



Concept-based Engineering Education: Designing Instruction to Facilitate Student Understanding of Difficult Concepts in Science and Engineering

Ron Miller, Ruth Streveler,
Barbara Olds (CSM),
Mary Nelson (CU-Boulder)



Background Knowledge Probe

- Rationale
- Process



Workshop Outcomes

- Participants will contribute to the analysis of projects on difficult concepts
 - Work in disciplinary teams
 - Look at the results of 3 Delphi surveys
- Participants will begin to form a conceptual framework about why these concepts are difficult
- Participants will design instruction to make these concepts easier to learn
 - Work in disciplinary teams



Form teams

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



Difficult Concept Methodology

➤ Delphi Surveys

- Method for gathering expert opinion (Rand Corporation, 1960s)
- Iterative survey (3 rounds = stability)
- Rated on importance and difficulty

➤ 3 Delphi Surveys completed

- Thermal and transport science (fluid mechanics, heat transfer, thermodynamics)
- Engineering mechanics (statics, dynamics, strengths of materials)
- Circuits

➤ Participants were experienced instructors



Delphi Survey results

- **Exercise:** Look at the results of the Delphi survey that most closely matches your interest or expertise (ChemE, ME, EE)
 - Do the results make sense in terms of your own experience teaching this content?
 - What topics do you think should be considered “most difficult” and “most important”? You can agree or disagree with the numerical findings of the Delphi survey.
- Discuss your thoughts with the group
- A spokesperson reports for the group



Why are these concepts difficult?

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



Some evidence from cognitive psychology

- In terms of a constructivist view of learning and knowledge, students create mental models describing their view of the world
- Students come to your classes with at least partially developed mental models which we may term prior knowledge
- Prior knowledge is often formed using everyday experience and may be incorrect. These incorrect conceptions are often called "misconceptions."



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

<i>Emergent process</i>	<i>Direct process</i>
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 can be stored or depleted
- Electricity is a substance that flows in wires
- Heat is a substance that flows between bodies



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



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Websites of interest

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