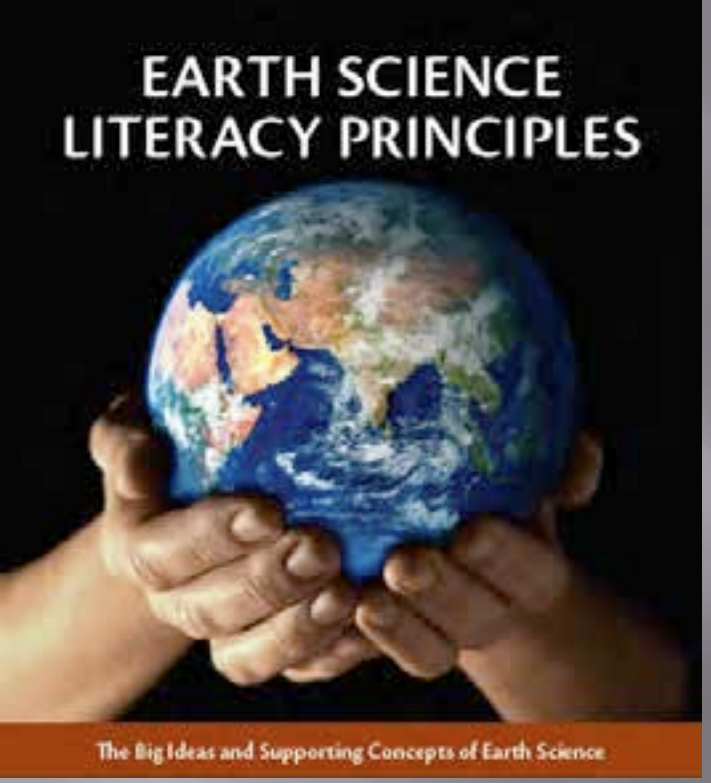
Mar 8th, 8:15 AM - 9:00 AM

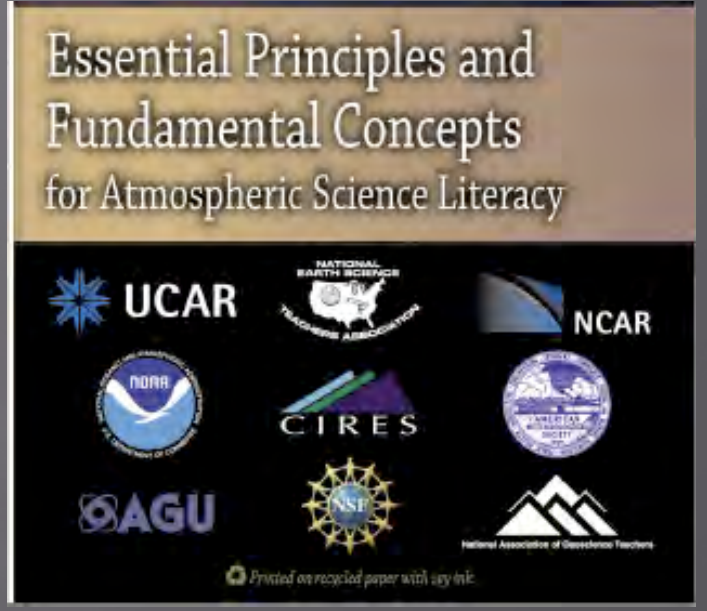
Building, Refining & Defining STEM Learning Outcomes: K-16 Implications

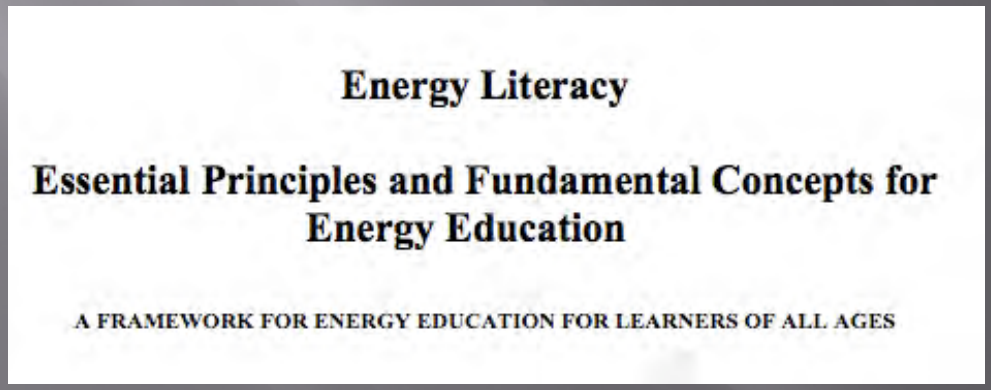
Richard A. Duschl

Penn State University and National Science Foundation


EARTH SCIENCE
LITERACY PRINCIPLES
The Big Ideas and Supporting Concepts of Earth Science


