Concept-Based Learning in Science and Engineering Education

Ruth Streveler

Center for Engineering Education

Colorado School of Mines

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Session Overview

- Background information to provide context
- Our research questions regarding concept-based learning
  - Research team: Ron Miller (CSM), Barbara Olds CSM), Michelene Chi (Pitt), Mary Nelson (CU-Boulder)
- Unresolved questions
- Some useful web links

Background information

- Colorado School of Mines – an engineering school in Golden, CO
- Center for Engineering Education
- Current research involves the creation of concept inventories in engineering
  - Developing an Outcomes Assessment Instrument for Identifying Engineering Student Misconceptions in Thermal and Transport Science (NSF DUE 01279806)
  - Center for the Advancement of Engineering Education (NSF ESI 0227558)

Our research questions

- What concepts do engineering students find most difficult to learn?
- How can we measure students' understanding of those concepts?
- WHY are these concepts difficult to learn?
- How can we design instruction to help students understand these concepts?

What Concepts are Difficult?

- Used Delphi methodology to query over 30 experienced professors
- Concepts that are MOST DIFFICULT and MOST IMPORTANT
  - Enthalpy
  - Heat vs. Temperature vs. Energy
  - Conservation of linear momentum
  - Bernoulli equation

How to Measure Understanding

- Create a concept inventory patterned after the FCI
- Create "essay questions" focusing on each difficult concept identified by the Delphi survey and subsequent student interviews
- Students think aloud while discussing the questions
- Write distractors based on incorrect student responses
- Test for reliability and validity of the instrument

WHY are Some Concepts so Difficult?

- Students' knowledge of everyday life conflicts with the knowledge we would like them to learn.
  - Example: Things that feel warm have a higher temperature than things that feel cold. Therefore a carpet has a higher temperature than a tile floor.
- Students have no "schema" for the processes we are trying to teach.
  - Example: Students may think of Force as a "substance" and therefore attribute to Force the properties of a substance (can be used up, contained, pushed or pulled)

How Can We Design Instruction to Improve Conceptual Understanding?

- We know active learning helps (FCI gains plotted by type of instruction)
- It is important to stress conceptual understanding in addition to problem-solving
- Some preliminary work by Slotta and Chi suggests that "schema training" may be useful.

Questions We are Wrestling With

- What is a scientific or engineering concept?
- At what level do students (graduates) need to understand the concepts?

What is a Concept?

Concepts are mental categories of objects, events, or ideas that have a common set of features.

Concepts are units of thought or elements of knowledge that allow us to organize experience.

What Level of Understanding is Needed?

- Undergraduate Physics texts tell students 'you don't know enough to be told the truth' – Traweek
- "Newton was wrong." – President's Report, *Announcer,* Winter 2003, p.6

Some Web Sites of Interest

- CSM Center for Engineering Education

  www.mines.edu/research/cee/

- Foundation Coalition Concept Inventories

  www.eas.asu.edu/~cresmet

  and click on the **concept inventories** link.

- Michelene Chi

  www.pitt.edu/~chi