Conceptual Frameworks for Student Learning of Complex Earth Systems

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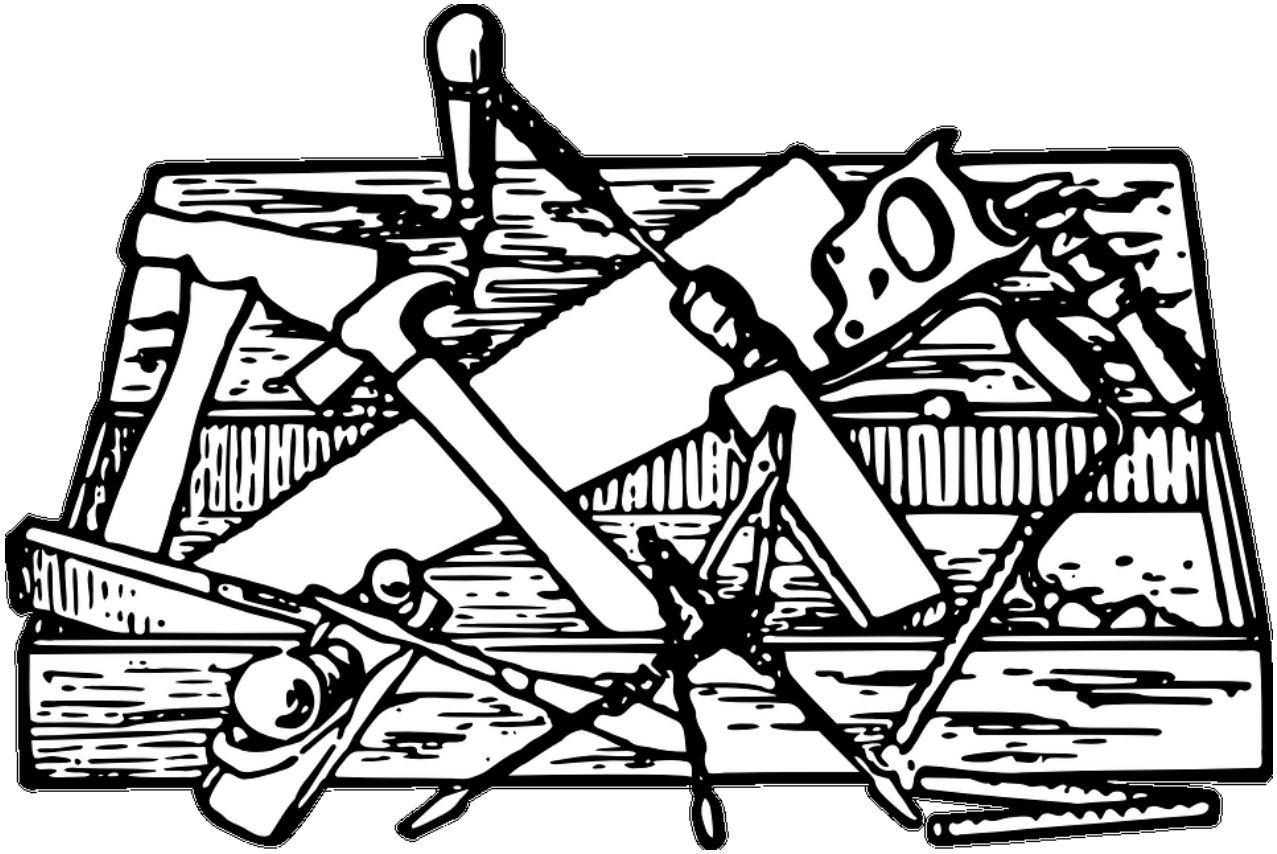
Systems thinking can be part of a student's toolbox



Problem-solving in near surface complex Earth systems

recognize that Earth is a dynamic system
(Orion and Libarkin, 2014)

