Overview: Learning Progressions that Connect Science Practices, Crosscutting Concepts, and Disciplinary Core Ideas

Related Paper Set Presented at the Annual Meeting of the National Association for Research in Science Teaching, Pittsburgh, April 2, 2014

Website: http://edr1.educ.msu.edu/EnvironmentalLit/index.htm

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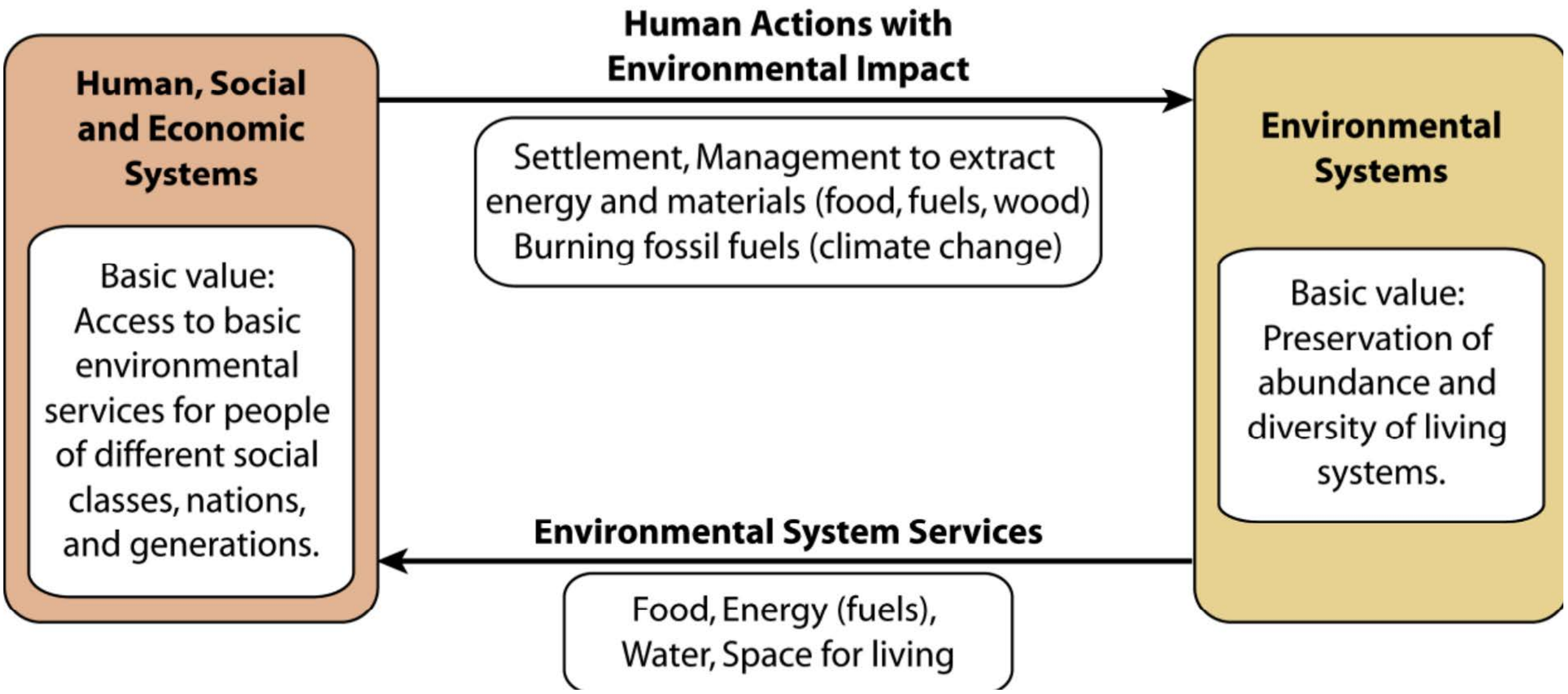
Definitions

- *Environmental science literacy* is the capacity to understand and participate in evidence-based discussions of socio-ecological systems.
- *Learning progressions* are descriptions of increasingly sophisticated ways of thinking about or understanding a topic

Defining Environmental Science Literacy: Processes in Socio-ecological Systems



Strands of Environmental Science Literacy

- *Carbon.* Carbon-transforming processes in socio-ecological systems at multiple scales, including cellular and organismal metabolism, ecosystem energetics and carbon cycling, carbon sequestration, and combustion of fossil fuels.
- *Water.* The role of water and substances carried by water in earth, living, and engineered systems, including the atmosphere, surface water and ice, ground water, human water systems, and water in living systems.
- *Biodiversity.* The diversity of living systems, including variability among individuals in population, evolutionary changes in populations, diversity in natural ecosystems and in human systems that produce food, fiber, and wood.

