# Cognitive Legos: Helping Your Students Construct Scientifically Accurate Mental Models

Ruth Streveler, Ron Miller
Barbara Olds
Colorado School of Mines

# Overview of the Session

The session will address three questions:

- What is a mental model?
- What mental models do students construct to explain certain difficult scientific concepts?
  - Look at transcripts of student interviews
- How can we design instructional environments to help students construct accurate models of these scientific concepts?

# Workshop Outcomes

- Participants will be able to describe a mental model and explain why it is useful for instructors to know about their students' mental models.
- Participants will practice analysis of student transcripts.
- Participants will develop ideas about how to design instruction that helps students construct mental models of scientific concepts that are scientifically accurate.

# Form teams

- By discipline
  - ME, ChemE, EE, Other
- Introduce yourself to your team members

# What are mental models?

- Write down your ideas
- Share with your team
- Teams report

# What are mental models?

- Mental models are **representations** of reality that people use to **understand specific phenomena or concepts**.
- Mental models are usually:
  - Evolving
    - Students come to your class with at least partially developed mental models
  - Provide simplified explanations of complex phenomenon.
  - Incomplete (and often inaccurate or incorrect)
    - Incorrect models may lead to **misconceptions**

tip.psychology.org/

# An Example Misconception

- Adding a droplet of colored dye into a beaker of water
- Students sometimes describe this process using macroscopic causal models:
  - "dye molecules want to move towards water molecules"
  - "dye molecules stop moving when dye and water become mixed"

# Some ways to describe incorrect mental models

- Emergent vs. direct processes
- Substance-based models

# Some Attributes of Emergent and Direct Processes (Chi, et al.)

| *Emergent process* | *Direct process* |
|---|---|
| collection | distinct subgroups |
| random | constrained |
| simultaneous | sequential |
| independent | dependent |
| continuous | terminating |

# "Substance-Based" conceptions

Chi's research also indicates that some students believe that:

- Force is a substance that is a property of bodies
- Voltage is a substance that is stored in batteries
- Heat is a substance that flows between bodies

# Learning about students' mental models

- Why do it?
- How to do it?

# Why do it?

- Why might it be useful/important to know about your students' mental models of the phenomenon or concepts they should be learning in your course?
  - Discussion at your table
  - Report to the group

# How to learn about students mental models

- Starting assumptions
  - All measures are **secondary** (we can't [yet] measure the models themselves) – we can only PROBE for mental models
  - Mental models will **vary** among your students (idiosyncratic – each student's model will be at least SLIGHTLY different from other students' models)

# Measuring mental models

- How do you know what students are thinking?
  - How they **represent** the thing you are interested in. For example:
    - Verbal descriptions
    - Concept maps
    - Drawings
  - By what they **do** – performance measures

# Data you'll see today

- Summary of the process
  - Delphi surveys starting point – what's difficult and important?
  - Open-ended questions created by content experts
  - Students talk about the questions
    - Recorded
    - Transcribed
    - Coded
  - For confidentiality, transcripts will be collected at the end of the session.

# Transcript Activity

- Individually - read through the transcripts
  - What does the transcript suggest about what the student is thinking about the respective phenomenon?
- Share your thoughts with your table
  - Recorder summarizes ideas from your table.
  - Recorder reports to the whole group.

# Transcript Activity

- Some of our research group's ideas
  - ME – tension is a property of the ropes
    - Substance-based schema?
  - EE – voltage is a property of a specific location
    - Substance-based schema?
  - ChemE – confusion between rate vs. amount
    - Also seen in our concept inventory results
    - Related to misunderstanding of emergence?

# Guidelines for helping students master difficult concepts

- Think about the **conceptual** knowledge you want students to acquire
- Find ways to gather feedback about students' understanding
- Allow students to "experiment" with the concepts
- Help students construct a new conceptual framework for understanding these concepts

# Helping students construct a new conceptual framework

- Help students visualize the process
  - Hands on exercises
  - Demonstrations
  - Simulations
- Ask students questions about their conceptions
  - Explain, justify
  - WHY does this happen?
  - Focus on concepts and situations, not equations

# Instructional Design Activity

- Return to your team's discussion of the most difficult concepts in your field (from earlier in this session)
- What concept is the most interesting to you?
- Discuss how you might you might design a course unit to help students understand this difficult concept
- Group reporter shares ideas with the whole group

# Wrap up

- Evaluations
- Collect transcripts

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# Websites of interest

- www.mines.edu/research/cee/Misconceptions.html
- www.engr.washington.edu/caee/
- www.pitt.edu/~chi/