Educational Technologies
WS2008/9

Multimedia Learning Principles

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Review of Syllabus

http://www.activemath.org/Teaching/edtechws0809/

28.10.2008: Introduction
04.11.2008: Intelligent tutoring systems (1) - Cognitive Tutors
11.11.2008: Intelligent tutoring systems (2) - ActiveMath
18.11.2008: Student modelling (1)
25.11.2008: Student modelling (2)
02.12.2008: Pedagogical components, instructional planning
09.12.2008: Meta-cognitive support (1) - Help
16.12.2008: Error diagnosis and feedback
06.01.2009: Error diagnosis and feedback
13.01.2009: Collaborative learning technologies
20.01.2009: Multimedia Learning principles
27.01.2009: Web-based systems
03.02.2009: Educational data mining
23.02.2009: Project presentations by students
Today’s Lecture

- **What is multimedia learning?**

- How do people learn? What are the limitations on their ability to learn?

- How do we apply multimedia principles to account for how people learn?
  - Specific examples of multimedia principles

- Take Home Message
Multimedia Learning Principles (Richard E. Mayer)

Principles for online learning, based on scientific results

- Multimedia Principle
- Contiguity principle
- Modality principle
- Redundancy principle
- Coherence principle
- Personalization principle
- Politeness principle
- Worked-examples principle
The “Multimedia Principle”: Include both text and graphics to enhance learning

E-Learning Lesson #25:

Today we will cover how a bicycle pump works. 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.

In 10 studies, students who received a multimedia lesson consisting of words and pictures performed better on a subsequent transfer test than students who received the same information only in words.
The Multimedia Principle – Try describing this in words!
The Multimedia Principle

How does graphics help?

- Instructional vs. decorative role
- Focus attention on salient features
- Illustrate organization (relations between ideas, lessons...)
- Show relationships among variables or make invisible phenomena visible
- Animation to illustrate process, procedure
Today’s Lecture

► What is multimedia learning?

► How do people learn? What are the limitations on their ability to learn?

► How do we apply multimedia principles to account for how people learn?
  ► Specific examples of multimedia principles

► Take Home Message
What do Multimedia Principles have to do with learning theory?

<table>
<thead>
<tr>
<th>Theory</th>
<th>Starting point</th>
<th>Goal</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Delivery</td>
<td>Capabilities of multimedia technology</td>
<td>Feed the student information</td>
<td>How can we use cutting-edge technology?</td>
</tr>
<tr>
<td>Learner-centered</td>
<td>How the human mind works</td>
<td>Aid to human cognition</td>
<td>How can we adapt multimedia technology to aid human cognition?</td>
</tr>
</tbody>
</table>

Better to adapt presentation to the way the human mind works!
Reasons for a Learner-Centered Approach

Mental processes transform information into knowledge and skills in memory

- Information processing through limited channels:
  - visual, auditory, haptic

- Human memory has limited capacity

- Learning occurs by active & integrative processing in memory
Cognitive Theory of Multimedia Learning

Five Cognitive Processes for Meaningful Learning

1. Selecting words
2. Selecting images
3. Organizing words
4. Organizing images
5. Integrating

Source: Bruce McLaren, Erica Melis, Rich Mayer

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## Three Types of Learning Outcomes

<table>
<thead>
<tr>
<th>Type</th>
<th>Cognitive processing during learning</th>
<th>Retention performance</th>
<th>Transfer performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>No learning</td>
<td>None</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Rote learning</td>
<td>Selecting</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Meaningful learning</td>
<td>Selecting, organizing and integrating</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

Source: Bruce McLaren, Erica Melis, Rich Mayer  
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Where might the human model of processing break down?

1. If words and relevant pictures are far away from one another?

2. If words are both written and spoken?

3. If unfamiliar words are written?
Three Types of Cognitive Processes

**Extraneous processing**
Cognitive processing that is not related to the objective of the lesson; involves no learning processes.
*Example*: Student thinks about how cool the icon is on the screen.

**Essential processing**
Basic cognitive processing that is relevant to the objective of the lesson; involves selecting and some organizing.
*Example*: Student thinks about the meaning of a symbol in an equation.