Inquiry: Developing Scientific Knowledge

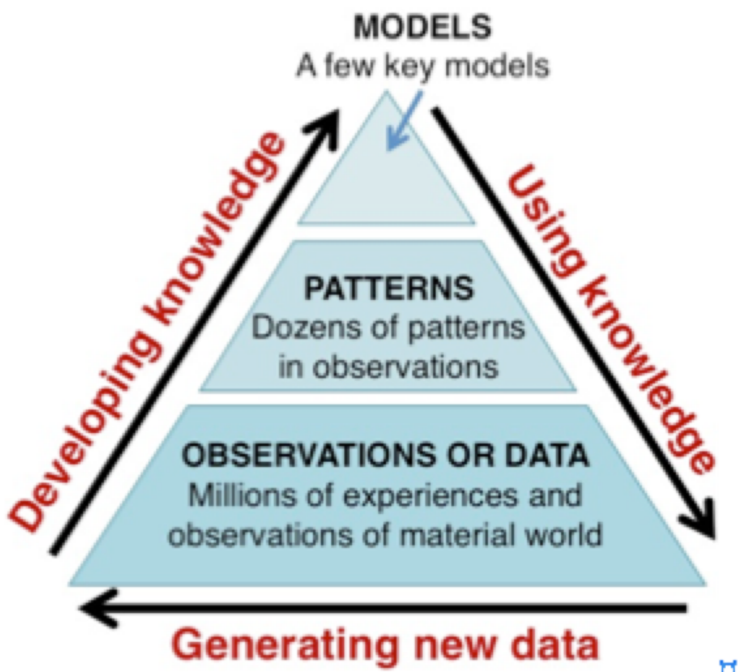
1. Asking questions (for science) and defining problems (for engineering)

2a. Developing **models**

3. Planning and carrying out investigations

4. Analyzing and interpreting **data**

7. Engaging in **argument** from **evidence**



Application: Using Scientific Knowledge

2b. Using **models**

6. Constructing **explanations** (for science) and designing solutions (for engineering)

General Practices Associated with the Three Arrows

5. Using mathematics and computational thinking

8. Obtaining, evaluating, and communicating information

NGSS Focus for this Work

- Three key *practices*: interpreting and analyzing data, engaging in arguments from evidence, and constructing explanations.
- Two *crosscutting concepts:* systems and system models, and energy and matter: flows cycles, and conservation.
- *Disciplinary core ideas* in the life sciences (LS 1: From molecules to organisms: Structures and processes; LS 2: Ecosystems: Interactions, energy, and dynamics), Earth sciences (ESS 2: Earth’s systems; ESS 3: Earth and human activity), and physical sciences (PS 1: Matter and its interactions; PS 3: Energy)

Learning Progressions Include:

- A **learning progression framework**, describing levels of achievement for students learning (Model of cognition)
- **Assessment tools** that reveal students' reasoning: written assessments and clinical interviews (Observation and interpretation)
- **Teaching tools and strategies** that help students make transitions from one level to the next (Empirical validation)

What Progresses?

- **Discourse:** “a socially accepted association among ways of using language, of thinking, and of acting that can be used to identify oneself as a member of a socially meaningful group” (Gee, 1991, p. 3)
- **Practices:** inquiry, accounts, citizenship
- **Knowledge** of processes in human and environmental systems