Ocean
Literacy


Essential Principles and
Fundamental Concepts
for Atmospheric Science Literacy
UCAR
NCAR
CIRES
AGU
NSF
Printed on recycled paper with soy ink

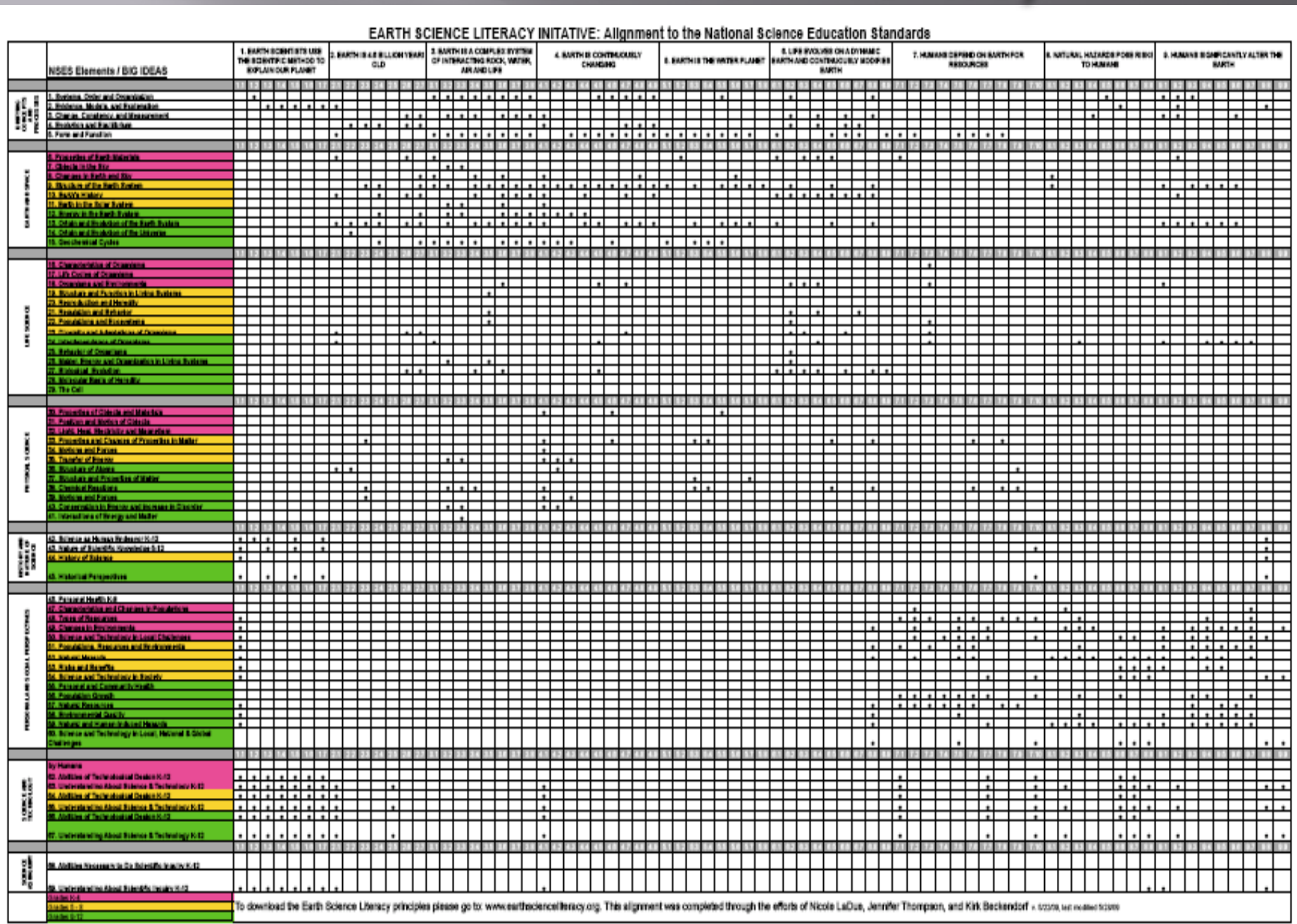

Energy Literacy
Essential Principles and Fundamental Concepts for Energy Education
A FRAMEWORK FOR ENERGY EDUCATION FOR LEARNERS OF ALL AGES


