Connecting NGSS to Other Literacy Initiatives: An Update of the Rainbow Chart of Earth Science Bigger Ideas

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Overarching Questions:
How do we know what we know? How does what we know inform our decision making?

Bigger Ideas (*ReaL Earth System Science* http://virtualfieldwork.org/Big_Ideas.html)		*The Next Generation Science Standards* http://nextgenscience.org: Scientific and Engineering Practices	Crosscutting Concepts	Earth & Space Science Core Ideas	Ocean Literacy Principles http://coexploration.org/oceanliteracy/documents/OceanLitChart.pdf	Climate Literacy Principles http://climateliteracynow.org	Atmospheric Science Literacy Principles http://eo.ucar.edu/asl/index.html	Earth Science Literacy Big Ideas http://www.earthscienceliteracy.org/	Energy Literacy Principles http://www1.eere.energy.gov/education/energy_literacy.html
System	**Earth is a system of systems.**	Asking Questions and Defining Problems	Systems and System Models	Dimension 3: Disciplinary Core Ideas: Earth & Space Science — **ESS2: EARTH'S SYSTEMS** *How and why is the earth constantly changing?*	The ocean is a major influence on weather and climate.	Climate is regulated by complex interactions among components of the Earth system.	Earth's atmosphere continuously interacts with the other components of the Earth System.	Earth is a complex system of interacting rock, water, air, and life.	Physical processes on Earth are the result of energy flow through the Earth system.
Energy	**The flow of energy drives the cycling of matter.**	Planning and Carrying Out Investigations	Patterns		The ocean supports a great diversity of life and ecosystems.	Life on Earth depends on, has been shaped by, and affects climate.	Energy from the Sun drives atmospheric processes.	Humans significantly alter the Earth.	Biological processes depend on energy flow through the Earth system.
Life	**Life, including human life, influences and is influenced by the environment.**	Analyzing and Interpreting Data	Energy and Matter	**ESS3: EARTH AND HUMAN ACTIVITY** *How do Earth's surface processes and human activities affect each other?*	The ocean makes Earth habitable.	The Sun is the primary source of energy for Earth's climate system.	Atmospheric circulations transport matter and energy.	Humans depend on Earth for resources.	Various sources of energy can be used to power human activities, and often this energy must be transferred from source to destination.
		Using Mathematics and Computational Thinking			The ocean and humans are inextricably interconnected.	Climate change will have consequences for the Earth system and human lives.	Earth's atmosphere and humans are inextricably linked.	Natural hazards pose risks to humans.	The quality of life of individuals and societies is affected by energy choices.
Change	**Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.**	Constructing Explanations and Designing Solutions	Cause and Effect		The ocean and life in the ocean shape the features of the Earth.	Human activities are impacting the climate system.	Earth has a thin atmosphere that sustains life.	Earth scientists use repeatable observations and testable ideas to understand and explain our planet.	Energy decisions are influenced by economic, political, environmental, and social factors.
		Engaging in Argument from Evidence	Structure and Function		The Earth has one big ocean with many features.	**Humans can take actions to reduce climate change and its impacts.**	Earth's atmosphere changes over time and space, giving rise to weather and climate.	Life evolves on a dynamic Earth and continuously modifies Earth.	Energy is a physical quantity that follows precise natural laws.
Models	**To understand (deep) space and time, models and maps are necessary.**	Obtaining, Evaluating, and Communicating Information	Stability and Change	**ESS1: EARTH'S PLACE IN THE UNIVERSE** *What is the universe, and what is Earth's place in it?*	The ocean is largely unexplored.	Climate varies over space and time through both natural and man-made processes.	We seek to understand the past, present, and future behavior of Earth's atmosphere through scientific observation and reasoning.	Earth is continually changing.	The amount of energy used by human society depends on many factors.
		Developing and Using Models	Scale, Proportion, and Quantity			Our understanding of the climate system is improved through observation, theoretical studies and modeling.		Earth is 4.6 billion years old.	
								Earth is the water planet.	

A coherent conceptual framework

The Essential Principles and Big Ideas from the Literacy Principles documents represent important consensuses about the most important ideas within each discipline, but also represent a challenge to educators. Collectively, they include 38 ideas and 247 concepts, all at the commencement level. There are *no* examples of creating sets of ideas everyone should understand about *any* topic that has led to broad understanding the target content, in spite of countless attempts to do just that throughout history. Without a coherent framework to connect them one to another, it isn't likely that learners will understand or remember them. This "Rainbow Chart" is intended to illustrate those connections.

What do the colors mean?