Learning Progression Levels of Achievement for Carbon Accounts

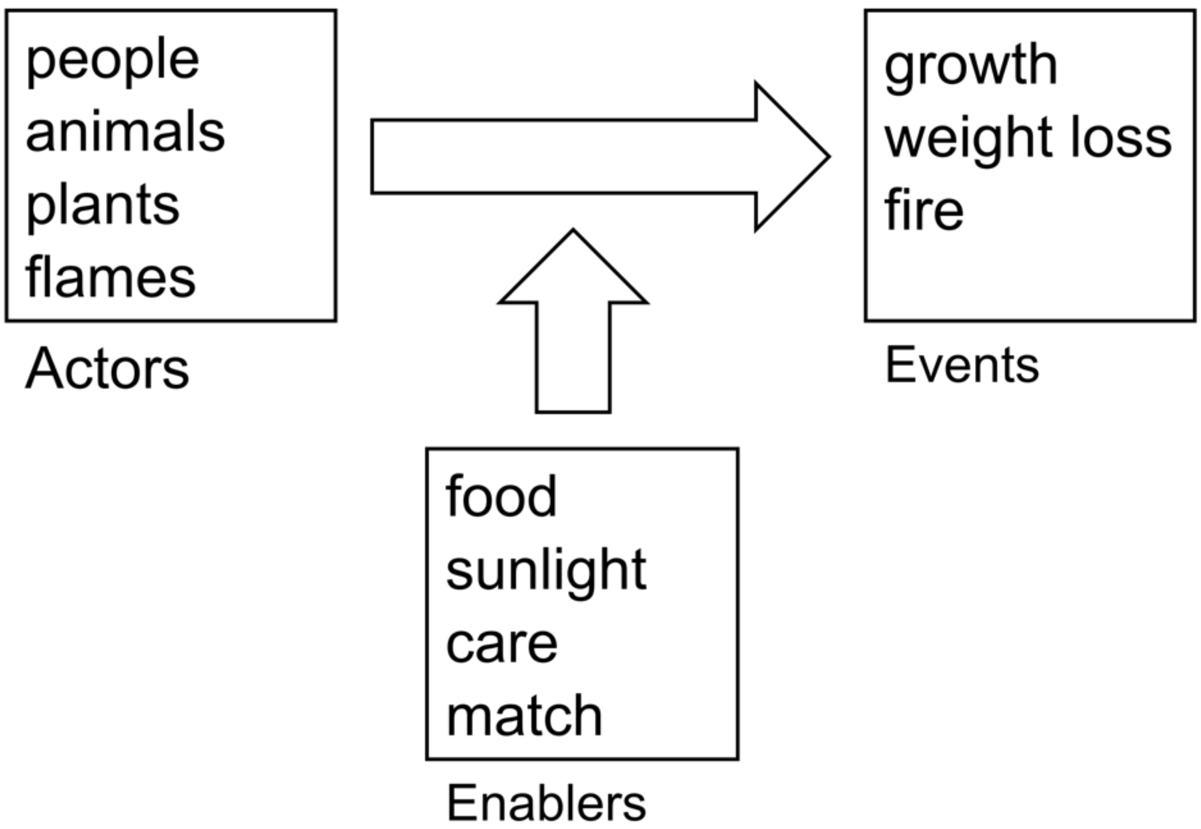
Level 4: Coherent scientific accounts: Students successfully trace matter and energy through carbon-transforming processes at multiple scales in space and time (generally consistent with current national science education standards and with the draft framework for new standards).

Level 3: Incomplete or confused scientific accounts: Students show awareness of important scientific principles and of models at smaller and larger scales, but they have difficulty connecting accounts at different scales and applying principles consistently.

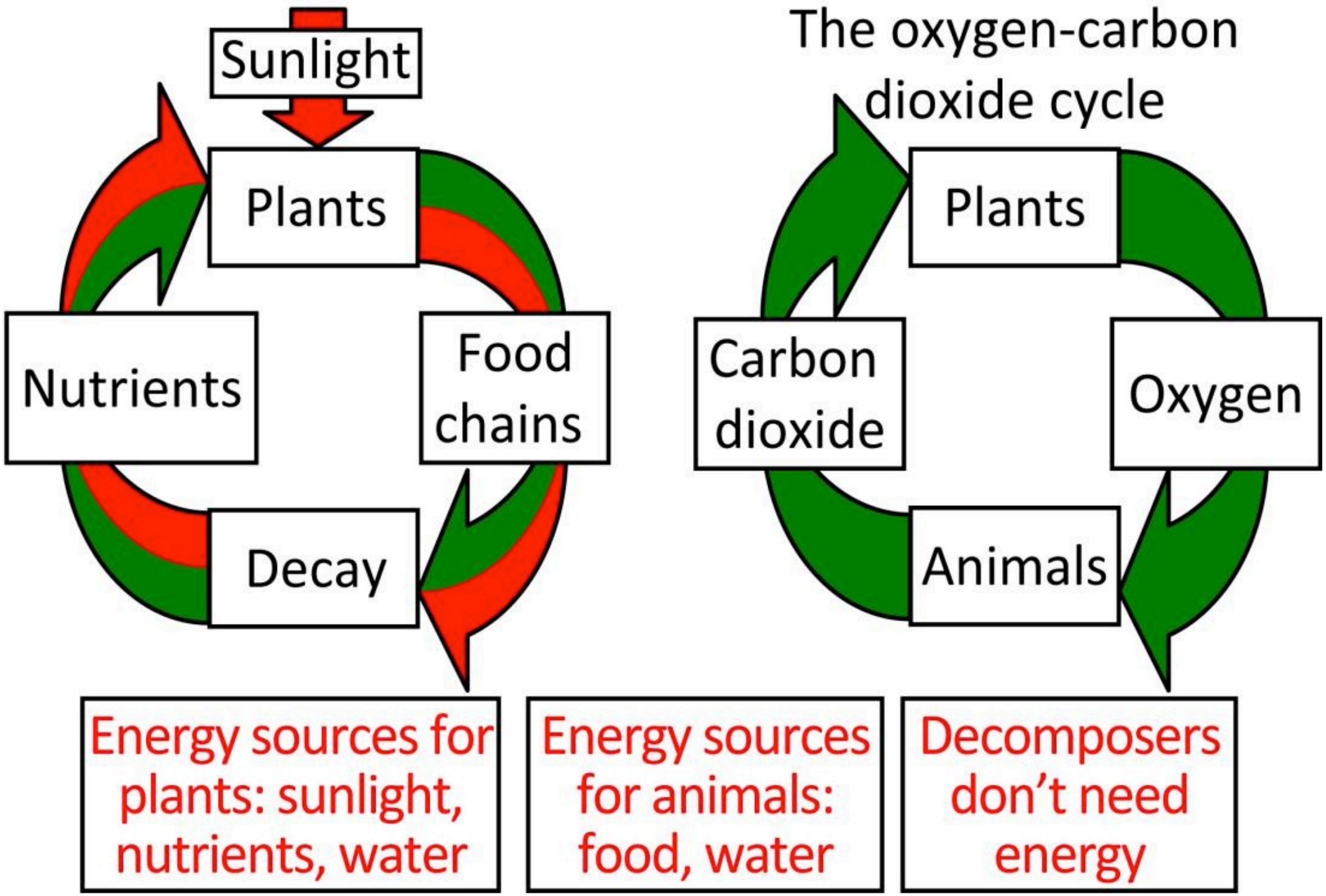
Level 2: Elaborated force-dynamic accounts: Students' accounts continue to focus on actors, enablers, and natural tendencies of inanimate materials, but they add detail and complexity, especially at larger and smaller scales.

