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

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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
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.)

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<thead>
<tr>
<th><strong>Emergent process</strong></th>
<th><strong>Direct process</strong></th>
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<tbody>
<tr>
<td>collection</td>
<td>distinct subgroups</td>
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<tr>
<td>random</td>
<td>constrained</td>
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<tr>
<td>simultaneous</td>
<td>sequential</td>
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<tr>
<td>independent</td>
<td>dependent</td>
</tr>
<tr>
<td>continuous</td>
<td>terminating</td>
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</tbody>
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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 design a course unit to help students understand this difficult concept
- Group reporter shares ideas with the whole group
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- Center for the Advancement of Engineering Education (ESI-0227558)
Websites of interest

- [www.mines.edu/research/cee/Misconceptions.html](http://www.mines.edu/research/cee/Misconceptions.html)
- [www.engr.washington.edu/caee/](http://www.engr.washington.edu/caee/)
- [www.pitt.edu/~chi/](http://www.pitt.edu/~chi/)