**Generative processing**
Deep cognitive processing that is relevant to the objective of the lesson; involves organizing and integrating.
*Example*: Student thinks about how the symbol relates to other symbols.

Cognitive Capacity =
Extraneous Processing + Essential Processing + Generative Processing
Three Types of Cognitive Problems

Extraneous Overload
Extraneous processing exhausts cognitive capacity.
Occurs when lesson contains extraneous material or is poorly designed.

Essential Overload
Essential processing exhausts cognitive capacity.
Occurs when lesson is difficult, lesson is presented at a fast pace,
and the learner is unfamiliar with the material.

Generative Underutilization
Learner has cognitive capacity available but
does not engage in sufficient generative processing.
Occurs when learner lacks motivation, does not exert effort.
Three Ways to Overcome Cognitive Problems in Multimedia Learning

1. Reduce extraneous processing
2. Manage essential processing
3. Foster generative processing
Today’s Lecture

► What is multimedia learning?

► How do people learn? What are the limitations on their ability to learn?

► How do we apply multimedia principles to account for how people learn?
  ▶ Specific examples of multimedia principles

► Take Home Message
But first, how can we test the principles?

Do an empirical study with
- Control Group, e.g., Study a standard multimedia lesson
- Experimental Group, e.g., Subjects study a multimedia lesson with music in background

Calculate the test scores (or learning gain, i.e., pre – post), e.g.,
- Mean of Control Group = 90%; sd = 10
- Mean of Experimental Group = 80%; sd = 10

Calculate whether the difference is statistically significant
- ANOVA, T-Test
- p < 0.05 is typically considered statistically significant (i.e., the probability is > 95% that the difference is real)

Calculate how strong the effect is – the effect size (ES)
- \[
\frac{(\text{Mean of Exp.} - \text{Mean of Control})}{\text{sd of Control}} \text{ (e.g., } (90 - 80)/10 = 1.0)\]
- ES < 0.2 (very small); 0.2 <= ES < 0.5 (small); 0.5 <= ES < 0.8 (moderate); ES >= 0.8 (large)
Reducing Extraneous Processing

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

Solution:
Reduce Extraneous Processing

1. Coherence principle
2. Redundancy principle
3. Signaling principle
4. Spatial contiguity principle
5. Temporal contiguity principle
Reducing Extraneous Processing - Coherence Principle

- People learn more deeply when extraneous material is excluded rather than included, i.e., adding (interesting) material can hurt learning
  - Avoid e-Lessons with extraneous discussion
  - Avoid e-Lessons with inessential sound, graphics, videos

Empirical Evidence

- Confirmed in: 11 of 12 tests
- Median effect size: 1.13
Reducing Extraneous Processing - Coherence Principle Example

Step 4: Copying the Virus's Genetic Code

The injected genetic material recruits the host cell's enzymes to help copy the virus's genetic material. Thus, the host cell's enzymes produce parts, such as genetic instructions and proteins, for making more virus particles.

The HIV virus is different in every infected person. Some people die soon after getting infected, while others live fairly normal lives for many years, even after they "officially" have AIDS. A few HIV-positive people stay healthy for many years even without taking anti-HIV medications.
Reducing Extraneous Processing - Redundancy Principle

Presenting words in text *and* audio can hurt learning
- Avoid spoken words and identical text in the presence of graphics (redundant information)
- Consider narration of on-screen text only in special situations, e.g., when language is challenging

Empirical Evidence
- Confirmed in: 10 of 10 tests
- Median effect size: 0.69
Reducing Extraneous Processing - Redundancy Principle Example

A good example…

Step 4: Copying the Virus's Genetic Code

The injected genetic material recruits the host cell's enzymes to help copy the virus's genetic material. Thus, the host cell's enzymes produce parts, such as genetic instructions and proteins, for making more virus particles.

A not-so-good example…

Audio narration: “The injected genetic material recruits the host cell's enzymes to help copy the virus's genetic material. Thus, the host cell's enzymes produce parts, such as genetic instructions and proteins, for making more virus particles.”
Redundancy Principle - Unnecessary Processing!

