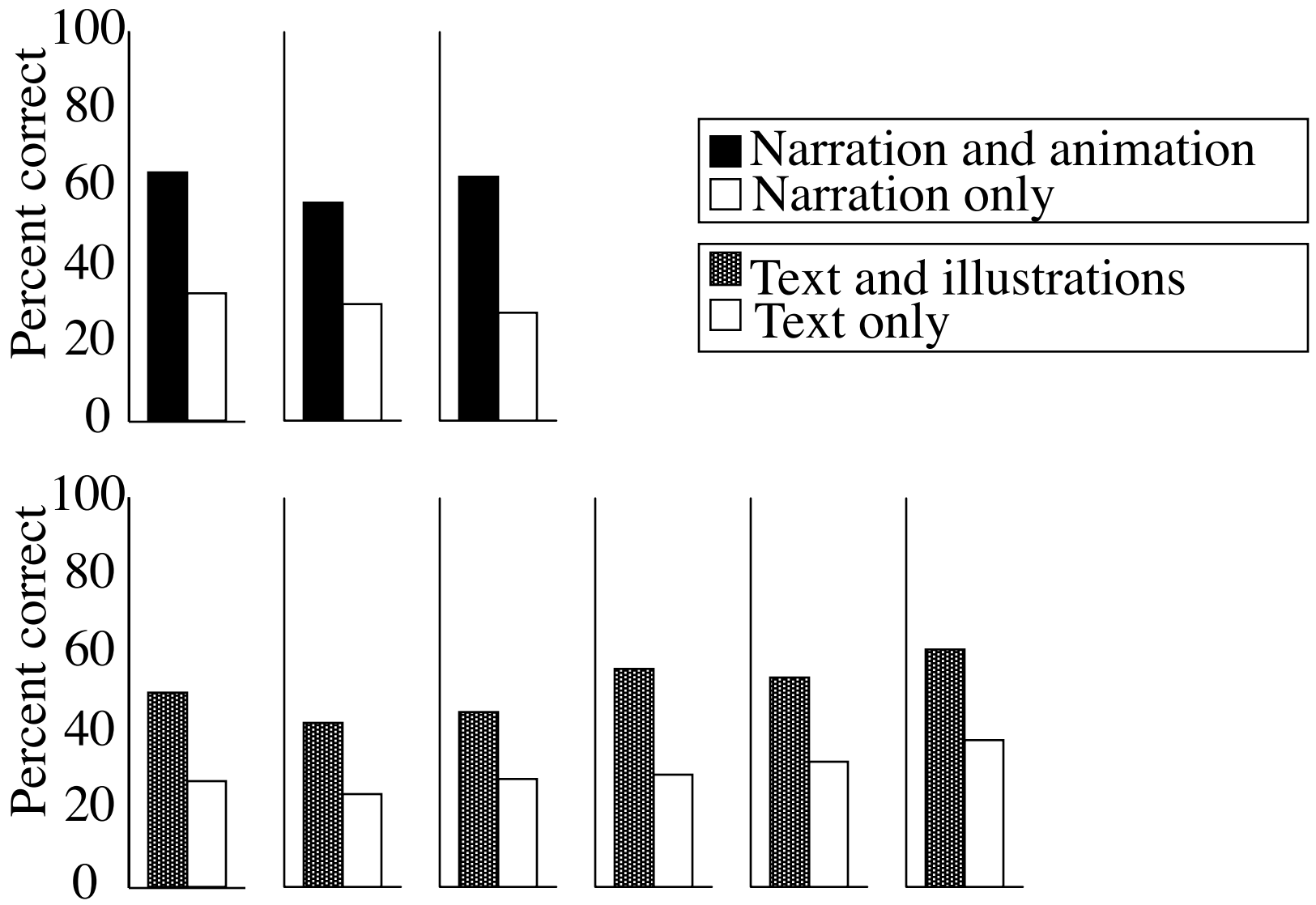
"When the handle is pulled up, the piston moves up, the inlet valve opens, the outlet valve closes, and air enters the lower part of the cylinder."



"When the handle is pushed down, the piston moves down, the inlet valve closes, the outlet valve opens, and air moves out through the hose."

Multimedia Principle

People learn better from words and pictures(dark bars) than from words alone (white bars).



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

Coherence Principle

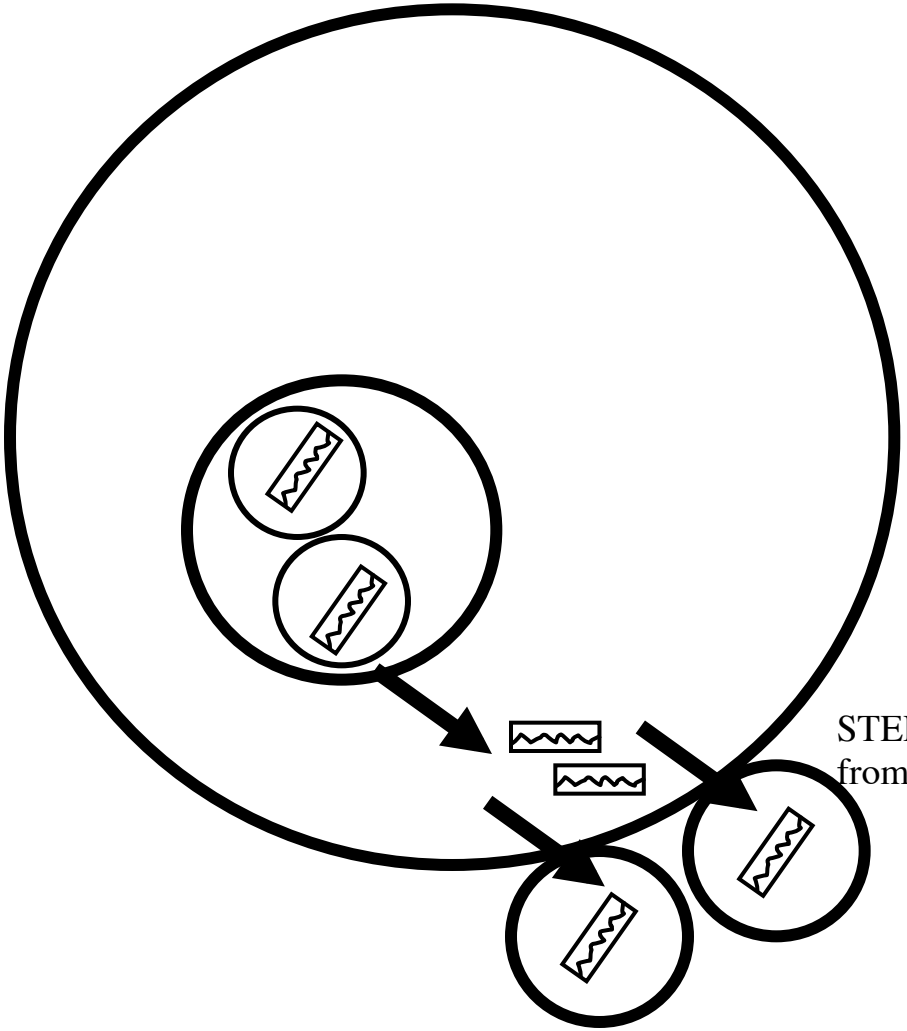
People learn more deeply when extraneous material is excluded rather than included.