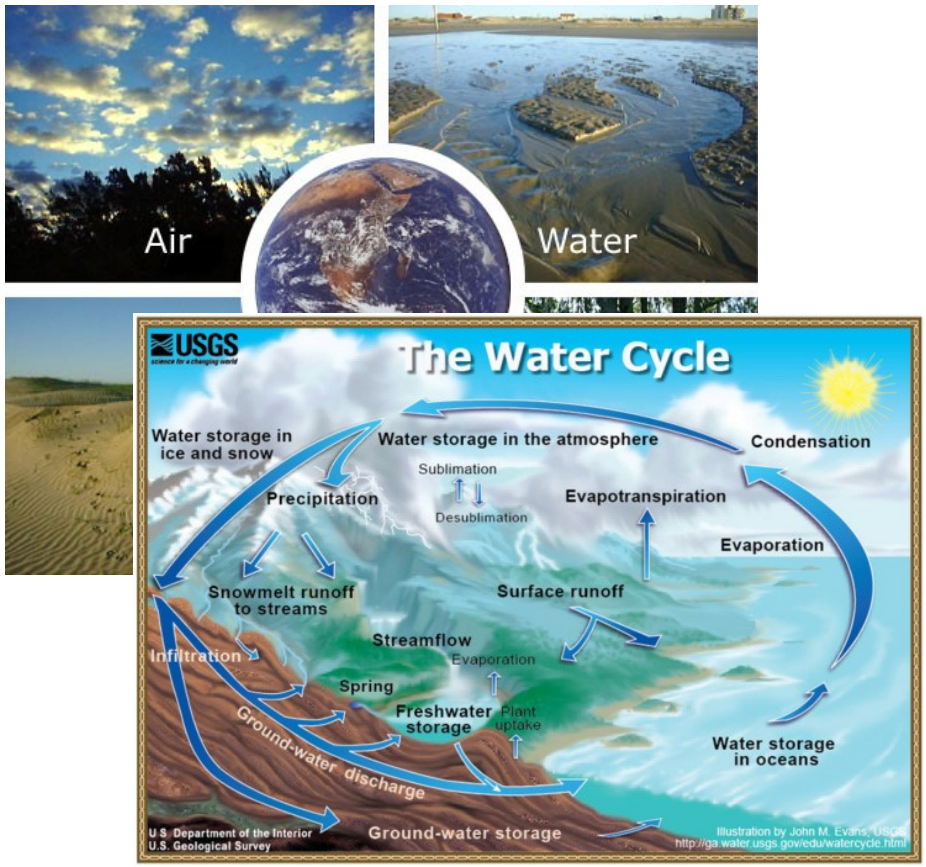
develop accurate mental models of near-surface Earth systems
(Herbert, 2006)

reason about "sophisticated, initially counterintuitive conceptions of causality and mechanism"
(Stillings, 2012, p. 104)

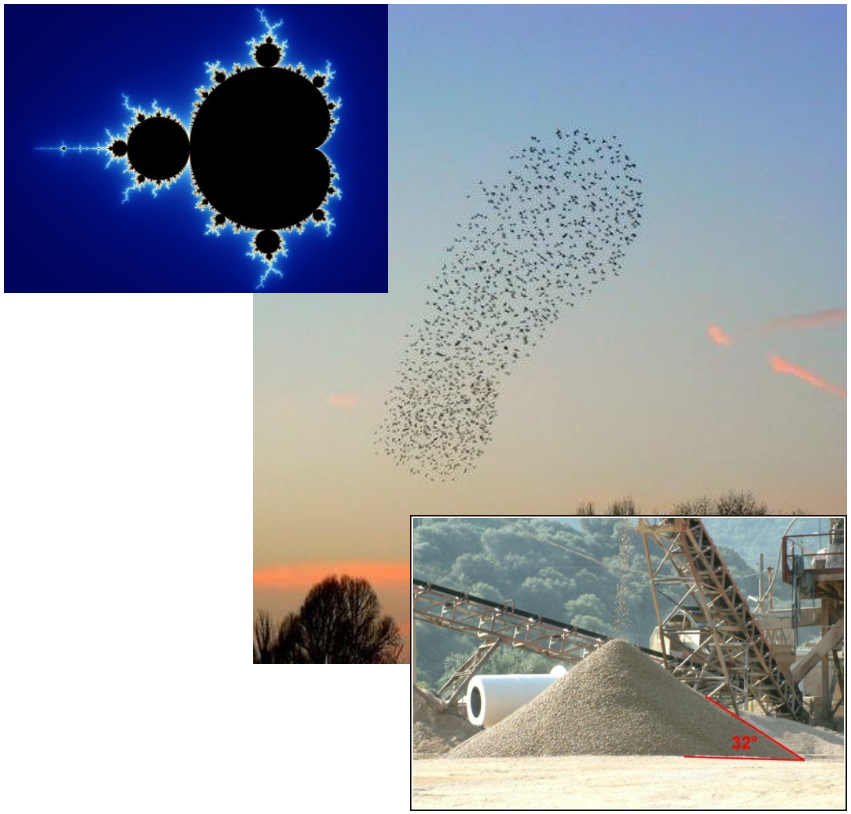
see the Earth system as a whole instead of disconnected parts
(Orion and Ault, 2007)