MULTIMEDIA
- Printed words
- Animation
- Narration

SENSORY MEMORY
- Eyes
- Ears

WORKING MEMORY
- Visual component
- Auditory component

Unnecessary integration?
Reducing Extraneous Processing - Signaling Principle

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

Empirical Evidence
- Confirmed in: 3 of 3 tests
- Median effect size: 0.60
Reducing Extraneous Processing - Signaling Principle Example

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…
Reducing Extraneous Processing - Spatial Contiguity Principle

- Place corresponding words and graphics close, e.g.,
  - Place feedback close to question and solution
  - Place explanatory text adjacent to graphic
  - Parallel access to exercise and directions
  - Use pop-ups etc to support integration

Empirical Evidence

- Confirmed in: 8 of 8 tests
- Median effect size: 1.11
Reducing Extraneous Processing - Spatial Contiguity Principle Example

A not-so-good example…

STEP 4:
Copying the virus’ genetic code.

A much better example…

STEP 4:
Copying the virus’ genetic code.
Reducing Extraneous Processing - Temporal Contiguity Principle

- People learn more deeply when corresponding graphics and narration are presented simultaneously rather than successively.
  - Audio narration should occur in real-time synchronization with graphics

Empirical Evidence
- Confirmed in: 8 of 8 tests
- Median effect size: 1.31
Simultaneous audio narration: “The next step is to cancel the grams in the first term, as well as introducing moles, by multiplying by the molecular weight of COH4.”
Managing Essential Processing

Problem:
Essential Processing + Generative Processing Exceeds Cognitive Capacity

Solution:
Manage Essential Processing

1. Modality principle
2. Pre-training principle
3. Segmenting
Managing Essential Processing - Modality Principle

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

- Empirical Evidence
  - Confirmed in: 21 of 21 tests
  - Median effect size: 0.97
Audio narration: “The next step is to cancel the grams in the first term, as well as introducing moles, by multiplying by the molecular weight of COH4.”
Modality Principle: Overloading Visual Channel

MULTIMEDIA

<table>
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<tr>
<th>Printed words</th>
<th>Pictures</th>
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SENSORY MEMORY

| Ears | Phonetic processing |
| Eyes | Visual processing |
Managing Essential Processing -
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.

Empirical Evidence
- Confirmed in: 7 of 7 tests
- Median effect size: 0.92
Managing Essential Processing – Pre-Training Principle Example

- Brake Fluid in the Tube
- Brake Drum
- Smaller Piston in the Wheel Cylinder
- Piston in Master Cylinder
- Brake Shoe

Click on blue text for descriptions.

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

Back to Front Page  Show Me
Managing Essential Processing - Segmenting Principle

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

Empirical Evidence

- Confirmed in: 3 of 3 tests
- Median effect size: 0.98
Managing Essential Processing – Segmenting Principle Example

“Cool moist air moves over a warmer surface and becomes heated.”
Fostering Generative Processing

Problem:
Insufficient Generative Processing Although Cognitive Capacity is Available

Solution:
Foster Generative Processing

1. Personalization principle
2. Voice principle
Fostering Generative Processing -
Personalization Principle

▶ People learn more deeply when words are in conversational, personal style rather than formal style
▶ (I, we, you)

Empirical Evidence
▶ Confirmed in: 10 of 10 tests
▶ Median effect size: 1.30
Fostering Generative Processing - Personalization Principle Example

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…”
Fostering Generative Processing - Voice Principle

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

Empirical Evidence

- Confirmed in: 4 of 4 tests
- Median effect size: 0.79
## Summary of Research Evidence

### Reduce Extraneous Processing

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### Managing Essential Processing

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### Fostering Generative Processing

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<td>Voice</td>
<td>0.79</td>
<td>4 of 4</td>
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Source: Bruce McLaren, Erica Melis, Rich Mayer
Other Principles

➤ Worked Example Principle

➤ Politeness Principle
Worked Example Principle

Another Principle to Reduce Extraneous Processing

- Mix worked examples and problem solving
- Apply other media principles to worked examples
- Prompt students to self-explain (Chi et al, 1989)
Audio narration: “The next step is to cancel the grams in the first term, as well as introducing moles, by multiplying by the molecular weight of COH4.”
Worked Example Principle – McLaren et al., 2008

Problem Statement
Suppose you are an engineer responsible for a water supply which has become contaminated with alcohol (COH4). To determine the extent of the contamination, you need to determine the number of moles of alcohol / kg of H2O in a solution of 6.00 grams COH4 in 100.0g of H2O. Your result should have 3 significant figures. (Here is a hint to help you: the molecular weight of COH4 is 32.04 g COH4 / mol of COH4).