Confirmed in: 22 of 23 tests

Median effect size: 0.86

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.

Tests of Coherence Principle

Source	Content	Effect size
Mayer, Bove et al. (1996, Expt. 1)	lightning	-0.17
Mayer, Bove et al. (1996, Expt. 2)	lightning	0.70
Mayer, Bove et al. (1996. Expt. 3)	lightning	0.98
Harp & Mayer (1997, Expt. 1)	lightning	1.33
Harp & Mayer (1998, Expt. 1)	lightning	1.68
Harp & Mayer (1998, Expt. 2)	lightning	1.45
Harp & Mayer (1998, Expt. 3)	lightning	1.27
Harp & Mayer (1998, Expt. 4)	lightning	1.58
Moreno & Mayer (2000, Expt. 1)	lightning	1.49
Moreno & Mayer (2000, Expt. 2)	brakes	0.51
Mayer, Heiser et al. (2001, Expt. 3)	lightning	0.70
Mayer & Jackson (2005, Exp. 1a)	ocean waves	0.94
Mayer & Jackson (2005, Exp. 1b)	ocean waves	0.97
Mayer & Jackson (2005, Exp. 2)	ocean waves	0.69
Mayer, et al. (2007, Exp. 1)	brakes	0.53
Mayer, et al. (2007, Exp. 2)	brakes	0.17

Tests of Coherence Principle (Continued)

Source	Content	Effect size
Sanchez & Wiley (2006)	ice age	0.97
Lehman et al. (2007)	lightning	0.78
Mayer et al. (2008; Exp. 1)	cold virus	0.80
Mayer et al. (2008; Exp. 2)	digestion	0.86
Doolittle & Alstraedter (2009)	lightning	0.06
Park et al. (2011)	biology	0.34
Sung & Mayer (2012)	distance education	1.10
MEDIAN		0.86

Signaling Principle

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

Confirmed in: 24 of 28 tests

Median effect size: 0.41

Examples of Signaled Steps in Lift Lesson

Wing Shape: Curved Upper Surface is Longer

… surface on **top** of the wing is **longer** than on the **bottom**…

Air Flow: Air Moves Faster Across Top of Wing

…air traveling over the curved **top** of the wing **flows faster** than air that flows under the **bottom** of the wing…

Air Pressure: Pressure on the Top is Less

… the **top** surface of the wing now has **less pressure** exerted against it than the **bottom** surface of the wing…

Tests of Signaling Principle

Source	Content	Effect size
Jeung, Chandler, & Sweller (1997, Exp.1a)	geometry	0.63
Jeung, Chandler, & Sweller (1997, Exp.1b)	geometry	-0.14
Jeung, Chandler, & Sweller (1997, Exp.2)	geometry	0.08
Jeung, Chandler, & Sweller (1997, Exp.3)	geometry	0.13
Harp & Mayer (1998, Exp. 3a)	lightning	0.34
Mautone & Mayer (2001, Exp. 3a)	airplane	0.60
Mautone & Mayer (2001, Exp. 3b)	airplane	0.70
Stull & Mayer (2007, Exp. 1)	biology	-0.03
Stull & Mayer (2007, Exp. 2)	biology	0.58
Stull & Mayer (2007, Exp. 3)	biology	0.45
Naumann et al. (2007, Exp. 1, low skill)	perception	0.42
Naumann et al. (2007, Exp. 2, low skill)	perception	0.65
Mautone & Mayer (2007)	geography	0.50
de Koning et al. (2007)	heart	0.81
Kriz & Hegarty (2007)	mechanical system	0.24
Moreno (2007, Exp. 1)	teaching skills	0.27
Moreno (2007, Exp. 2)	teaching skills	0.32

Tests of Signaling Principle (Continued)

Source	Content	Effect size
Jamet et al. (2008)	language production	-0.07
Doolittle & Alstraedter (2009)	brakes	0.04
Boucheix & Lowe (2010, Exp. 1a)	piano	0.75
Boucheix & Lowe (2010, Exp. 1b)	piano	-0.03
de Koning et al. (2010)	heart	0.37
Ozcelik et al. (2010)	jet engine	0.74
Rey (2010)	neural networks	0.41
Scheiter & Eitel (2010)	heart	0.85
Amadieu et al. (2011)	biology	0.63
Boucheix (2013)	piano	0.80
Jarodzka et al. (2013)	fish locomotion	0.35
MEDIAN		0.41

