



Research on Conceptual Understanding: Foundations & Future Challenges

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Getting Stated in PER: Conceptual Understanding

- What has been researched?
- How does one do this kind of research?
- What are some areas of future research?


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Disclaimers About This Talk

- Is one (my) perspective of the issues
 - May not be shared by others
- Will exclude and may 'misinterpret' some issues, ideas or contributions

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What has been researched?

Students' Difficulties & Misconceptions

- Why can students solve textbook problems, but have difficulties with conceptual questions?
- Investigating students' difficulties in various topics in introductory physics^{1,2}
- Developing ways to assess students' conceptions in various topics in introductory physics e.g. Force Concept Inventory³ and others

¹(Arons, 1978) ²(McDermott, 1984) ³(Hestenes et. al., 1992) ⁵

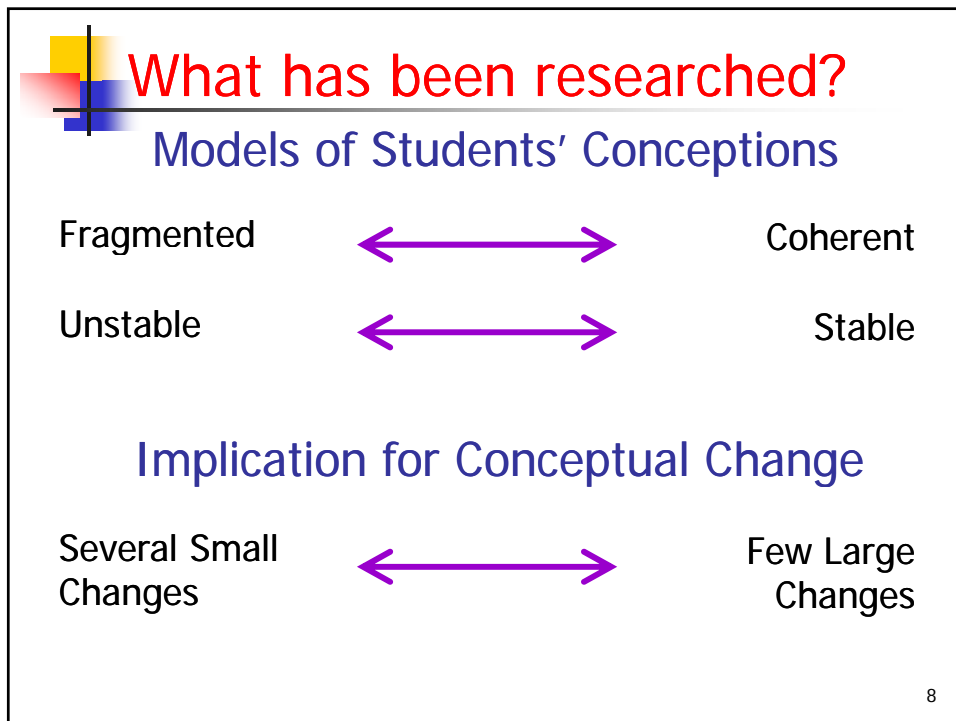
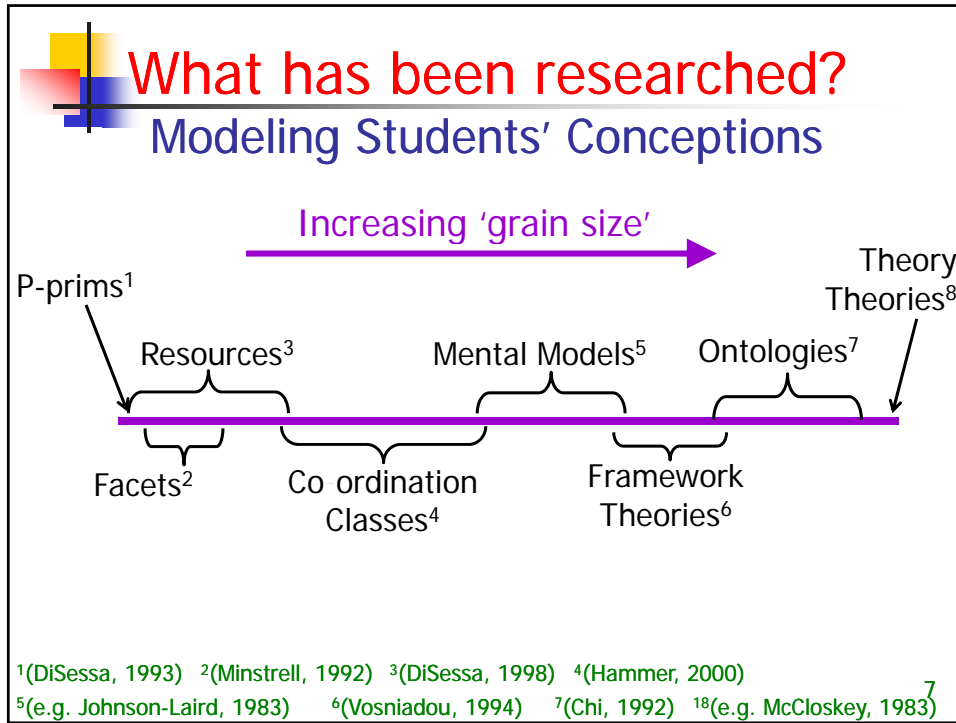