Here's where it gets "complex"

Complicated systems



Complexity sciences



Systematic review of the Earth education literature

Inclusion criteria
1. Student systems thinking skills addressed
2. Near-surface Earth environments context
3. Some interaction with the geosphere
4. SoTL or DBER (student data reported)
5. Grades 7-16
6. Case or cohort studies
7. Date range: 1991-2015

Research approach

Content analysis

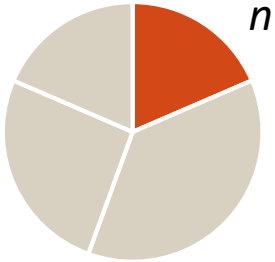
- What are the **characteristics** of studies that address systems thinking in the context of earth systems?

Coding, theme development

- What **conceptual frameworks** for systems are present in the GER literature on systems thinking in the context of earth systems?

Descriptions of interventions and research studies

- How are these conceptual frameworks **operationalized in research and educational interventions** aimed at understanding and supporting systems thinking in the context of earth systems?



Earth systems perspective

high-level interconnections between major Earth spheres

systems thinking abilities

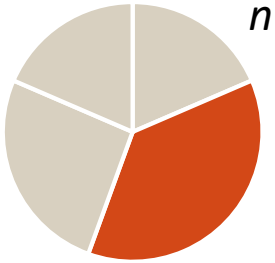
- ✓conceptualizing the Earth system as a whole
- ✓identifying connections between the spheres

Interdisciplinary research *(Hurtt et al., 2006)*

Service learning *(Davies, 2006)*

Place-based *(Davies, 2006)*

Inquiry *(Hurtt et al., 2006)*



n = 10

Earth system thinking skills

transformation of matter in Earth cycles

systems thinking abilities

- ✓identifying and organizing system components, processes, and relationships
- ✓dynamic and cyclic thinking

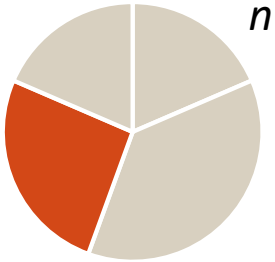
Targeted instruction *(Ben-Zvi Assaraf & Orion, 2009)*

Knowledge integration activities *(Kali et al., 2003; Ben-Zvi Assaraf & Orion, 2005a, 2010)*

Outdoor learning *(Ben-Zvi Assaraf & Orion, 2005a, 2009, 2010)*

Scientific inquiry *(Ben-Zvi Assaraf & Orion, 2005a, 2009, 2010)*

Diagramming *(Sibley et al., 2007; Clark et al., 2009)*



Complexity sciences

scientific study of complex systems

systems thinking abilities

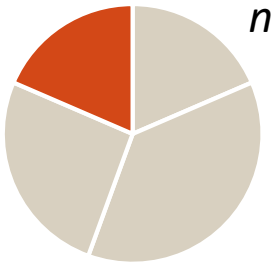
- ✓ recognizing complex system characteristics such as feedbacks, emergence, and self-organization

Computer-based models, simulations, and visualizations
(Fitcher et al., 2010; Hmelo-Silver, 2014)

Learning journals
(Haigh, 2001, 2014)

Teach different forms of causality
(Raia, 2008)