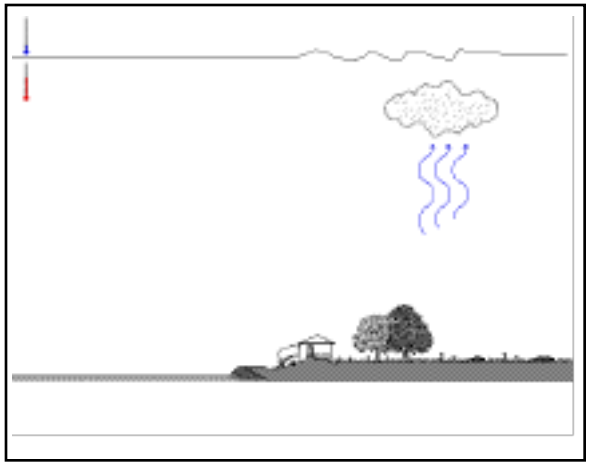
Redundancy Principle

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

Confirmed in: 16 of 16 tests

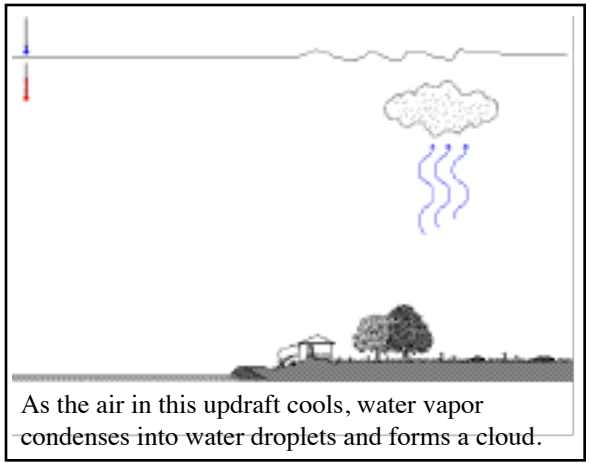
Median effect size: 0.86

Animation and Narration



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

Animation, Narration, and On-Screen Text



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

Tests of Redundancy Principle

Source	Content	Effect size
Mousavi, Low, & Sweller (1995, Exp. 1)	math problems	0.65
Mousavi, Low, & Sweller (1995, Exp. 2)	math problems	0.49
Kalyuga, Chandler, & Sweller (1999, Exp. 1)	engineering	1.38
Kaluga, Chandler, & Sweller (2000, Exp. 1)	engineering	0.86
Craig, Gholson, & Driscoll (2002, Exp. 2)	lightning	0.67
Mayer, Heiser, & Lonn (2001, Exp. 1)	lightning	0.88
Mayer, Heiser, & Lonn (2001, Exp. 2)	lightning	1.21
Moreno & Mayer (2002b, Exp. 2)	lightning	0.72
Moreno & Mayer (2002a, Exp. 2a)	botany game	0.19
Moreno & Mayer (2002a, Exp. 2b)	botany game	0.25
Leahy, Chandler, & Sweller (2003)	temperature graphs	1.13
Jamet & Le Bohec (2007)	human memory	0.67
Austin (2009, Exp. 1)	lightning	0.87
Austin (2009, Exp. 2)	lightning	1.15
Austin (2009, Exp. 3)	lightning	1.80
Austin (2009, Exp. 4)	lightning	1.91
MEDIAN		0.86

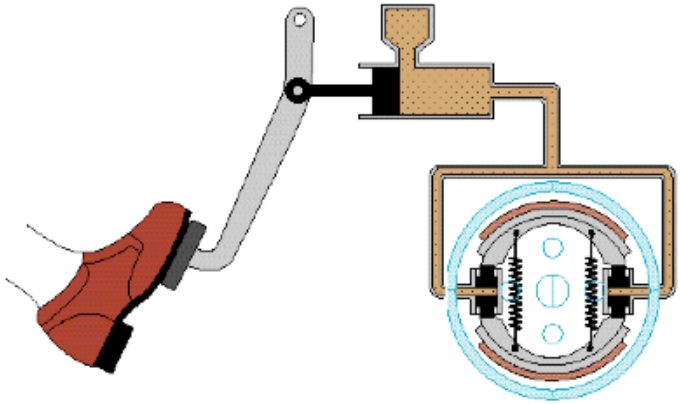
Spatial Contiguity Principle

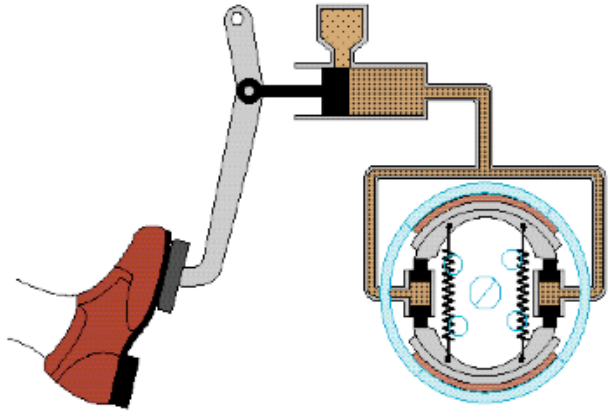
People learn more deeply when corresponding printed words and graphics are placed near rather than far from each other on the page or screen.

Confirmed in: 22 of 22 tests

Median effect size: 1.10

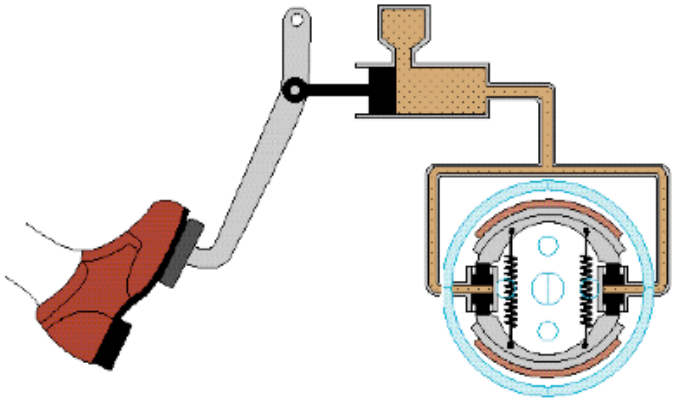
Separated Presentation

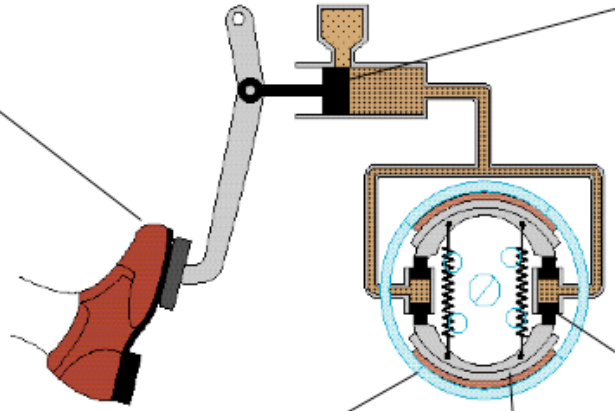




When the driver steps on the car's brake pedal, a piston moves forward inside the master cylinder. The piston forces brake fluid out of the master cylinder and through the tubes to the wheel cylinders. In the wheel cylinders, the increase in fluid pressure makes a smaller set of pistons move outward.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

Integrated Presentation





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.

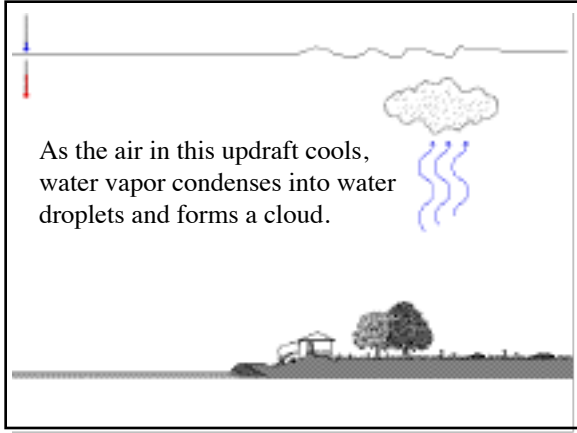
5. These smaller pistons activate the brake shoes.