Level 1: Simple force-dynamic accounts: focus on actors, enablers, and natural tendencies of inanimate materials, using relatively short time frames and macroscopic scale phenomena.

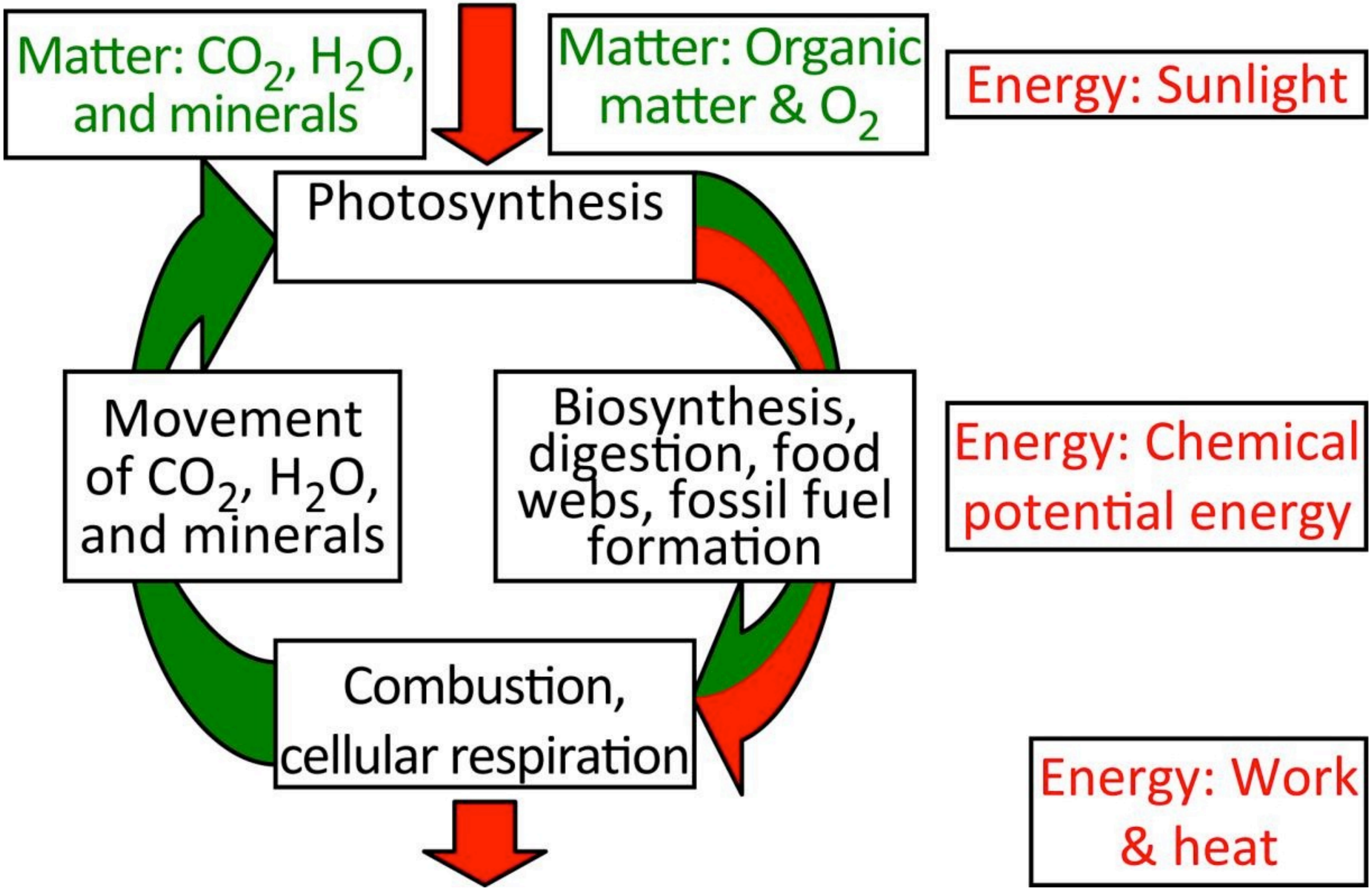
Levels 1 and 2: Actors Using Enablers to Accomplish Purposes



