

How Do We Know How Students Approach Complexity

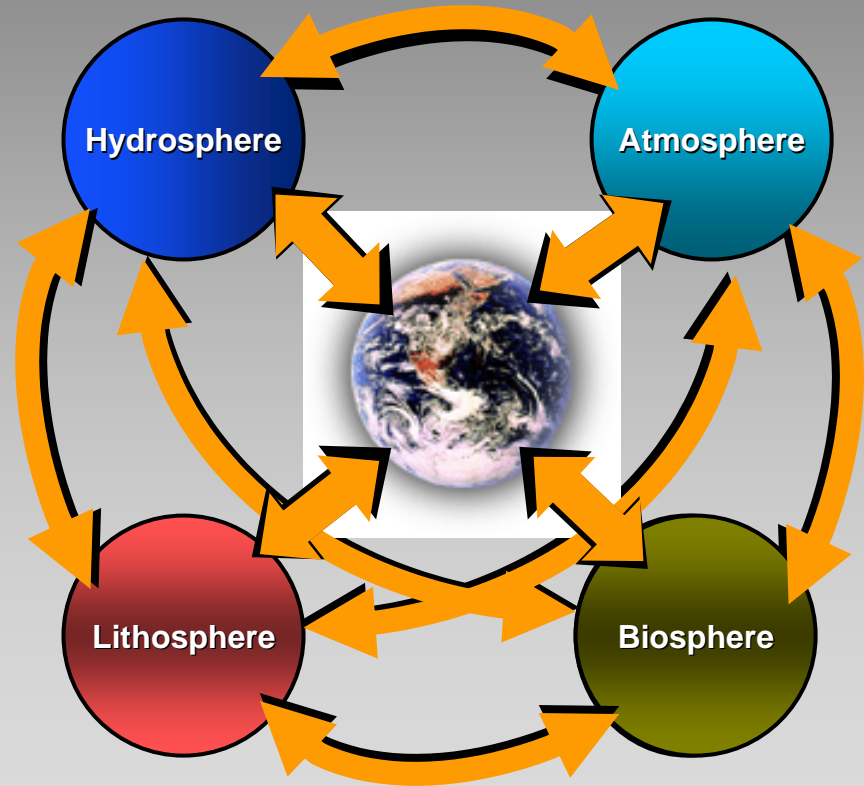
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NASA's MISSION 1

To Understand and Protect Our Home Planet We Must Approach Earth as a System:

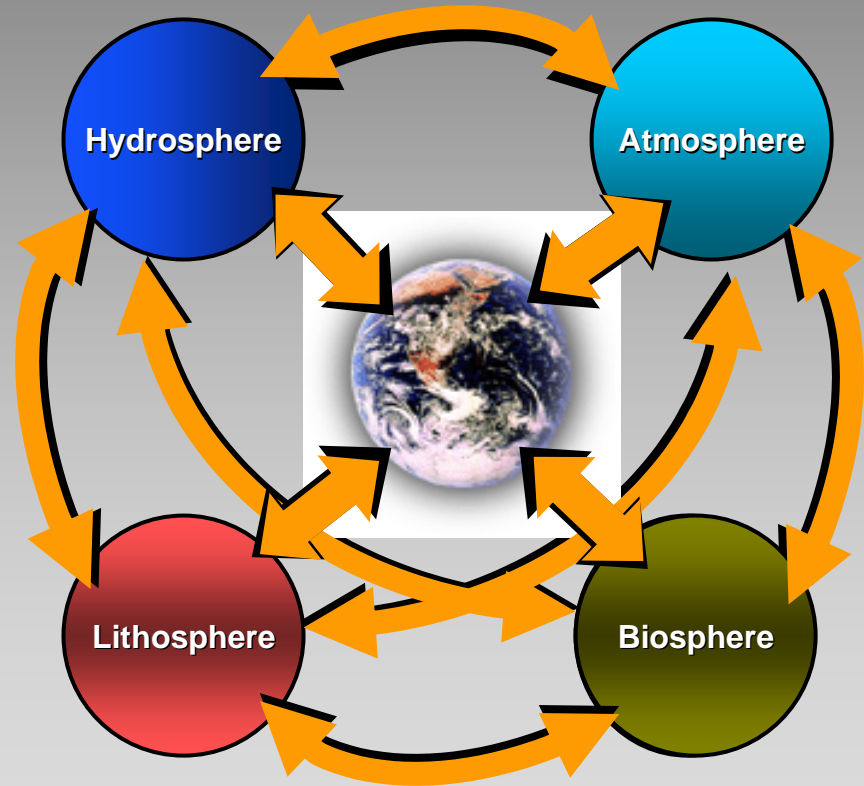
*a view of our planet as
a single, integrated
dynamic system
governed by complex
relations among the
Spheres*