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

Separated Presentation

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

Integrated Presentation



Tests of Spatial Contiguity Principle

Source	Content	Effect size
Mayer (1989, Exp. 2)	brakes	1.36
Sweller, et al. (1990, Exp 1)	mathematics problems	0.71
Chandler & Sweller (1991, Exp. 1)	engineering	0.41
Chandler & Sweller (1991, Exp. 6)	heart	0.60
Chandler & Sweller (1992, Exp. 1)	engineering	1.19
Mayer et al. (1995, Exp. 1)	lightning	1.09
Mayer et al. (1995, Exp. 2, low PK)	lightning	1.35
Mayer et al. (1995, Exp. 3)	lightning	1.12
Tinsdall-Ford, et al. (1997)	electrical engineering	1.08
Moreno & Mayer (1999)	lightning	0.82
Bodemer et al. (2004, Exp.1)	tire pump	0.56
Bodemer et al. (2004, Exp. 2)	statistics	0.22
Kester et al. (2005)	electrical circuits	0.78
Chung (2007, Exp. 1)	Chinese vocabulary	2.06
Chung (2007, Exp. 2)	Chinese vocabulary	1.56
Pociask & Morrison (2008)	medical procedures	1.26
Owens & Sweller (2008)	musical notation	0.62

Tests of Spatial Contiguity Principle (Continued)

Source	Content	Effect size
Austin (2009)	lightning	1.39
Cierniak et al. (2009)	kidney	1.11
Johnson & Mayer (2012, Exp. 1)	brakes	0.80
Johnson & Mayer (2012, Exp. 2)	brakes	0.73
Johnson & Mayer (2012, Exp. 3)	brakes	0.35
MEDIAN		1.10

Temporal Contiguity Principle

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

.

Confirmed in: 9 of 9 tests

Median effect size: 1.22

Tests of Temporal Contiguity Principle

Source	Content	Effect size
Mayer & Anderson (1991, Expt. 1)	pump	0.92
Mayer & Anderson (1991, Expt. 2a)	pump	1.14
Mayer & Anderson (1992, Expt. 1)	pump	1.66
Mayer & Anderson (1992, Expt. 2)	brakes	1.39
Mayer & Sims (1994, Expt. 1)	pump	0.91
Mayer & Sims (1994, Expt. 2)	lungs	1.22
Mayer, Moreno et al. (1999, Expt. 1)	lightning	2.22
Mayer, Moreno et al. (1999, Expt. 2)	brakes	1.40
Owens & Sweller (2008)	musical notation	0.86
MEDIAN		1.22

Five Evidence-Based and Theoretically-Grounded Principles for Reducing Extraneous Processing

Principle	Definition	Effect size	Number of tests
Coherence	Reduce extraneous material.	0.86	22 of 23
Signaling	Highlight essential material.	0.41	24 of 28
Redundancy	Do not add on-screen text to narrated animation.	0.86	16 of 16
Spatial contiguity	Place printed words next to corresponding graphics.	1.10	22 of 22
Temporal contiguity	Present corresponding narration and animation at the same time.	1.22	9 of 9

Manage Essential Processing

Problem: Essential Processing + Generative Processing Exceeds Cognitive Capacity

Solution: Manage Essential Processing

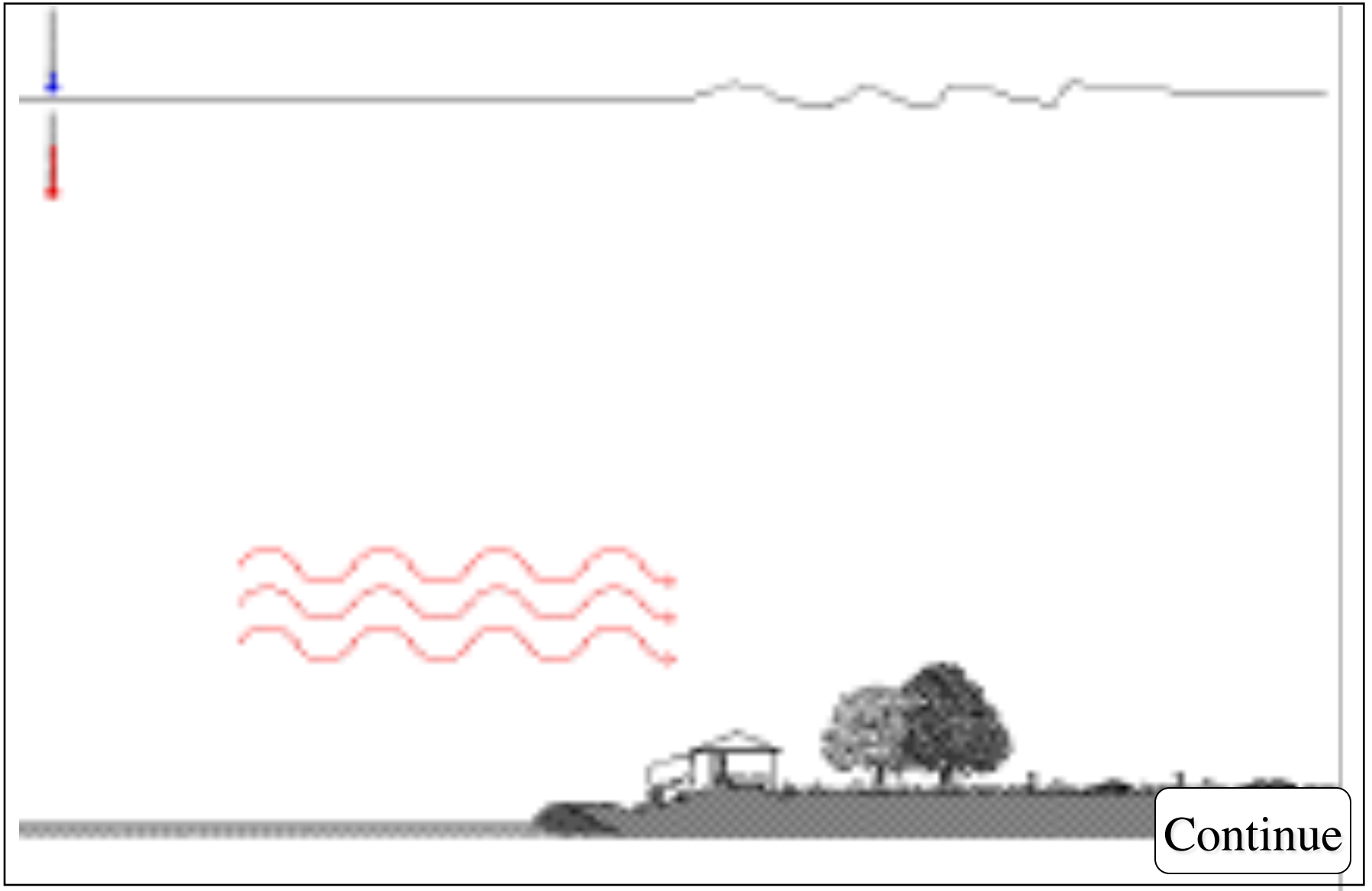
1. Segmenting principle
2. Pre-training principle
3. Modality principle

