Complex Systems and the Learning Sciences

URI WILENSKY AND MICHAEL J. JACOBSON
Complex System

- Complex system
  - A system composed of many elements that interact with each other and their environment
- Emergence – how large scale patterns arises
- Two views of emergence
  - events and actions (micro-level) / systems (macro-level)

- All Phenomena can be described as a complex system.
- So students should study complex systems in school.
Complex system of the global food system
Computation make it possible

• The powerful computational methods make it possible
• Computer simulation
Why student should learn?

• A framework to integrate different scientific domains
• It enables students to connect across domains and to make that knowledge useful outside of the narrow school context.
• The world is increasingly connected, so the world cannot be understood in terms of isolated systems.
• It has many attributes in learning complex systems

• But, now education missed it.
Two trends of research

• Several cognitive challenges
  • Challenging and counterintuitive
  • Tendency of centralized control and deterministic causality
  • Expert and novice differences in terms of spectrum
  • a process of ‘strong’ or ‘radical’ conceptual change

• Pedagogical research
  • StarLogo
    • agent-based modeling of traffic jams and ants foraging for food
  • NetLogo
    • Decomposes the phenomenon by agents and rules
  • Hubnet
    • Enables “participatory simulations”
Conclusion

- 7 cross-cutting concepts to structure K-12 science learning
  - patterns, similarity, and diversity
  - cause and effect
  - scale, proportion, and quantity
  - systems and system models
  - energy and matter
  - structure and function
  - stability and change.
Question

• How do you agree with the argument that all students should learn complex systems?
• What can complex systems perspectives provide toward our research or in daily lives?
• To the extent how much do you expect that the computational modeling will become important?
• Is it possible that studying from a more complex systems perspective can result in increased in conceptual change?
A History of Conceptual Change Research: Threads and Fault Lines

ANDREA A. DISESSA
Conceptual change

Novice

Experts
What can we learn from Piaget

- Not a “blank slate”
  - Children think quite differently than adults
- The core idea of constructivism
  - New ideas always emerge from old ones.
- Conceptual change relies on Piaget’s work
  - the idea of disequilibration and re-equilibration
  - assimilation vs. accommodation
  - Except “stage theory”
    - Conceptual change research takes a domain-specific approach
The history of science

• Thomas Kuhn
  • “The Structure of Scientific Revolutions”
  • Puzzle-solving periods of science (Normal Science)
  • Paradigm shift - Period of radical change
  • Incommensurability
    • claims of the new theory cannot be stated in the terms of the old theory, and vice versa
  • Coherence of knowledge
Toulmin’s rejection

• “Human Understanding”
• Rejection of assumptions of Thomas Kuhn
• “before-and-after” view had to be abandoned.
Misconception

• False beliefs acting as "critical barriers" to learn science
  • alternative conceptions, alternative frameworks, intuitive or naïve theories, and naïve beliefs
• Entrenched but false prior beliefs interfere with learning and need to be overcome
Misconception movement

• The analogy with a history of science
  • Children undergo a spontaneous and important conceptual revolution

• The theory theory
  • Children or beginning students have theories in very much the same sense that scientists do
  • Conceptual change replaces one coherent theory with another

• Rational model
  • Students, like scientists, maintain current ideas unless there are good reasons to abandon them
Assessing the misconception movement

• Positive contribution
  • Highlighted qualitative understanding and explanation
  • Established visibility for constructivist thinking
  • Diminished attention to domain-general difficulties and emphasized domain-specific issues

• Negative contribution
  • Lack of theory to support
  • Mostly emphasized negative contributions of prior knowledge
  • How learning is actually possible is minimally discussed.
  • Preemptive dominance for theory theory points of view and “conflict” models of instruction
Fragments of theory

• Entities involved in conceptual change and structure
  • Concept?
  • The distinguish between belief and concepts
  • framework theories and nested models

• How it happens?
  • diffuse initial concepts or coalescence of old categories
Knowledge in Pieces

• A fragmented side of naïve biology, psychology
  • They challenges that naïve ideas are simply wrong.
  • Naïve ideas as resources for instruction much more than blocks to conceptual change in physics
  • p-prim or facets to describe the fragmented knowledge
KiP Perspectives

- *KiP allows “watching” conceptual change*
- *KiP explains why conceptual change takes time*
- *KiP requires learning in many contexts*
- *Students have rich conceptual resources on which to draw*
- *Confront and replace is an implausible instructional strategy.*
- *Coaching students meta-conceptually is very different from a KiP perspective.*
- *KiP is flexible and fine-grained enough to track individual differences in learning.*
Coherence view of instruction

• Instruction is a complex mixture of design and theory
• Researchers of different theoretical persuasions advocate similar instructional strategies
• rely primarily on pre/post evaluations
Foci for Near-future work

- Pursue detailed specification of the content development of conceptual domains.
- Make contextuality a central concern.
- Assume variation across domains, and empirically validate commonalities (or differences)
- Develop explicit models of constructs like “concept” and “theory,” and test them against data
- Accept the challenge of process validation of models of entities and change
Question

• How do you define the notion of “Concept”?  
• Do you think we have any area concerning conceptual change except science learning? 
• Which side between coherence vs. fragmented do you feel more convinced?  
• Where do you think naïve theory comes from?
Addressing Challenges to Public Understanding of Science: Epistemic Cognition, Motivated Reasoning, and Conceptual Change

Sinatra, Kienhues, & Hofer (2014)
3 critical challenges in thinking and reasoning

• 3 critical challenges
  • reasoning about knowledge and the processes of knowing (epistemic cognition)
  • overcoming biases in reasoning (motivated reasoning)
  • overcoming misconception (conceptual change)
Epistemic cognition

• Epistemic beliefs and theories
  • The conceptions of the nature of knowledge and knowing
  • Individuals bring these beliefs to their reasoning about knowledge and knowing
• It can help to understand the challenges the public faces the scientific topics.
• Epistemic cognition is especially salient when people are confronted with contradictory knowledge statements
The dimension of epistemic cognition

• Certainty of knowledge
  • How tentative or absolute and stable knowledge is perceived to be.

• Structure of knowledge
  • How interrelated or isolated knowledge is perceived to be.

• Justification for knowing
  • How individuals evaluate the use of evidence, and their assessment of authority and expertise.

• Source of knowledge
  • Where individuals believe knowledge originates and resides
Motivated reasoning

• Individual’s attitudes and moral convictions also influence how science-related information is processed cognitively and emotionally.
• Unconscious biases in information processing
• In a way that the evidence fits the recipient’s preexisting attitudes or moral convictions.
Conceptual change

• Fragmented or well-structured prior knowledge
• Individuals are motivated to retain their existing conceptions in conflict with scientific perspectives.
• They explore the cognitive, affective, and motivational factors involved in knowledge restructuring.
The hat trick of change

• Conceptual change
  • Traditional views of conceptual change were based in a knowledge deficit perspective.
  • Lack key knowledge or hold misconceptions about the topic

• Attitudinal change
  • “Justified vs Unjustified” - “Pro vs. Con” profile
  • Whether it is accurate as well as they have a positive or negative attitude

• Epistemic conceptual change
  • how individuals think and reason about the nature of knowledge itself.
  • misconceptions about the nature of knowledge, thinking, and reasoning that must be overcome.
Question

• Which factors would make it worse to keep a misconception of a public? Or how can we eradicate the misconception?
• What do you think of "need for closure"?
• How can we approach to average teachers not researcher?
• What are ways we can refocus our curriculum to better educate students in how to do this effectively?