Level 3: Nutrient and O_2-CO_2 Cycles



Level 4: Carbon Cycling and Energy Flow



Data Sources

Type of Data	Baseline Data	Pre-assessments	Post-assessments	Papers in this set
Cohort 1 written assessments	661	474	939	
Cohort 2 written assessments	184	550	983	
Cohort 2 interviews		25	25	1, 2
Large-scale interviews	30			3
Sustainability interviews	33			4

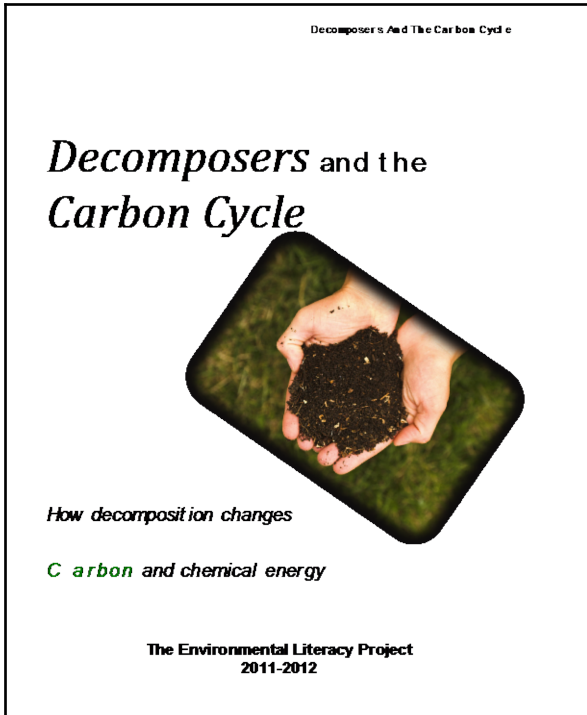
Carbon TIME Curriculum (available on National Geographic Website, 2015)

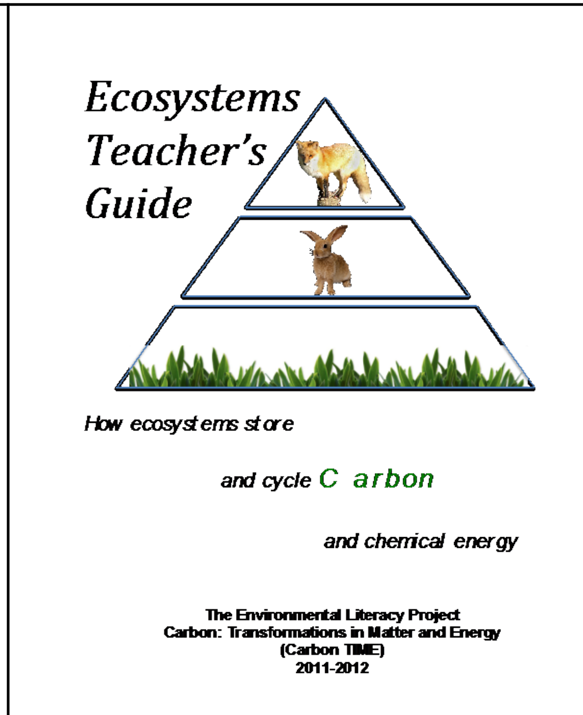
Systems and Scale 1 *Systems* and *Scale Teacher's Guide*  *How our systems depend on Carbon and chemical energy: Finding chemical change in life and lifestyles* **The Environmental Literacy Project** **Carbon: Transformations in Matter and Energy** **(Carbon TIME)** **2011-2012**	Plants and the Carbon Cycle  *How seeds grow to trees and plants transform Carbon* **The Environmental Literacy Project** **Carbon: Transformations in Matter and Energy** **(Carbon TIME)** **2011-2012**	*Animals* and the *Carbon Cycle*  *How animals use and change Carbon and chemical energy* **The Environmental Literacy Project** **2011-2012**
Powers of 10 Combustion	Photosynthesis Biosynthesis Cellular respiration	Digestion Biosynthesis Cellular respiration

