You are asked to design a visualization for educational purposes, for example, to learn about:
- The ideal gas laws
- The carbon cycle
- Bird migration patterns
- The system of voting districts in the U.S.
- Air traffic control
- The history of the Gulf War

How do Visual and Verbal Information differ from one another?
- Visual Information:
  - analogous representations
  - inherently relational
  - encoded simultaneously
- Verbal Information:
  - discrete units of symbolic information
  - propositional
  - processed sequentially
**Visual Learning**

**Dual Coding Theory**

<table>
<thead>
<tr>
<th>Verbal Stimuli</th>
<th>Nonverbal Stimuli</th>
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<tr>
<td>Sensory Systems</td>
<td>Representational Connections</td>
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</tr>
</tbody>
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**Dual Coding Theory (Paivio, 1986, 1990)**

- **Verbal Stimuli**
- **Nonverbal Stimuli**
- **Sensory Systems**
- **Representational Connections**
- **Logogens**
- **Imagens**
- **Verbal System**
- **Nonverbal System**
- **Verbal Responses**
- **Nonverbal Responses**

**Visual Cognitive Load**

- **Intrinsic Load**: Load related to complexity of the information. Element interactivity.
- **Extraneous Load**: Load pertaining to formal and design of the interface. (presentation mode, modality, temporal & spatial arrangement, representation type).
- **Germane Load**: Mental effort expended by learner.

**Cognitive Load Components (Sweller, 1999)**

- Intrinsic Load
  - Load related to complexity of the information
  - Element interactivity
- Extraneous Load
  - Load pertaining to formal and design of the interface
    - (presentation mode, modality, temporal & spatial arrangement, representation type)
- Germane Load
  - Mental effort expended by learner

**Visual Learning Environments**

- **Highly visual learning environments**
- **Examples**
  - Simulations, virtual worlds, microworlds, games

**Introduction**

**Examples**

- Ideal Gas Law (Oklahoma State University)
- Odyssey Simulation Package
Visual Learning

Group Discussion (3-4 students, 15min)
Discuss Design Principles that increase the effectiveness of visual representations for learning (Animations and Simulations)?
- List and discuss principles from the assigned reading
- Find and discuss examples

Cognitive Design Factors

- Representation of information (Information Design)
- Instructional Approach (Interaction Design)
- Interactivity (Interaction Design)
- Function of Visuals (in support of cognitive processes)
- Scaffolds
- Feedback
- Narrative structure

Cognitive Design Factors

Which mode of relationship between signs and their referents best facilitates learning?
- Icon: Most basic representation, relies on physical resemblance to convey meaning
- Symbol: Abstract, arbitrary, relies on social conventions for meaning (Peirce, 1956)

Question of Interest:
- Comparison of Icons v. Symbolic representations

Research Materials

Ideal Gas Law

Chemistry Simulations

Does adding icons facilitate learning in chemistry simulations?
- Study with 93 11th grade students in a NYC high school:
  - Adding icons increased recall
  - Icons especially helped learners with low prior knowledge

Results: Representation
Which instructional approach best facilitates learning?

Consider:
• Difficulty of content: Intrinsic Cognitive Load
• Complexity of interactions: Extraneous Load
• Educational goals / Cognitive Function of materials
• Learner characteristics

Option
• Direct instruction v. guided exploration

Instructional Approach: Level of Learner Control

In other words:
• Comparison of direct instruction v. guided exploration (Simulation)

Or, in even different terms:
• Kirschner, Sweller, & Clark (2006) v. Everybody Else

Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching

Research Materials
• Kinetic Theory of Heat

Chemistry Simulations
• Kinetic Theory of Heat

Results: Simulation (exploratory) vs. Animation (worked-out)

Does ability to manipulate parameters facilitate learning?
• Study with 93 11th grade students in a NYC high school:
  - For comprehension: Simulation > Direct Exploration > Instruction

(Plass et al., 2007)
Visual Design of Simulations

Cognitive Function of Visual Information

What purpose does the visual information serve in the construction of mental models? (Plass, 1998)

  - Decorative: motivational function; little relation to content
  - Representative: depicts content of the instruction
  - Organizing: depicts knowledge structures
  - Interpreting: visualizes abstract concepts
  - Transforming: supports higher-level cognitive processes

Cognitive Function of Visual Information

What purpose does the visual information serve in the construction of mental models? (Plass, 1998)

- Our approach: Define function based on Mayer’s CTML
  - Selecting
  - Organizing
  - Integrating

- Different types of visuals support different learning outcomes (recall, comprehension, transfer)
  (Plass, Hamilton, & Wallen, 2004; Wallen, Plass, & Brünken, 2005)

Function of Multimedia Aids in Text Comprehension

- Split Attention Principle
  Avoid requiring learners to split their attention between, and mentally integrate, several sources of physically or temporally disparate information, where each source of information is essential for understanding the material.” (Ayres & Sweller, 2005)

- Modality Principle
  Present animation with narration rather than with on-screen text (Mayer, 2001)

- Contiguity Principle
  Present related information near to each other in time and space (Mayer, 2001)
Emerging Visual Design Principles

- **Cueing**: Adding design elements that direct learners’ attention to the important part of a simulation reduces cognitive load and enhances learning (Dwyer, 1978; Jeung et al., 1997; Tabbers et al., 2004; de Koenig et al., 2007)

- **Representation of Information**: Adding icons or representations can enhance learning, especially for learners with low prior knowledge (Lee et al., 2006; Plass et al., 2009)

- **Color Coding**: Use color to highlight important features and attributes of the visual display (Dwyer and Moore, 1991; Keller et al., 2006)

- **Multiple Dynamic Visual Representations**: Multiple dynamic representations should be integrated and linked (Lee et al., 2006)

Established Interaction Design Principles

- **Learner Control of Segmentation**: Learner control over the advancement from one segment of visual materials to the next improves learning (Mayer & Chandler, 2001; Mayer et al., 2003; Nunez, 2007)

- **Guided Discovery Principle**: Provide guidance in discovery-based learning environments (de Jong, 2006; de Jong & van Joolingen, 1998; Kirschner et al., 2006; Mayer, 2004)

Established Interaction Design Principles

- **Learner Control of Pacing**: Learner control over the pace of the presentation of visual materials improves learning (Keller et al., 2007; Schunn & Riepp, 2004; Tabbers et al., 2004)

- **Task-Appropriate Representations**: Simulations need to prepare learners for future tasks to be performed Facilitating, Enabling, or Inhibiting Effects: Cognitive Function of Simulations (Retention, Understanding, Transfer) (Carney & Lewis, 2002; Lewis et al., 1987; Press, Walace, & Wartune, 2004)

- **Content-Manipulating Interactivity**: Learner control over the content of visual materials improves learning (Chandler, 2004; Hegarty, 2004; Kester, 1990; Wooster et al., 1997)

Other Emotional Design Principles

- **Personalization Principle**: Learning more deeply when words in a multimedia presentation are in conversational rather than formal style (Mayer, 2005)

- **Social Presence Hypothesis**: Learning is facilitated by giving learners a sense of the presence of others in a learning environment. This effect is expected to be especially strong in self-learning
Group Activity (3-4 students, 30min)

Apply the Design Principles we discussed to your own projects by designing a simulation or animation.

- Select which topic to cover
- Discuss which principles apply
- Describe how you will apply the principles for the information design and interaction design of the simulation