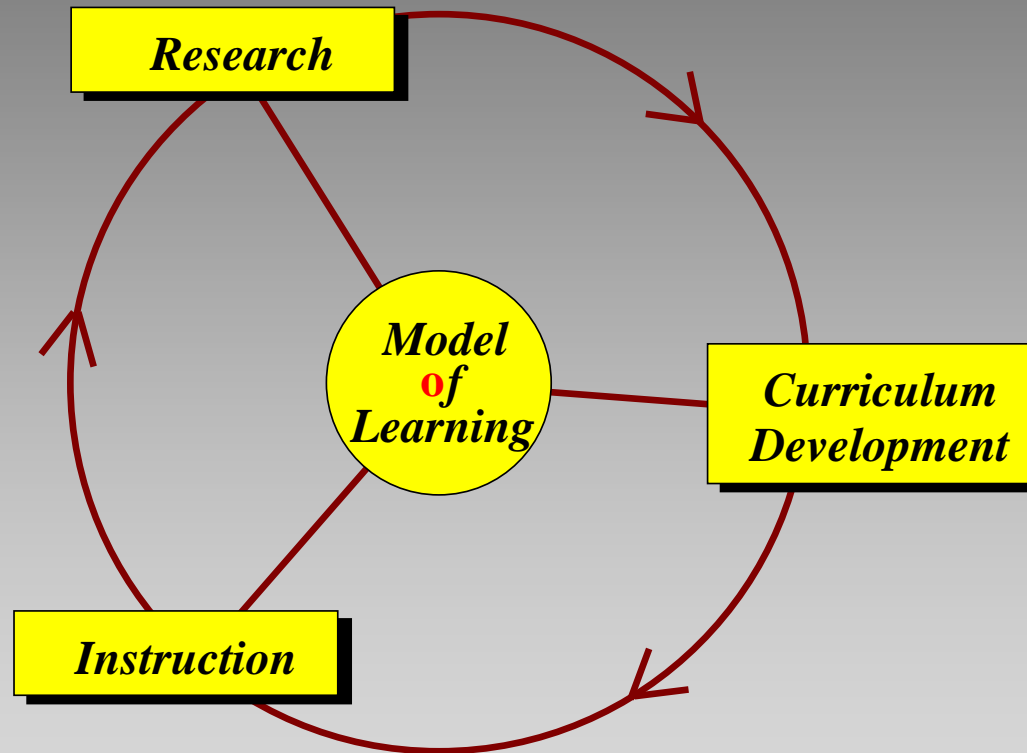
Complex Dynamic Systems

What do these words and concepts mean to us? What do they mean to our students?

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Student-Centered Research-Based Model of Instruction: how do we know what students know?



* Redish, Saul, and Steinberg. *Am J. Phys*, 66. 1998

STUDY HYPOTHESIS

Students entering college have a linear mono-causal approach to complex dynamic systems which is inadequate to

- ***approach the complexities of natural phenomena***
- ***understand our living planet***

Generative Question

Many of us had observed at times a goose flock flying in a V shape. How do you think that shape arises?



Vicsek, et al., 1995; Czirok and Vicsek, 2001; Schechter, 1998.

ANSWER to Generative Question

Roy: “They arrange themselves according to the rank. The king patriarch (male) is the one who leads and the others follow according to the rank position”.

Janie: “An older leader, not necessarily a male, it is in the center front”

Amy: “Each goose instinctively knows its role in relation to the pack”

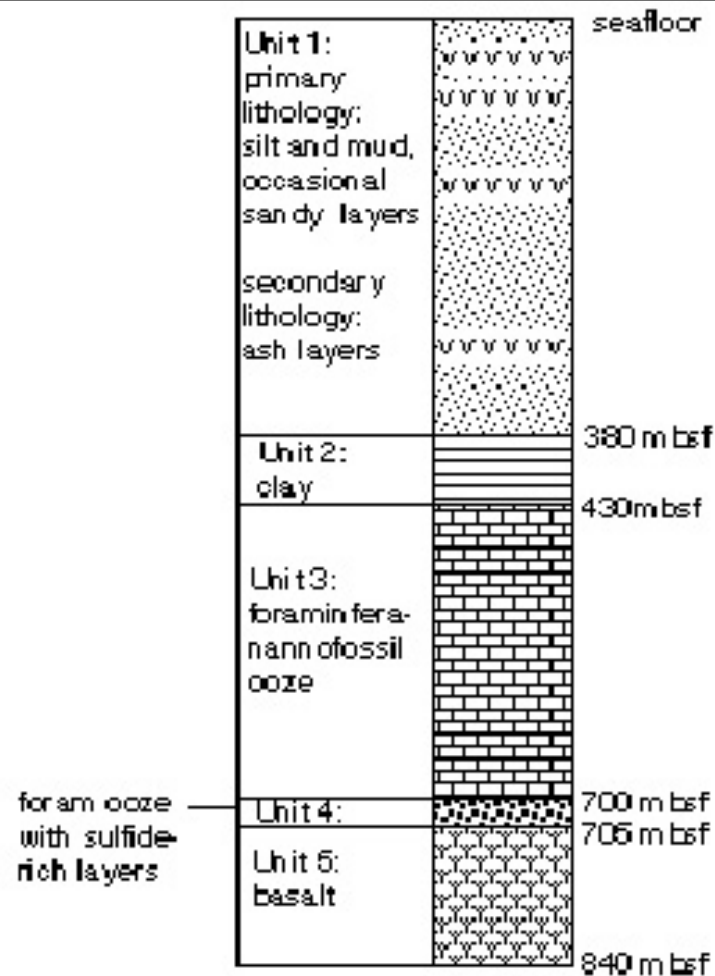
Geese “must have” a specific gene that “force them to know.”