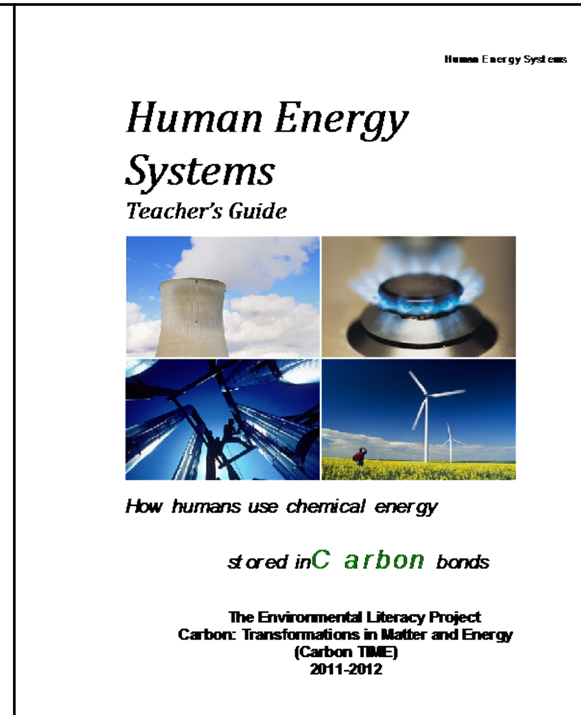
PROCESSES

KBS LTER
Kellogg Biological Station
Long-term Ecological Research

Carbon TIME Curriculum, cont.







PROCESSES			
	Digestion Biosynthesis Cellular respiration	All processes except combustion in ecosystems	Combustion of fossil fuels for energy

KBS LTER
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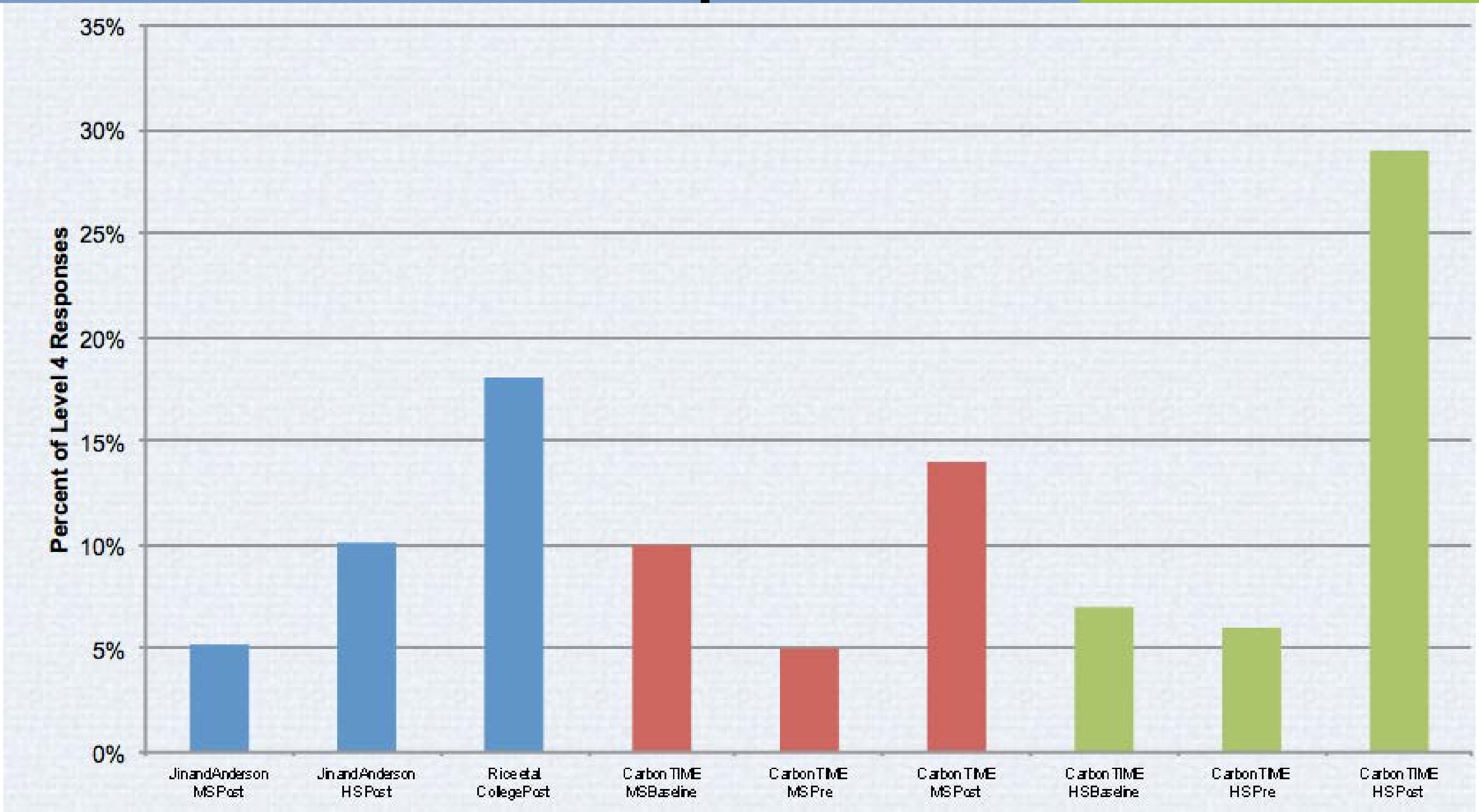
Percentages of Level 4 Responses