Segmenting Principle

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

Confirmed in: 10 of 10 tests

Median effect size: 0.77



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

Tests of Segmenting Principle

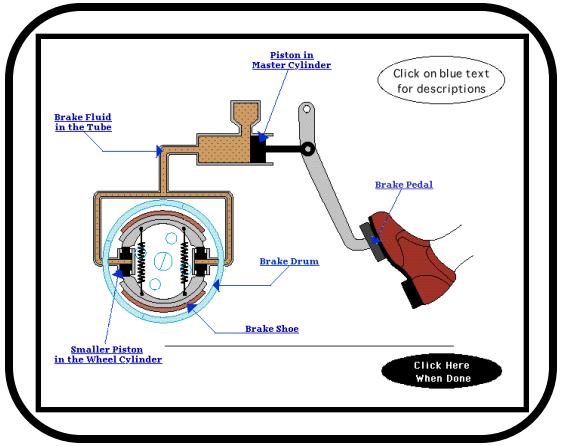
Source	Content	Effect size
Mayer & Chandler (2001, Expt. 2)	lightning	1.13
Mayer, Dow et al. (2003, Expt. 2a)	electric motor	0.82
Mayer, Dow et al. (2003, Expt. 2b)	electric motor	0.98
Moreno (2007, Exp. 1)	teaching skills	0.54
Moreno (2007, Exp. 2)	teaching skills	0.77
Hasler, Kersten, & Sweller (2007)	astronomy	0.81
Lusk (2009, low WM capacity)	history	0.77
Boucheix & Schneider (2009)	pulley system	0.31
Stiller et al (2009)	human eye	0.18
Hassanabadi (2011)	lightning	0.17
MEDIAN		0.77

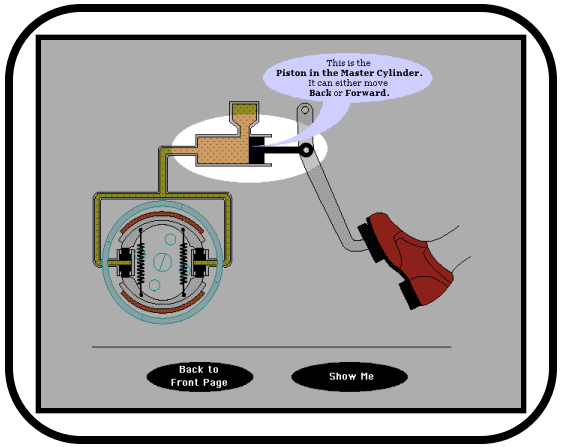
Pre-training Principle

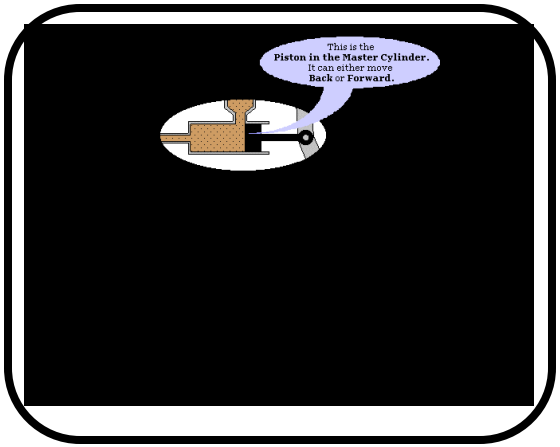
People learn more deeply from a narrated animation when they have had training in the names and characteristics of the main concepts.

Confirmed in: 13 of 16 tests

Median effect size: 0.75


Piston in Master Cylinder
Click on blue text for descriptions
Brake Fluid in the Tube
Brake Pedal
Brake Drum
Brake Shoe
Smaller Piston in the Wheel Cylinder
Click Here When Done


This is the Piston in the Master Cylinder. It can either move Back or Forward.
Back to Front Page
Show Me


This is the Piston in the Master Cylinder. It can either move Back or Forward.

Tests of Pre-training Principle

Source	Content	Effect size
Pollock et al. (2002, Expt. 1, LK)	engineering	1.22
Pollock et al. (2002, Expt. 2, HK)	engineering	0.11
Pollock et al. (2002, Expt. 3, LK)	engineering	1.15
Pollock, et al. (2002, Expt. 4, HK)	engineering	-0.68
Mayer, Mathias et al. (2002, Expt. 1)	brakes	0.79
Mayer, Mathias et al. (2002, Expt. 2)	brakes	0.92
Mayer, Mathias et al. (2002, Expt. 3)	pump	1.00
Mayer, Mautone et al. (2002, Expt. 2)	geology game	0.57
Mayer, Mautone et al. (2002, Expt. 3)	geology game	0.85
Clarke, Ayres, et al. (2005, Exp. 1a)	mathematics	1.87
Clarke, Ayres, et al. (2005, Exp. 1b)	mathematics	-0.38
Kester, Kirshner, et al.(2004a)	statistics problems	-0.01
Kester, Kirshner, et al. (2004b)	electrical circuits	0.06
Kester, Kirshner, et al. (2006)	electrical circuits	0.72
Kester et al. (2006)	neural networks	0.05
Eitel, Scheiter, & Schuler (in press)	pulley systems	1.37
Median		0.75