What has been researched?

Understanding Students' Models

- Recognizing limitations of inventories¹ : cannot provide deeper insights into students' conceptions
- Investigating root causes of students' conceptions and difficulties – underlying mental models²
- Extracting information about students' models from conceptual inventories e.g. Model Analysis³

¹(e.g. Huffman & Heller, 1995) ²(e.g. Redish, 1994) ³(Bao, 1999) ⁶



What has been researched?

Modeling Conceptual Change




<h4>Small Changes</h4> <ul style="list-style-type: none"> ■ Anchoring examples & bridging analogies⁵ ■ Appropriate resource activation⁶ ■ Refinement of raw intuition⁷ 	<h4>Large Changes¹</h4> <ul style="list-style-type: none"> ■ Cognitive conflict² ■ Ontological change³ ■ Hierarchical change⁴
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¹(Kuhn, 1962) ²(e.g. Posner *et al*, 1982) ³(Chi, 2002) ⁴(Thagard, 1992)
⁵(Clement, 1987) ⁶(Hammer, 2000) ⁷(Elby, 2001)

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What has been researched?

Overview of Some Trends

Student knowledge is described in terms of stable misconceptions and difficulties		Student knowledge is described in terms of finer grained, unstable knowledge elements
Investigating students' conceptions before and after instruction		Investigating dynamics of how conceptions change during instruction
Conceptual change research attends mainly to student cognition		Conceptual change research includes impact of students' epistemologies/expectations

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How does one do this research?

Overarching Goal

To create a **model** of the learners' **conceptions**

Remember...
It is only a
model!

Researcher

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How does one do this research?

Philosophical Assumptions

- Ontological
 - Realist (Knowledge external to individual) vs.
 - Nominalist (Knowledge created by individual consciousness)
- Epistemological
 - Positivist (Knowledge is objective, researcher observes) vs.
 - Post-Positivist (Knowledge is subjective, researcher engages)
- Human Nature
 - Mechanistic (Humans respond to their environment)
 - Free (Humans create and control their environment)

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How does one do this research?

Theoretical Perspective: Constructivism

Some Constructivist Perspectives

- Piaget
 - Stages of development
 - Disequilibrium or cognitive dissonance
 - Equilibration
- Vygotsky
 - Role of social interactions
 - Zone of Proximal Development (ZPD)
 - Scaffolding: Support so learners succeed in ZPD

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How does one do this research?