Climate
Literacy

US Geosciences Literacy

- Climate Literacy: The Essential Principles of Climate Science (2009) *A climate-oriented approach for learners of all ages.*
- Ocean Literacy: The Essential Principles of Ocean Sciences K-12 (2007) *An ocean-oriented approach to teaching science standards.*
- Earth Science Literacy: The Big Ideas and Supporting Concepts of Earth Science (2009).
- Atmospheric Science Literacy: Essential Principles and Fundamental Concepts of Atmospheric Science (2008).

Earth Science Literacy



ES Literacy: Big Ideas & (Supporting Concepts) of Earth Science

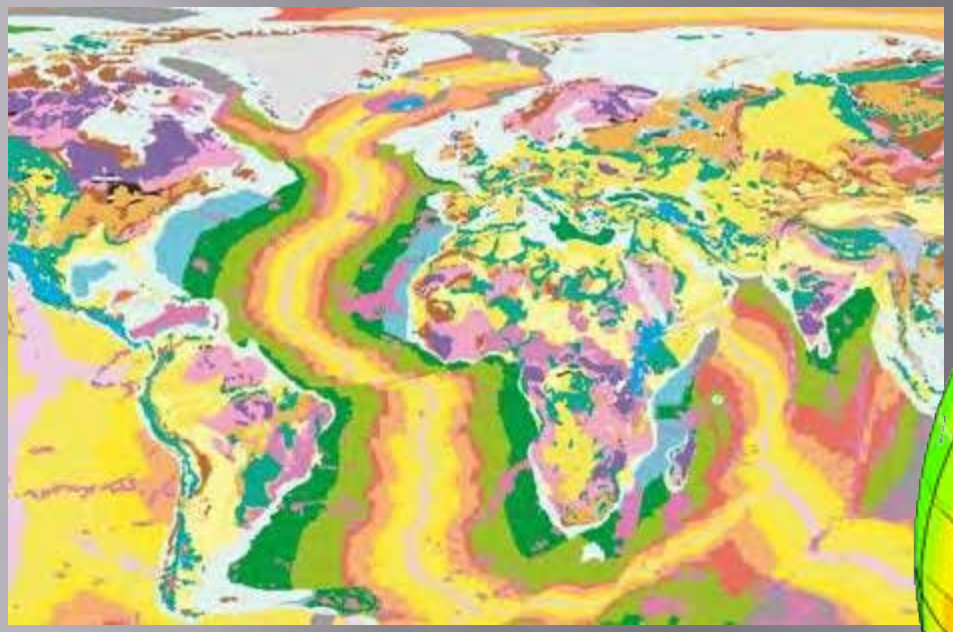
- 1.Earth sciences use repeatable observation and testable ideas to understand and explain our planet (7)
- 2. Earth is 4.6 billion years old (7)
- 3. Earth is a complex system of interacting rock, water, air and life. (8)
- 4. Earth is continuously changing.(9)
- 5. Earth is the water planet.(8)
- 6. Life evolves on a dynamic Earth and continuously modifies Earth (9)
- 7. Humans depend on Earth resources. (10)
- 8. Natural hazards pose risks to humans. (8)
- 9. Humans significantly alter the Earth. (9) (66)

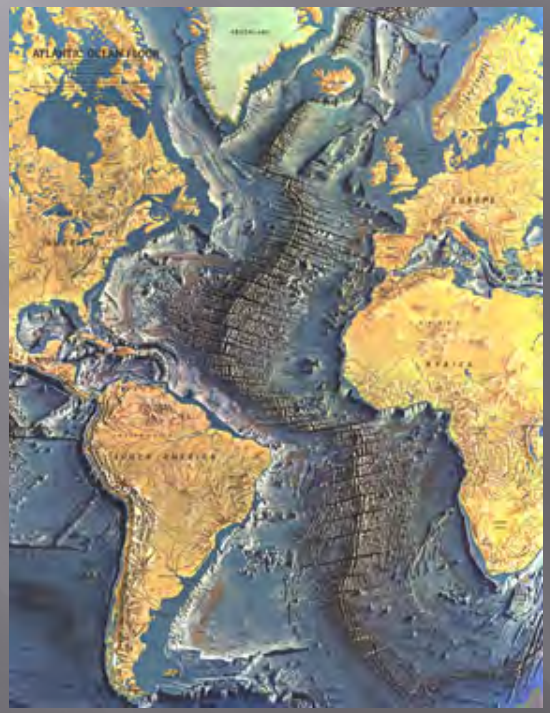
Disciplinary Core Ideas
Source-Transmission-Receptor