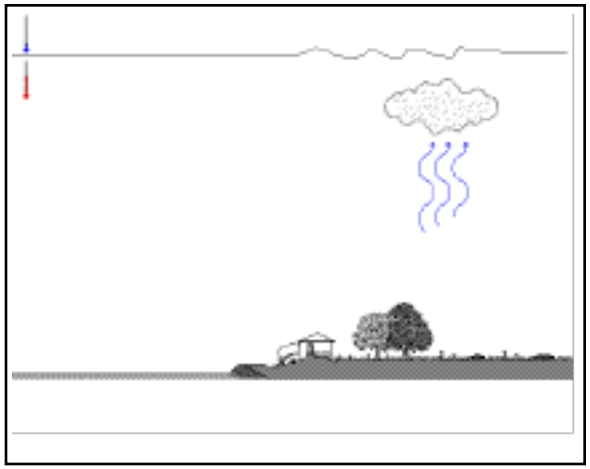
Modality Principle

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

Confirmed in: 52 of 61 tests

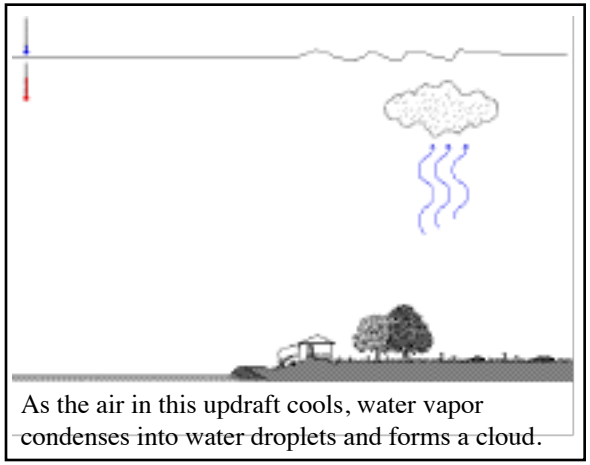
Median effect size: 0.76

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



Tests of Modality Principle

Source	Content	Effect size
FOUNDATIONAL STUDIES		
Mousavi, Low, & Sweller (1995, Exp. 1)	geometry	0.93
Mousavi, Low, & Sweller (1995, Exp. 2)	geometry	0.88
Mousavi, Low, & Sweller (1995, Exp. 3)	geometry	0.65
Mousavi, Low, & Sweller (1995, Exp. 4)	geometry	0.68
Mousavi, Low, & Sweller (1995, Exp. 5)	geometry	0.63
Tindall-Ford, et al. (1997, Exp. 1)	electronics	1.68
Tindall-Ford, et al. (1997, Exp. 1)	electronics	1.07
Tindall-Ford, et al. (1997, Exp. 1)	electronics	0.23
Jeung, Chandler, & Sweller (1997, Exp. 1)	math	0.87
Jeung, Chandler, & Sweller (1997, Exp. 2)	math	0.33
Jeung, Chandler, & Sweller (1997, Exp. 3)	math	1.01
Mayer & Moreno (1998, Exp. 1)	lightning	1.49
Mayer & Moreno (1998, Exp. 2)	brakes	0.78
Kalyuga, Chandler, et al. (1999, Exp. 1)	engineering	0.85
Moreno & Mayer (1999b, Exp. 1)	lightning	1.02
Moreno & Mayer (1999b, Exp. 2)	lightning	1.09

Tests of Modality Principle (Continued)

Source	Content	Effect size
Kalyuga, et al. (2000, Exp. 1, LK)	engineering	0.79
O'Neil et al. (2000, Exp. 1)	aircraft simulation	1.00
Moreno et al. (2001, Exp. 4a)	botany game	0.60
Moreno et al., (2001, Exp. 4b)	botany game	1.58
Moreno et al. (2001, Exp. 5a)	botany game	1.41
Moreno et al. (2001, Exp. 5b)	botany game	1.71
Craig, Gholson et al. (2002, Exp. 2)	lightning	0.97
Atkinson (2002, Exp. 1a)	math problems	0.89
Atkinson (2002, Exp. 1b)	math problems	0.72
Atkinson (2002, Exp. 2)	math problems	0.69
Moreno & Mayer (2002, Exp. 1a)	botany game	0.93
Moreno & Mayer (2002, Exp. 1b)	botany game	0.62
Moreno & Mayer (2002, Exp. 1c)	botany game	2.79
Moreno & Mayer (2002, Exp. 2a)	botany game	0.74
Moreno & Mayer (2002, Exp. 2b)	botany game	2.24
Mayer, Dow, & Mayer (2003, Exp. 1)	electric motor	0.79
Leahy, Chandler, et al. (2003, Exp. 1)	graph reading	0.76

Tests of Modality Principle (Continued)

Source	Content	Effect size
STUDIES TESTING BOUNDARY CONDITIONS		
Tabbers, Martens, & et al. (2004)	instructional design	-0.47
Harskamp et al. (2007, Exp. 1)	biology	0.86
Harskamp et al. (2007, Exp. 2a)	biology	1.02
Owens & Sweller (2008)	music theory	0.73
Woulters, Paas, et al. (2009)	probability	0.52
Witteman & Segers (2010)	lightning (immediate)	0.30
Witteman & Segers (2010)	lightning (delayed)	-0.09
Schmidt-Weigand, at al. (2010a, Exp. 1a)	lightning	0.60
Schmidt-Weigand, at al. (2010a, Exp. 1b)	lightning	0.57
Schmidt-Weigand, at al. (2010a, Exp. 1c)	lightning	-0.10
Schmidt-Weigand, at al. (2010a, Exp. 2)	lightning	0.15
Schmidt-Weigand, at al. (2010b, Exp. 1a)	lightning	1.99

Tests of Modality Principle (Continued)

Source	Content	Effect size
Park, Moreno, et al. (2011)	biology	0.54
Mayrath, et al. (2011, Exp. 1)	networking	-0.52
Mayrath, et al. (2011, Exp. 2)	networking	0.17
Lindow et al. (2011, Exp. 2)	lightning	-0.26
Kuhl, Scheiter, Gerjets et al. (2011)	fish locomotion	1.57
Kuhl, Scheiter, Gerjets et al. (2011)	fish locomotion	2.69
Leahy & Sweller (2011)	graphs (short)	0.56
Leahy & Sweller (2011)	graphs (long)	-1.03
Wong et al. (2012)	graphs (short)	0.66
Wong et al. (2012)	graphs (long)	-1.01
Crooks et al. (2012)	human speech	-0.45
Schuler, Scheiter, et al. (2012)	tornados	-1.61
Schuler, et al. (2013, Exp. 1)	biology	0.09
Schuler, et al. (2013, Exp. 2)	biology	0.29
Cheon, Crooks & Chung (2013)	lightning (with pauses)	0.08
MEDIAN		0.76

Three Evidence-Based and Theoretically-Grounded Principles for Managing Essential Processing

Principle	Definition	Effect size	Number of tests
Segmenting	Present animation in learner-paced segments.	0.77	10 of 10
Pretraining	Provide pretraining in the name, location, and characteristics of key components.	0.75	13 of 16
Modality	Present words as spoken text rather than printed text.	0.76	52 of 61

Foster Generative Processing

Problem: Insufficient Generative Processing Although Cognitive Capacity is Available

Solution: Foster Generative Processing

1. Personalization principle
2. Voice principle

Personalization Principle

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

Confirmed in: 14 of 17 tests

Median effect size: 0.79

Examples of Personalized and Non-Personalized Speech

Non-Personalized

"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…"

Personalized

"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…"