Question 1

Imagine that you are aboard the scientific drillship *Joides Resolution*, drilling in 7500m water depth, and you recover the section illustrated below.

Develop a hypothesis that could account for the observed sequence of rock and sediment types.

Kastens, K. A., 2000



Question 2

What do you know about the glaciations that the Northern Hemisphere experienced about 2.6 million years ago and left in our city visible evidences (moraines, boulders etc)?

3.a Please describe how can you account such climate change

3.b Draw your model(s)

3.c Explain your model(s)

Analysis of Students' Responses

	LINEAR-MONO-CAUSAL	COMPLEX DYNAMIC SYSTEM
	Categories	
1	Skipping levels	Recognizing Contiguous levels
2	Enumerating components	Considering Components and Their Interactions
3	Seeking <i>Lead</i> Entity	Recognizing Emergent Property
4	Recognizing only Upward <u>OR</u> Downward causation	Considering Emergent Property <u>AND</u> Downward Causation
5	Establishing Connections Through Accidental Factors or Forced Interaction	Establishing Relations Between Levels of Different Properties
6	Landmark view	Dynamic view

Question 1

S	Enumeration - Seeking Components C 2		Lead Entity C 3		Forced Interaction C 5		Landmark View C 6		Components and their Interactions C 2		Emergent Property C 3	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1			X	X	X	X	X	X				
2			X	X	X	X	X	X				
3			X	X	X	X	X	X				
4			X	X	X	X	X	X				
5	X			X		X	X	X				
6	X			X		X	X	X				
7	X			X		X	X	X				
8	X	X					X	X				
9									X	X	X	X
10									X	X	X	X
11	X			X	X	X	X	X				
12	X			X	X	X	X	X				
13			X	X	X	X	X	X				
14			X	X	X	X	X	X				
15			X	X	X	X	X	X				
16			X	X	X	X	X	X				
Total	6	1	8	13	10	12	14	14	2	2	2	2

ANSWERS to Question 1

Jack: “The basalt being at the bottom implies that it is the oldest layer. My hypothesis is that at first a volcano erupted depositing basalt. Then the ocean formed over it. [..] The foram population was very small during unit 4 then grew so there is large deposition of fossils. [...] Erosion from continents (would contribute to) form unit 2. This process continued during unit 1”

There are two possible explanations: one a volcanic eruption the other a meteorite impact”

ANSWER to Question 2

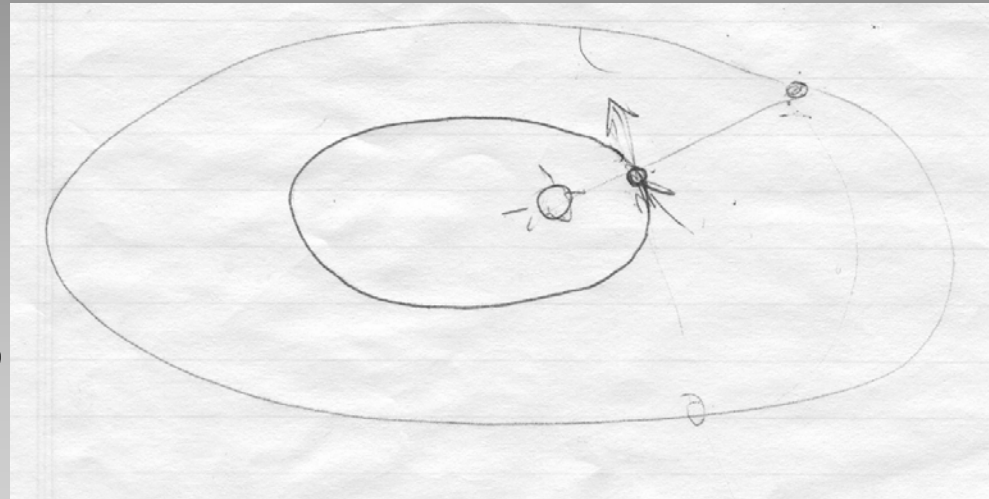
Lee “Earth Temperature = Input of Energy from the sun – Output Energy from Earth”.