Theory of Observation

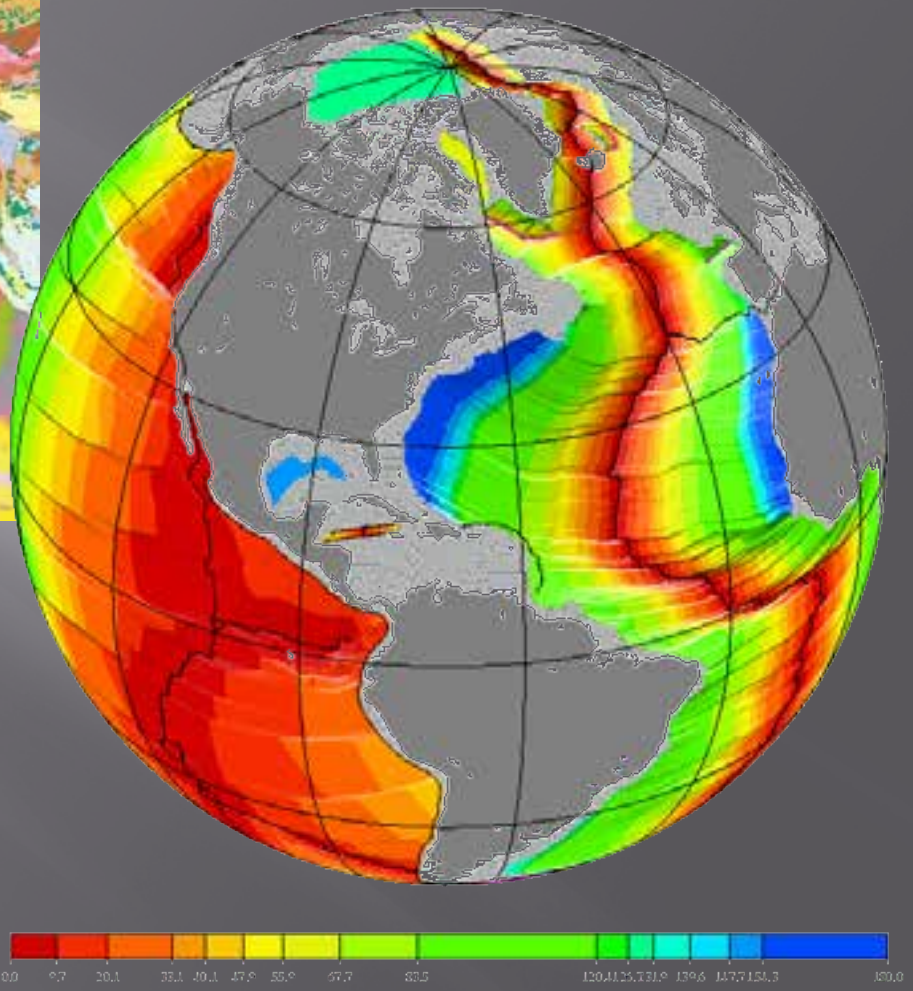
Shapere, D. (1982). The concept of observation in science and philosophy. *Philosophy of Science, 59*, 485-525.