Tests of Personalization Principle

Source	Content	Effect size
Moreno & Mayer (2000, Expt. 1)	lightning	1.05
Moreno & Mayer (2000, Expt. 2)	lightning	1.61
Moreno & Mayer (2000, Expt. 3)	botany game	1.92
Moreno & Mayer (2000, Expt. 4)	botany game	1.49
Moreno & Mayer (2000, Expt. 5)	botany game	1.11
Moreno & Mayer (2004, Expt. 1a)	botany game	1.58
Moreno & Mayer (2000, Expt. 1b)	botany game	1.93
Mayer, Fennell et al. (2004, Expt. 1)	lungs	0.52
Mayer, Fennell et al. (2004, Expt. 1)	lungs	1.00
Mayer, Fennell et al. (2004, Expt. 1)	lungs	0.79
McLaren et al. (2007)	chemistry	-0.15
Wang et al. (2008)	engineering	0.71
Kartal (2010)	astronomy	0.71
McLaren et al. (2011a, low experience)	chemistry	0.51
McLaren et al. (2011a, high experience)	chemistry	-0.01
McLaren et al. (2011b, low experience)	chemistry	0.64
McLaren et al. (2011b, high experience)	chemistry	-0.30
MEDIAN		0.79

Voice Principle

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

Confirmed in: 5 of 6 tests

Median effect size: 0.74

Tests of Voice Principle

Source	Content	Effect size
Mayer, Sobko et al. (2003, Expt 1)	lightning	0.90
Mayer, Sobko et al. (2003, Expt. 2)	lightning	0.79
Atkinson, Mayer et al. (2004, Expt 1)	math problems	0.69
Atkinson, Mayer et al. (2004, Expt. 2)	math problems	0.78
Mayer & DaPra (2012, Expt. 2a)	solar cell	0.63
Mayer & DaPra (2012, Expt. 2b)	solar cell	-0.16
MEDIAN		0.74

Two Evidence-Based and Theoretically-Grounded Principles for Fostering Generative Processing

Principle	Definition	Effect size	Number of tests
Personalization	Present words in conversational style rather than formal style.	0.79	14 of 17
Voice	Present words with human voice rather than machine voice.	0.74	5 of 6

Summary of Research Evidence

Principle	Median Effect Size	Tests
Coherence	0.86	22 of 23
Signaling	0.41	24 of 28
Redundancy	0.86	16 of 16
Spatial Contiguity	1.10	22 of 22
Temporal Contiguity	1.22	9 of 9
Segmenting	0.77	10 of 10
Pre-training	0.75	13 of 16
Modality	0.76	52 of 61
Personalization	0.79	14 of 17
Voice	0.74	5 of 6

Research-Based Principles for the Design of Multimedia Messages

Coherence principle: People learn more deeply when extraneous words, pictures, or sounds are excluded rather than included.

Signaling principle: People learn more deeply when cues are added that highlight the main ideas and the organization of the words

Redundancy principle: People learn more deeply from animation and narration than from animation, narration, and on on-screen text.

Spatial contiguity principle: People learn more deeply when corresponding words and pictures are presented near rather than far from each other on the page or screen.

Temporal contiguity principle: People learn more deeply when corresponding words and pictures are presented simultaneously rather than successively.

Segmenting principle: People learn more deeply when a narrated animation is presented in learner-paced segments than as a continuous unit.

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.

Modality principle: People learn more deeply from graphocs and narration than from graphics and on-screen text.

Personalization principle: People learn more deeply when the words are in conversational style rather than formal style.

Voice principle: People learn more deeply when the narration is spoken in a standard-accented human voice than a machine voice.

Conclusions About the Design of Multimedia Learning

1. *Theory-based*. The design of multimedia messages should be based on a theory of how the human mind works.
2. *Research-based*. The design of multimedia messages should be based on research findings.

Bottom Line

People learn better when multimedia messages are designed in ways that are consistent with how the human mind works and with research-based principles.

Additional Sources

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E-mail Address: mayer@psych.ucsb.edu

Mailing address: Richard E. Mayer
Department of Psychological and Brain Sciences
University of California
Santa Barbara, CA 93106-9660