Authentic complex Earth & environmental systems



a specific complex near-surface Earth system or phenomenon

systems thinking abilities

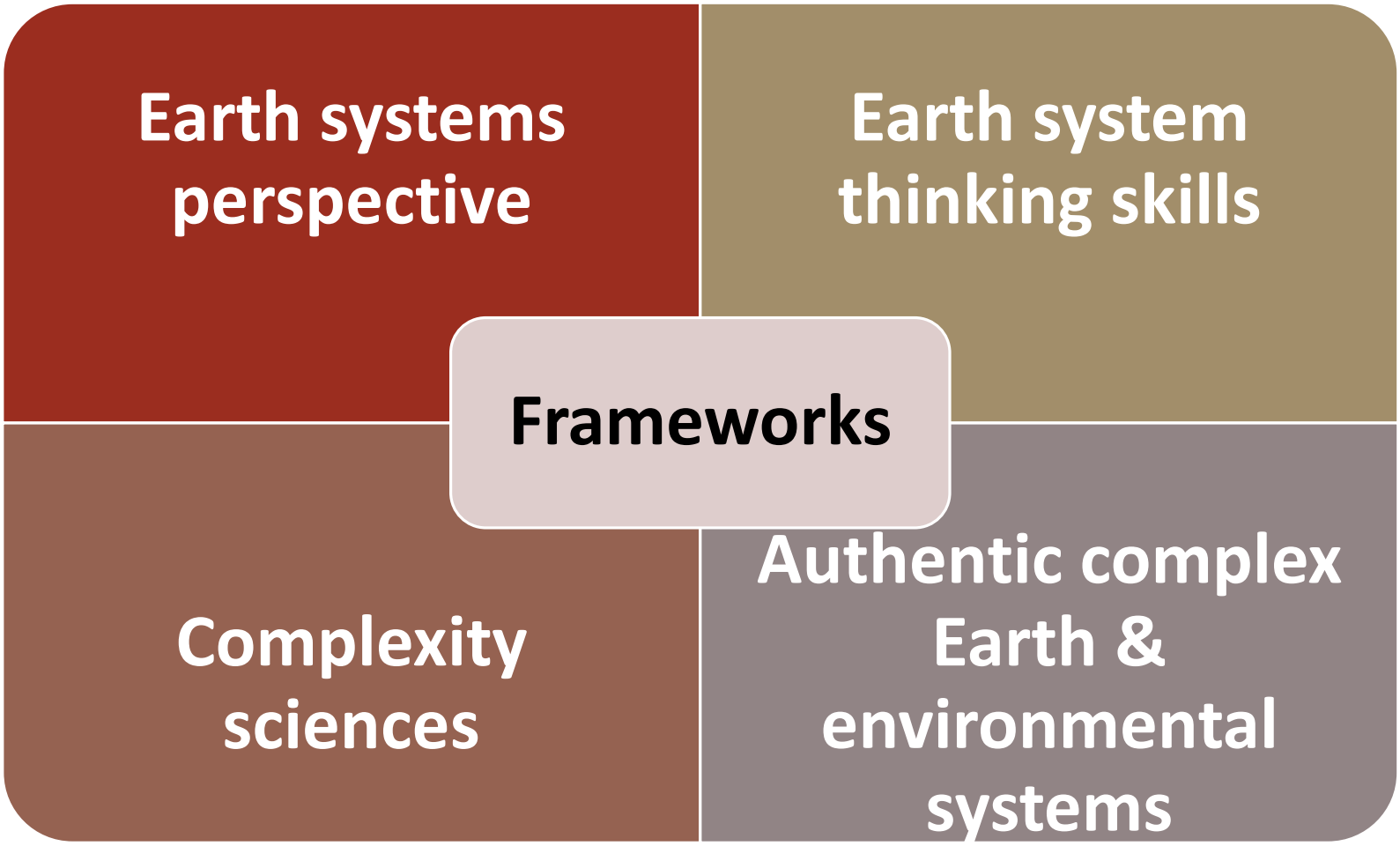
- ✓reasoning about the specific system or phenomenon

Coastal eutrophication: Inquiry, multiple representations *(Sell et al., 2006; McNeal et al., 2008)*

Ecosystem dynamics: virtual environment *(Grotzer et al., 2013)*

Soil microbial activity: authentic laboratory exercise *(Appel et al., 2014)*

Implications for teaching



Unit 5: Predicting the effects of climate change on soil loss

Module goal: Predict, using systems thinking, agricultural challenges that might result from climate change

Unit goals:

1. Explain how rainfall and runoff erosivity, soil properties, landscape characteristics, and agricultural practices contribute to soil erosion.
2. Differentiate between natural and human influences on soil sustainability.
3. Analyze, using systems thinking, how changes in precipitation predicted in climate change models for their region will impact erosion rates.

http://serc.carleton.edu/integrate/teaching_materials/sustain_agriculture/activity5.html

Authentic complex Earth and environmental systems

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Earth systems perspective

Unit 5: Predicting the effects of climate change on soil loss

Module goal: Predict, using systems thinking, agricultural challenges that might result from climate change

Explain how perturbations in the climate system (atmosphere) could impact agricultural sustainability by producing changes in the geosphere, hydrosphere, and biosphere.

Earth system thinking skills

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2. Differentiate between natural and human influences on soil sustainability.
3. Analyze, using systems thinking, how changes in precipitation predicted in climate change models for their region will impact erosion rates.
4. Identify physical and bio-chemical cycles that influence agricultural systems.