Blue: Comparison groups: Middle school, high school, college science majors

Red: Carbon TIME middle school: baseline, pre, post

Green: Carbon TIME high school: baseline, pre, post

IRT-based Analyses of Cohorts 1 and 2

Category	N.Pre	N.Post	Pre. mean	Pre. sd	Post. mean	Post. sd	Logit Gain	Effect size
Cohort 1 (11-12) Pre/Post	462	462	-0.67	0.80	0.46	1.39	1.13	1.00
Cohort 2 (12-13) Pre/Post	503	503	-0.78	0.87	0.48	1.25	1.26	1.17

Presentations in this Session

Paper 1: Learning trajectories of Principle-Oriented Level 3 and Fact-Oriented Level 3 science learners, by Hannah Miller, Allison Freed, Jenny Dauer, Jennifer Doherty, and Charles W. Anderson

Paper 2: Relationships between students' inquiry and application practices for carbon-transforming processes, by Allison Freed, Jenny Dauer, Hannah Miller, and Charles W. Anderson

Paper 3: Connecting macroscopic-scale and large-scale inquiry practices, by Jenny Dauer, Allison Freed, and Charles W. Anderson

Paper 4: Students' ideas about sustainability for agricultural production systems, by Elizabeth Xeng de los Santos, Sarah Stapleton, and Charles W. Anderson

Paper 1: What components of Level 3 reasoning help students advance to Level 4?

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Paper 2: Relationship between inquiry and application practices

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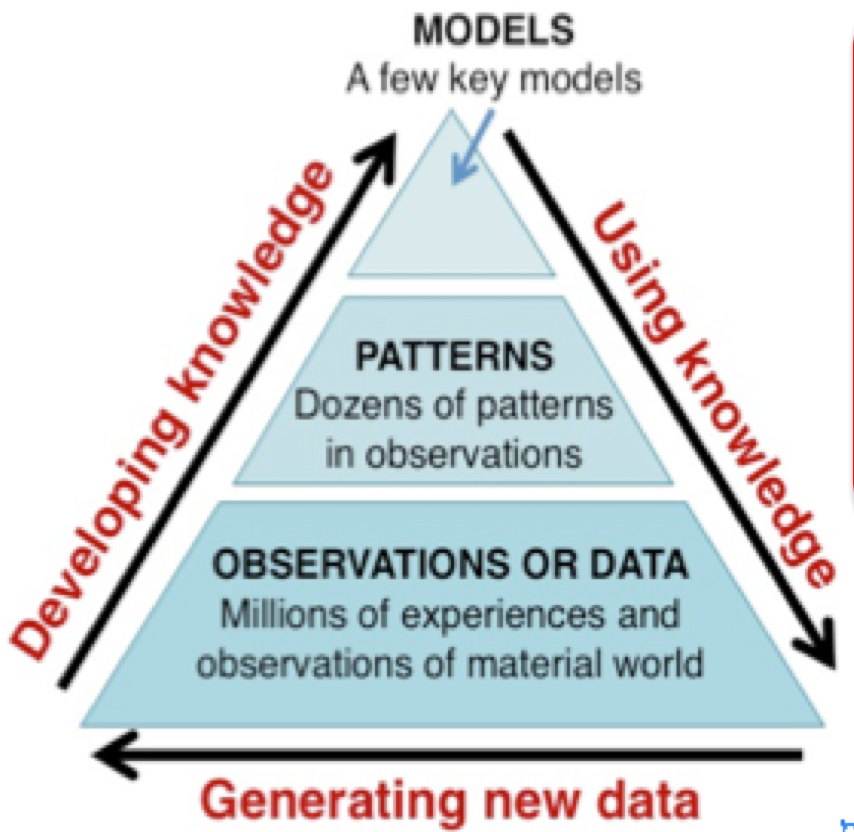