Classroom Studies

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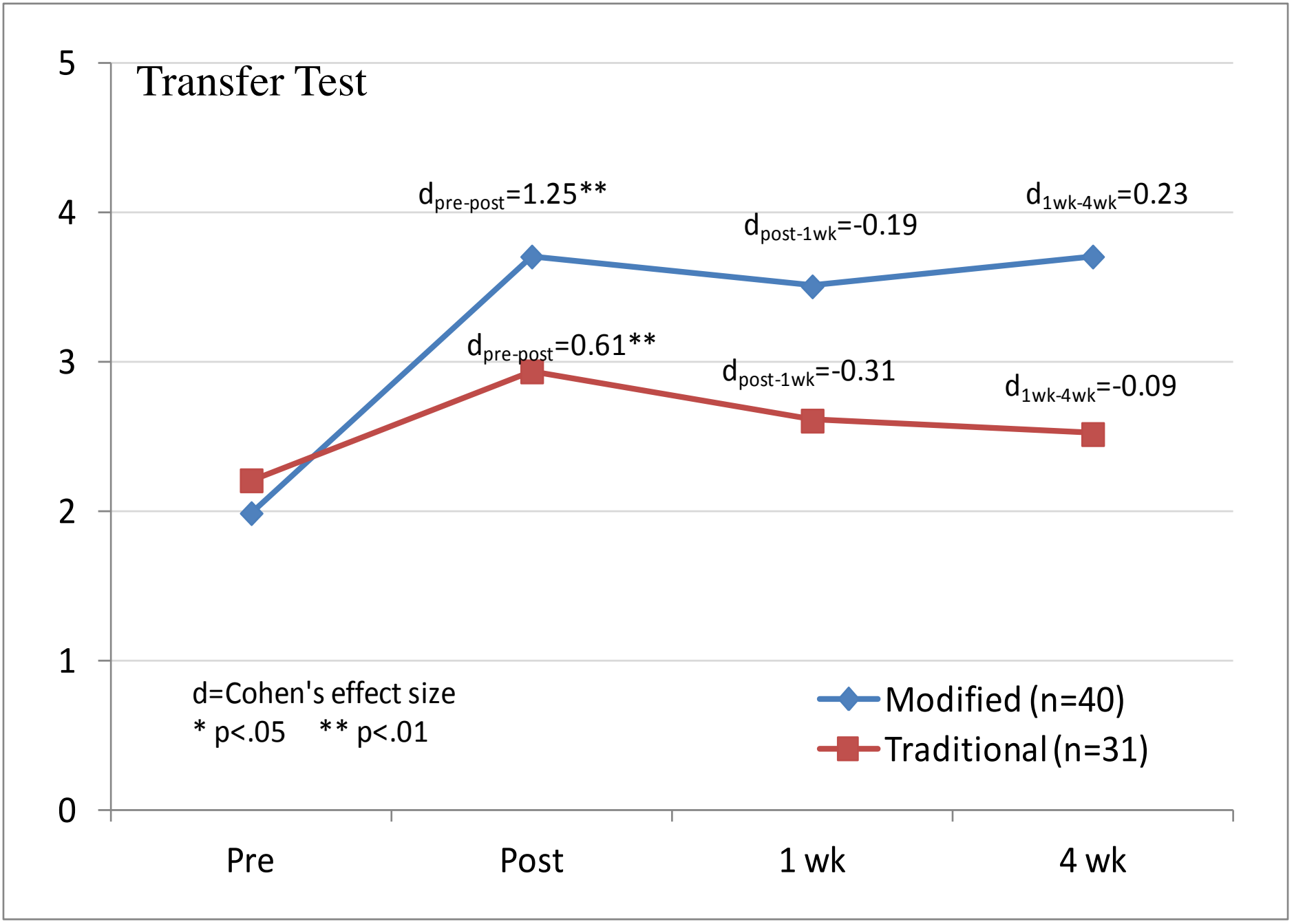
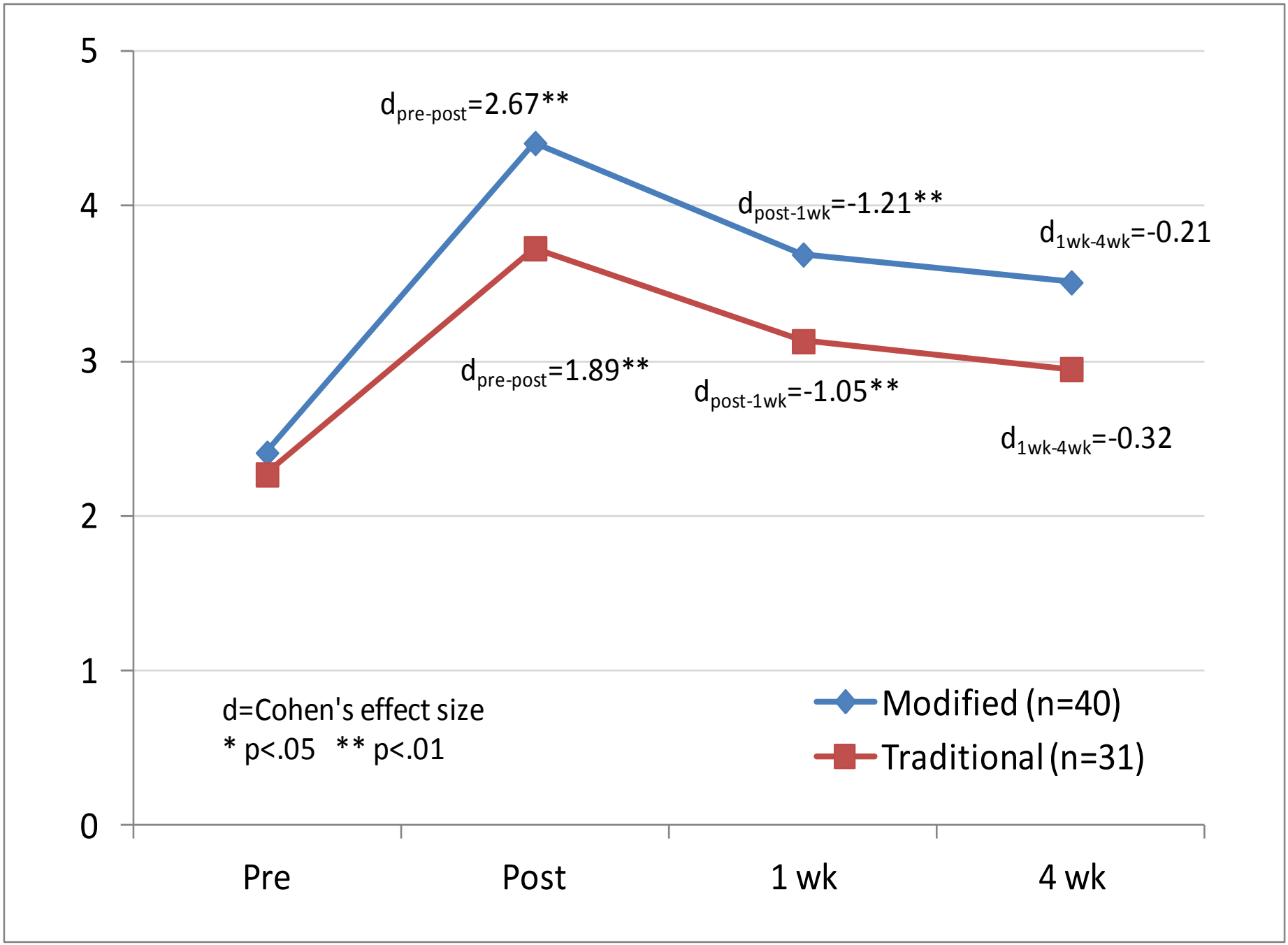
Mean Transfer Score (and SD) for Two Groups on Four Tests

Group	Pretest		Immediate Posttest		1-Week Posttest		4-Week Posttest	
	M	SD	M	SD	M	SD	M	SD
Modified	1.99	1.18	3.71	1.13	3.51	1.16	3.71	0.93
Traditional	2.21	1.05	2.94	0.83	2.61	0.99	2.52	1.12
T-test (p)	0.414		0.002		<.001		<.001	
ANCOVA (p)			<.001		<.001		<.001	
Effect size (d)	-0.20		0.76		0.83		1.17	


Transfer Test
5
4
3
2
1
0
$d_{pre\text{-}post}$=1.25**
$d_{post\text{-}1wk}$=-0.19
$d_{1wk\text{-}4wk}$=0.23
$d_{pre\text{-}post}$=0.61**
$d_{post\text{-}1wk}$=-0.31
$d_{1wk\text{-}4wk}$=-0.09
d=Cohen's effect size
* p<.05 ** p<.01
Modified (n=40)
Traditional (n=31)
Pre
Post
1 wk
4 wk

Mean Retention Score (and SD) for Two Groups on Four Tests

Group	Pretest		Immediate Posttest		1-Week Posttest		4-Week Posttest	
	M	SD	M	SD	M	SD	M	SD
Modified	2.41	0.65	4.41	0.47	3.69	0.77	3.51	0.81
Traditional	2.27	0.62	3.73	0.44	3.13	0.53	2.95	0.54
T-test (p)	0.416		<0.001		<.001		<.001	
ANCOVA (p)			<.001		.002		.002	
Effect size (d)	0.22		1.49		0.83		0.73	


5
4
3
2
1
0
$d_{pre\text{-}post}$=2.67**
$d_{post\text{-}1wk}$=-1.21**
$d_{1wk\text{-}4wk}$=-0.21
$d_{pre\text{-}post}$=1.89**
$d_{post\text{-}1wk}$=-1.05**
$d_{1wk\text{-}4wk}$=-0.32
d=Cohen's effect size
* p<.05 ** p<.01
Modified (n=40)
Traditional (n=31)
Pre
Post
1 wk
4 wk