Complexity sciences

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1. Explain how soil properties, landscape characteristics, and agricultural practices contribute to soil erosion.
2. Differentiate between natural and human influences on soil sustainability.
3. Analyze, using systems thinking, how changes in precipitation predicted in climate change models for their region will impact erosion rates.

Describe potential positive and negative feedbacks in models of soil erosion.

Explain how soil conservation practices could contribute to resilience in an agricultural system.

Planning for instruction

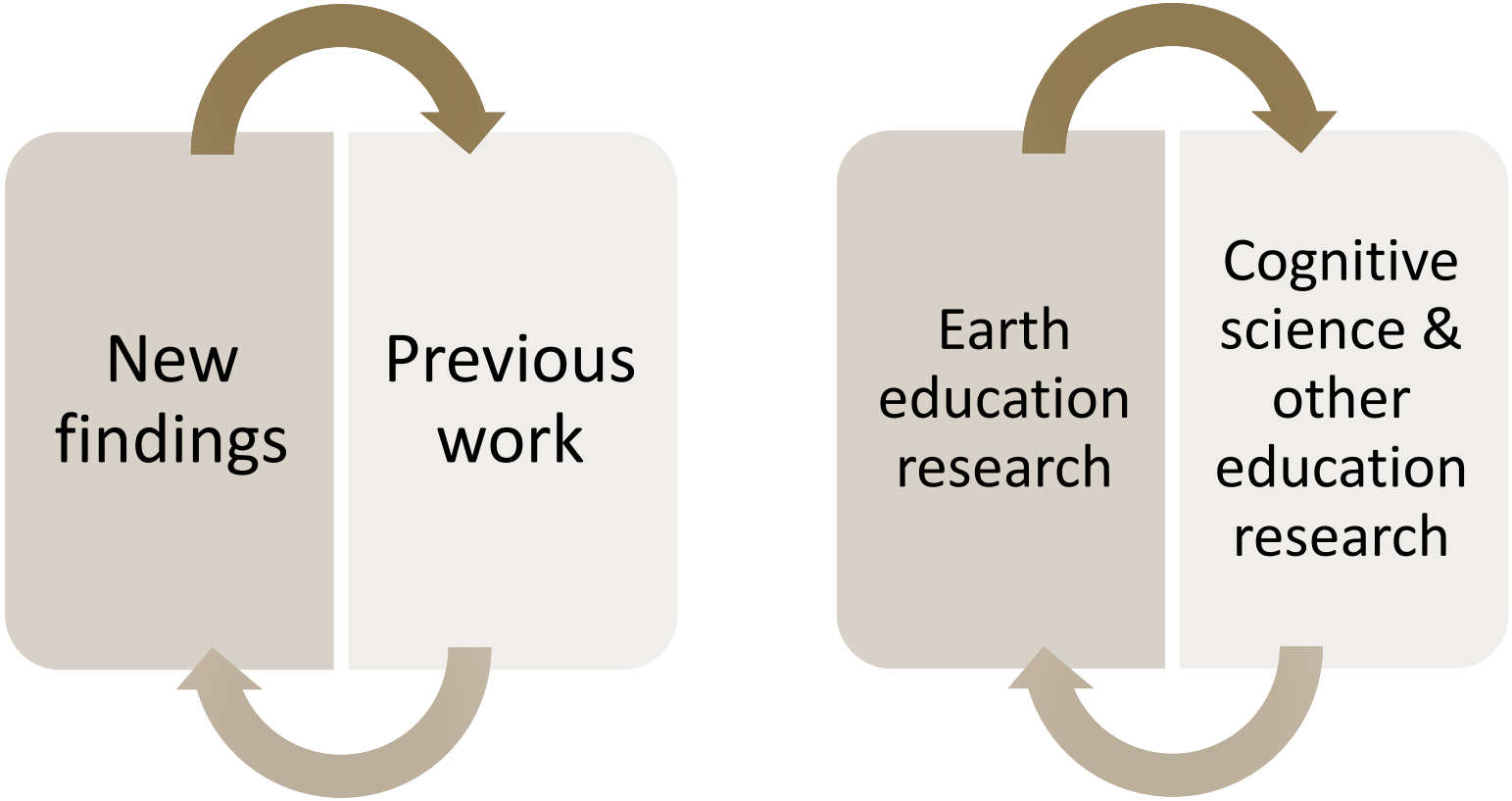
What type of system am I teaching about?

What are its important characteristics?

What systems concepts and processes do my students need to understand in order to reason about this system?

How does this system relate to other systems they have encountered?

Implications for research



Thanks!

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