“Hypothesis 1 : input Energy from sun might have been less than now”

“Hypothesis 2: Output Energy from Earth might have been much greater than now. So, that could cause the Earth Temperature cool down”

to change the input : “*a supreme intelligence ... God is necessary*”

Leroy: “Meteorite impacting Earth’s orbit”



Students Understanding of complexity

The Science Education Challenge Ahead: A Shift in Paradigm

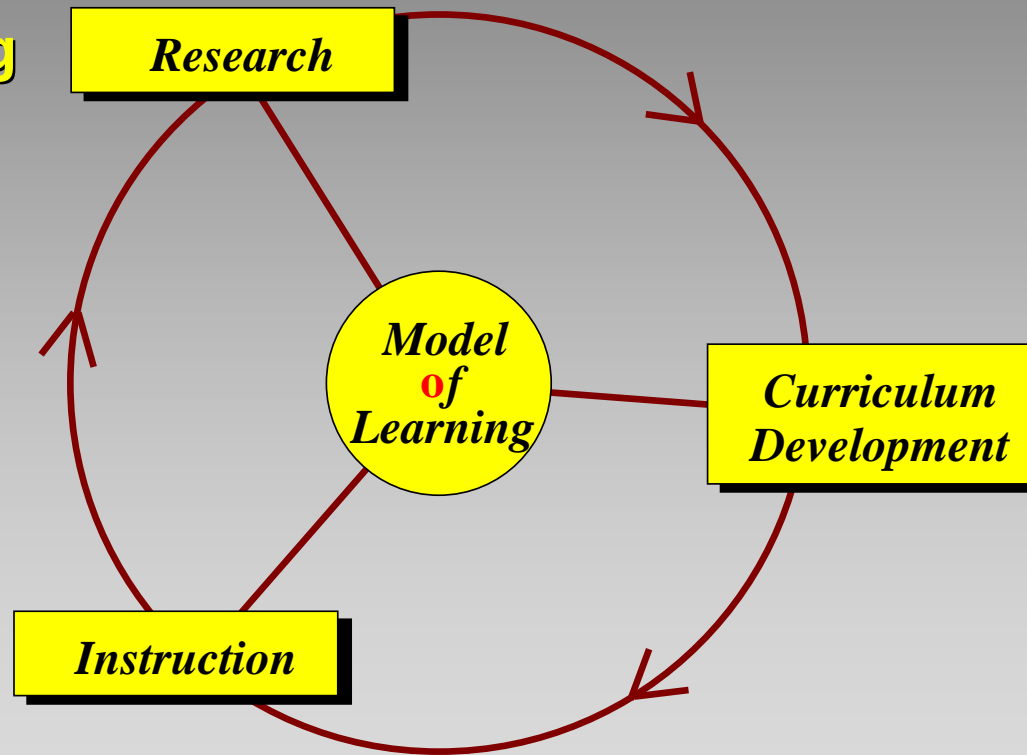
A Students seem to address complexity with a linear- mono-causal approach:

- discount interactions among components and emergent phenomena,**
- confuse levels of interactions and force connection among levels through only accidental external factors or a lead entity.**

Conclusion

Research-Based Model of Instruction

Assessment of students learning is based on Research of their understanding

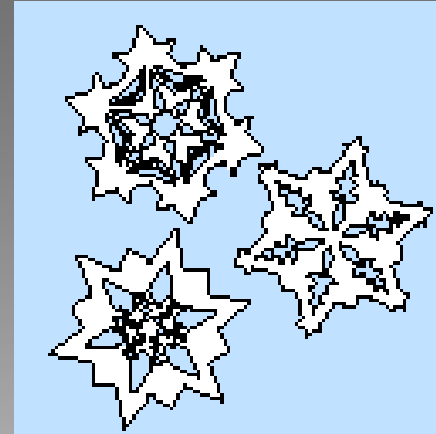


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On going research

Interview Questions

1 Although each crystal is unique, as snow crystals shown in the figure, they have a specific symmetry that is common for all crystal of same composition. Describe in details how do you think the symmetry of crystals arises



2. Dinosaurs became extinct, as it happened with other species. How can that happen? Develop a hypothesis that could account for the extinction of a species.

3 Imagine to have 4 containers like the one sketched below. Each contains the same amount of material. Container 1 is filled with clay, container 2 with sand, container 3 with gravel and container 4 with soil. has different material the same amount of material is stored. How long will the water take to pass through each material?