Types of Research

- Quantitative: Multiple-choice inventories e.g. FCI
 - Use: Different populations, different treatments
 - Analyses: Item Response, Factor, Model etc.
- Qualitative
 - Open-ended surveys on students' conceptions
 - Observations of students in various environments
 - Interviews to probe students' conceptions

Assumption: The choices on the inventory questions represent the entire range of students' responses to the question

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How does one do this research?

Research Tool: Clinical Interviews

Goal: Investigate students' conceptions

- Attempt not to perturb students' conceptions during interview
- Several Types:
 - Individual vs. Focus Group
 - Structured vs. Semi-structured vs. Unstructured
 - Other Formats: Think-aloud, Simulated Recall

Virtually impossible in a 'knowledge in pieces' perspective

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How does one do this research?

Research Tool: Teach/Learning Interview

Goal: Investigate how students learn

- Attempt to promote conceptual change¹ by providing:
 - A rich environment to promote dynamic transfer²
 - Scaffolding³ through hints and cues
 - Opportunities for interactions and self-reflection
- Several Formats:
 - Individual
 - Small Group (2-3 students)
 - Larger Focus Group: Many students together
- Interviewer is both researcher and facilitator

¹(Smith, diSessa, 1993) ²(Schwartz et. al., 2008) ³(Vygotsky, 1978)

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How does one do this research?

Several Methodologies Exist

One Methodology: Phenomenography¹

- Different ways in which learners, experience and conceptualize a phenomenon
- Data Collection Method: Interviews (can also use text)
 - Interviewee asked to reflect on aspects of a phenomenon.
 - Interview is transcribed verbatim.
 - Interview responses are coded.
 - Inter-rater reliability is checked and established.
 - Codes are collapsed into emergent categories.

¹(Marton, 1981)

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How does one do this research?

Phenomenography: Criticisms

- Equates actual experiences with accounts of experiences
 - Instead, should refer to studying “accounts” rather than “experiences”¹
- Assumes bracketing is plausible
 - Researcher should make background and beliefs explicit to readers²
- Does not examine effects of interview environment or linguistic practices on students’ accounts³
- Questionable repeatability

¹(Salijo, 1997)

²(Webb, 1997)

³(Richardson, 1999)

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How does one do this research?

Important Issue: **Credibility**

Do subjects actually perceive things the way researcher portrays it?

- Substantial engagement
- Persistent observation
- Triangulation
 - Peer debriefing
 - Member check

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How does one do this research?


Important Issue: **Dependability**

Does what the researcher observe change with repeated observations?

From a 'knowledge in pieces' perspective, this should be expected, so...

- Track and document any changes
- Ask participant to summarize and compare summaries at...
 - End of one interview session, with
 - Beginning of next session


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Thoughts For Future Research

- Learn from Learning Sciences, Cog. Psych.
 - New models of conceptual change
 - e.g. Complex Systems Perspective¹
 - Emergent views on transfer of Learning
 - e.g. Dynamic Transfer²
- Consider Emergent Tools
 - Eye tacking³
 - Functional MRI (fMRI)
 - Gesture and other fine-grained analysis of video

¹(Brown & Hammer, 2008) ²(Schwartz et. al., 2008) ³(Mestre & Feil, 2006) 21



Thoughts For Future Research

- Influences of a Technology Rich World
 - Real vs. virtual learning – no clear consensus
 - Computer supported collaborative learning
 - Tech. used in research on conceptual understanding
- Emerging Content Areas (e.g. Nanophysics, Biophysics)
 - New ideas that students bring to classroom
 - Multi- and interdisciplinary aspects of learning, e.g.
 - Transfer from one course to another
 - Transfer from One discipline to another
 - Transfer : Classroom \leftrightarrow Real world

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Finally...

“The trouble with problems in physics education is that they don’t stay solved.”

-- Melba Phillips