Findings by McLaren et al: Worked examples didn’t improve learning but they made it more efficient, i.e., students took less time to learn the same amount.

Source: Bruce McLaren, Erica Melis, Rich Mayer

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EXAMPLE 1: Boy rescued by a helicopter

Jake, an 80Kg undergraduate, is rescued from a burning building by a helicopter. He hangs at the end of a rope dangling beneath the helicopter. If the helicopter accelerates, straight downward with respect to the ground, with an acceleration \( a = 2\text{ m/s}^2 \),

**FIND:**
The tension \( T \) exerted by the rope.

\[ T = \frac{ma}{a} = \frac{80 \times 2}{2} = 80 \text{ N} \]

**SOLUTION**

Because we want to find a force, we apply Newton's 2nd law to solve this problem.

- We choose Jake as the body to which to apply Newton's 2nd law.
- The helicopter's rope exerts a tension force \( T \) on Jake.
- The tension force \( T \) is directed upwards.
- The other force acting on Jake is his weight \( W \).
- The weight \( W \) is directed downwards.

To apply Newton's 2nd law to Jake, we choose a coordinate system with the Y axis directed downward.

- The Y component of Jake's weight \( W \) is \( W_y = W \).
- The Y component of the tension \( T \) on Jake is \( T_y = -T \).

The net force acting on Jake along the Y axis is

\[ \text{Net-force}_y = W_y + T_y \]

Therefore, substituting \( W_y = W \) and \( T_y = -T \) into the net force equation, we obtain

\[ \text{Net-force}_y = W - T \]

If we apply Newton's 2nd Law to Jake, along the Y axis, we obtain

\[ W - T = ma_y \]

The Y component of Jake's acceleration \( a \) is \( a_y = a \).

Therefore, if we substitute \( a_y \) and

\[ \text{Net-force}_y = W - T \]

into

\[ W - T = ma_y \]

we obtain:

\[ W - T = m(a_y) = (80 \times 2) \text{ Newtons} \]

Solving the preceding equation for \( T \) gives:
Politeness Principle – McLaren et al., 2007

Another Principle to Foster Generative Processing

Brown & Levinson (1987) – Politeness Theory

- **Positive Face** refers to
  - a wish to be appreciated, approved, and respected by a partner in conversation
  - a desire to work cooperatively with others

- **Negative Face** refers to
  - a desire not to be impeded by others
  - a wish not to be controlled by a partner in conversation
Politeness Principle – Examples of Positive and Negative Face

▶ “Press the button now”; “The system requests that you respond now”
  ▶ Low on positive face – not cooperative with the learner
  ▶ Low on negative face – too bossy and controlling

▶ “You may want to press the button”; “Would you like to press the button?”; “Let’s press the button”
  – High on positive face – cooperative, guarded suggestions (“You may”) and statements of common goal (“Let’s press”)
  ▶ High on negative face – suggestive, but leaves decision to the learner

▶ “Nice job!”
  ▶ High on positive face – cooperative and supportive
**Politeness Principle – Findings and Lessons**

*Findings by McLaren et al, 2007:*

The Polite Tutor didn’t improve learning

*Lessons?*

The Multimedia principles don’t always work

Use of principles in live classroom setting is different than in the lab
Today’s Lecture

- What is multimedia learning?
- How do people learn? What are the limitations on their ability to learn?
- How do we apply multimedia principles to account for how people learn?
  - Specific examples of multimedia principles

- Take Home Message
Take Home Message

1. The design of multimedia messages should be based on a theory of how the human mind works. (*Theory based*)

2. The design of multimedia messages should be based on research findings. (*Research based*)

**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.
The End

Any Questions?