Each bigger idea has a unique color, and the overarching questions tie this rainbow of colors together and appear white when ideas or principles from the other idea sets reflect the nature of science that is inherent in those questions. Each set of literacy principles addresses all Bigger Ideas and the overarching questions.

What makes ideas bigger?

A bigger idea has the following characteristics:

- The idea cuts across the Earth science curriculum.
- Understanding of the idea is attainable by students and the understanding holds promise for retention.
- The idea is essential to understanding a variety of topics.
- The idea requires uncoverage; has a bottomless quality.

Furthermore, the entire Earth science curriculum is represented by this (small) set of ideas.

Overarching Questions: **How do we know what we know? How does what we know inform our decision-making?**

Earth System Science Bigger Ideas	Systems	Energy	Life	Change	Models
	The Earth is a System of Systems.	**The Flow of Energy Drives the Cycling of Matter.**	**Life, including human life, influences and is influenced by the environment.**	**Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.**	**To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.**
	The Earth System is composed of and part of a multitude of systems, which cycle and interact resulting in dynamic equilibrium (though the system evolves). The Earth is also nested in larger systems including the solar system and the universe. However there is an inherent unpredictability in systems, which are composed of an (effectively) infinite number of interacting parts that follow simple rules. Each system is qualitatively different from, but not necessarily greater than the sum of its parts.	The Earth is an open system – it is the constant flow of solar radiation that powers most surface Earth processes and drives the cycling of most matter at or near the Earth's surface. Earth's internal heat is a driving force below the surface. Energy flows and cycles through the Earth system. Matter cycles within it. Convection drives weather and climate, ocean currents, the rock cycle and plate tectonics.	Photosynthetic bacteria reformulated the atmosphere making Earth habitable. Humans have changed the lay of the land, altered the distribution of flora and fauna and are changing atmospheric chemistry in ways that alter the climate. Earth system processes affect where and how humans live. For example, many people live in the shadow of volcanoes because of the fertile farmland found there, however they must keep a constant vigil to maintain their safety. The human impact on the environment is growing as population increases and the use of technology expands.	Earth processes (erosion, evolution or plate tectonics, for example) operating today are the same as those operating since they arose in Earth history and they are obedient to the laws of chemistry and physics. While the processes constantly changing the Earth are essentially fixed, their rates are not. Tipping points are reached that can result in rapid changes cascading through Earth systems.	The use of models is fundamental to all of the Earth Sciences. Maps and models aid in the understanding of aspects of the Earth system for which direct observation is not possible. Models assist in the comprehension of time and space at both immense and sub-microscopic scales. When compared to the size and age of the universe, humanity is a speck in space and a blip in time.

Bottomless ideas stated at multiple depths

Here the Bigger Ideas are stated at different depths – a "nickname" of a single word, at the sentence level, and in a short paragraph. We have described each idea in more detail in our series of regionally focused *The Teacher Friendly Guides to Geoscience,* (see: http://teacherfriendlyguide.org). Of course, many books have been written about each idea, and entire scientific careers may be based upon any one of them and the interplay amongst them.

Stating them as a single word in the form of an idea's nickname is intended to reduce the demands on working memory. This matters, as Daniel Kahneman notes, "because anything that occupies your working memory reduces your ability to think."[1]

How might I use Bigger Ideas in Instruction?

A simple idea is to have learners describe how a particular activity demonstrates (or is otherwise connected to) one or more of the Bigger Ideas, and to draw connections between ideas and the topic or field site under study.

Bigger Ideas and the Next Generation Science Standards

There are a number of sets of ideas that frame *NGSS.* and the highest level of these are the three dimensions from *A Framework for K-12 Science Education.* Each dimension is defined by a set of concepts, topics, or practices and the defining sets of concepts. The different natures of the framing ideas for the dimensions is revealed in their coloration on the Rainbow Chart. The Crosscutting Concepts are more similar in coloration than are either the Science and Engineering Practices or the Disciplinary Core Ideas (DCIs). The Science and Engineering Practices reflect the nature of science issues that undergird the Overarching Questions and the Models Bigger Idea. Each of the DCIs is individually connected to the all of the Bigger Ideas. This suggests that the DCIs are not based upon a definition similar to the definitions used in crafting the Literacy Principles or our set of Bigger Ideas. The DCIs are more akin to the topics used to structure a textbook than to the ideas used to define the different literacies. Four sets of DCIs are included in *NGSS*: Physical Sciences; Life Science; Earth & Space Sciences; and Engineering & Technology.

Explore Bigger Ideas further at:
http://virtualfieldwork.org/Big_Ideas.html.

[1] Thinking, Fast and Slow (p. 30). Macmillan. Kindle Edition