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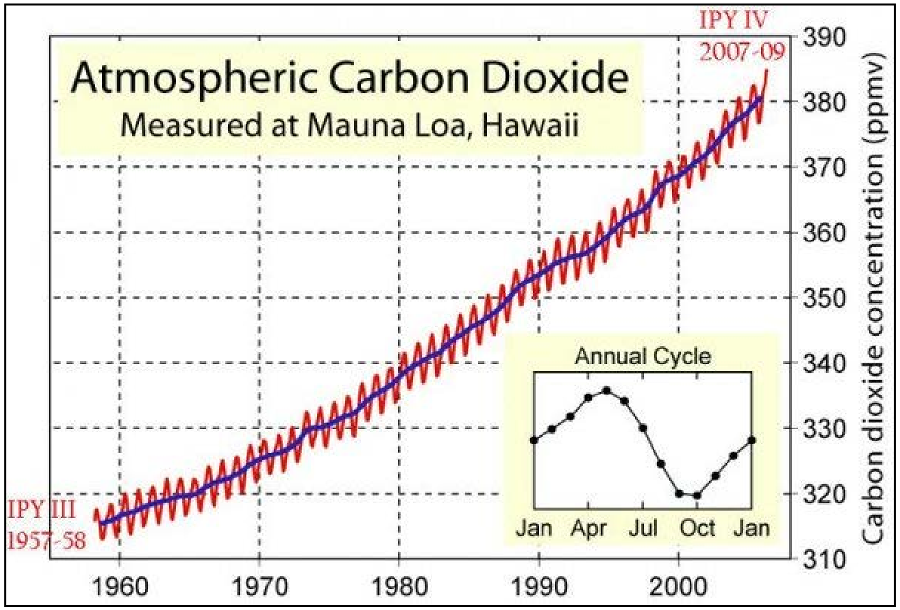
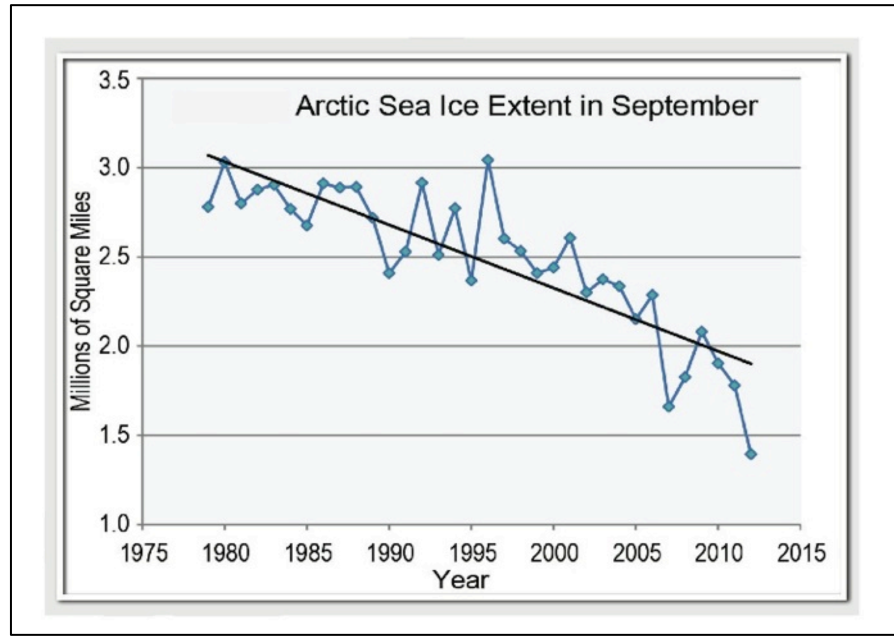
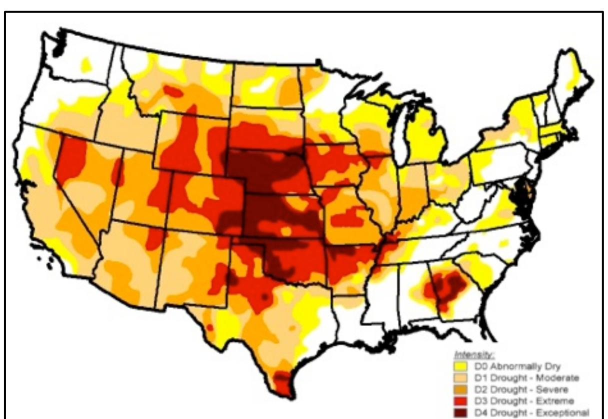
Paper 3: Investigating students' reasoning about large-scale data and climate change







Paper 4: Students' reasoning about sustainability