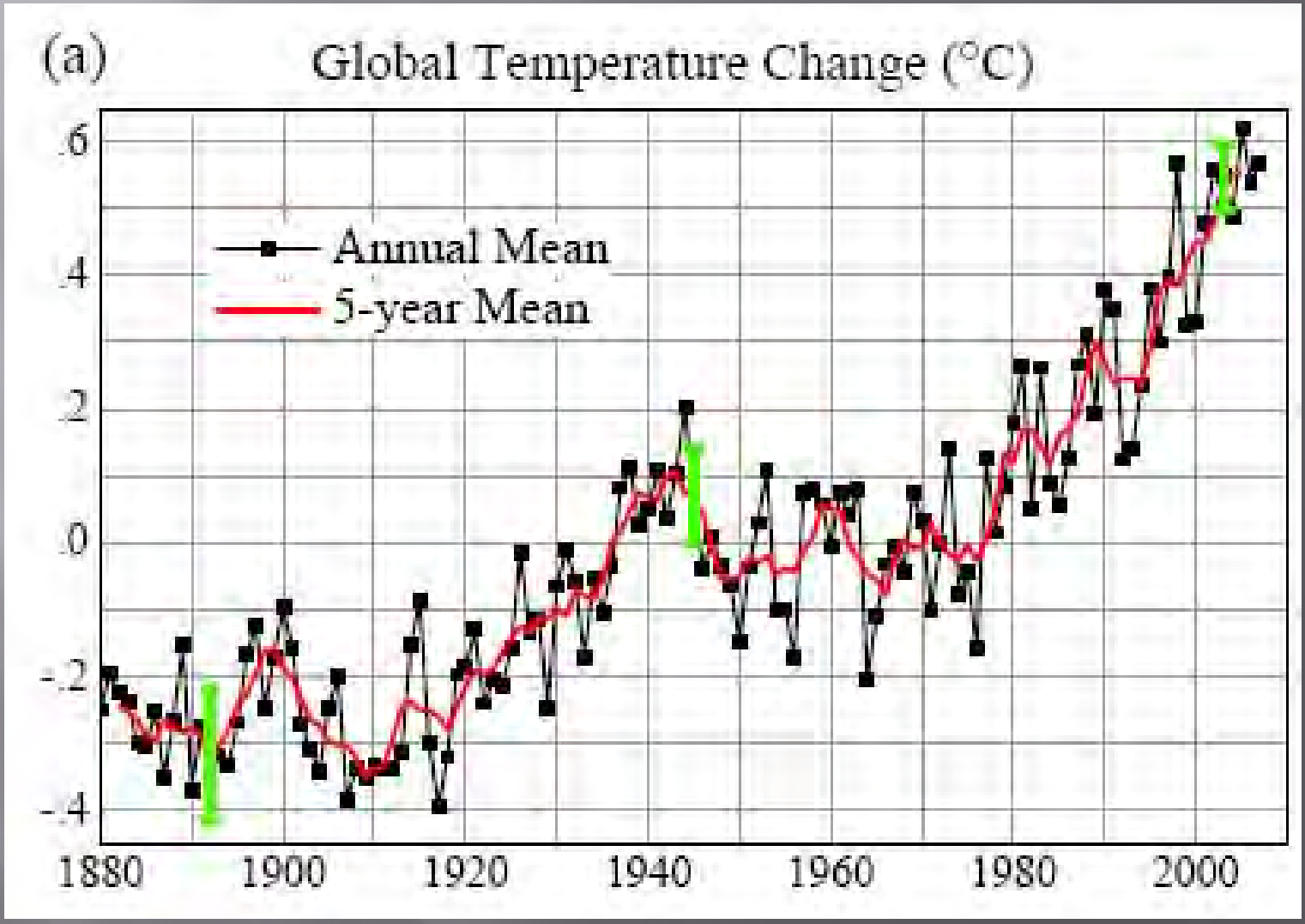
- *Theory of Source - Theory of Reception - Theory of Transmission*
- Neutrino Capture Experiments – Vats in Deep Earth Mines
- Ocean Salinity Measurements – Satellite detected Salinity Variations in Oceans to Model Climate Change
- Groundwater Depletion Measurements – Coupled satellites processing gravity fluctuations
- There is no current nor anticipated computational capacity to model cloud formation, a major factor for climate modeling (Data Proxy – Relative Humidity)





Age of the Ocean Floor




(a)
Global Temperature Change (°C)
.6
.4
.2
.0
-.2
-.4
Annual Mean
5-year Mean
1880
1900
1920
1940
1960
1980
2000

Thomas Eakin

“The Gross Clinic”

1875

Deepening & Broadening Scientific Explanations (Thagard, 2007)

- **Epistemic Achievements**
- Relativity Theory
- Quantum Theory
- Atomic Theory of Matter
- Evolution by Natural Selection
- Genetics Genome Maps
- Germ Theory of Disease
- Plate Tectonic Theory
- Mapping the Ocean-floor

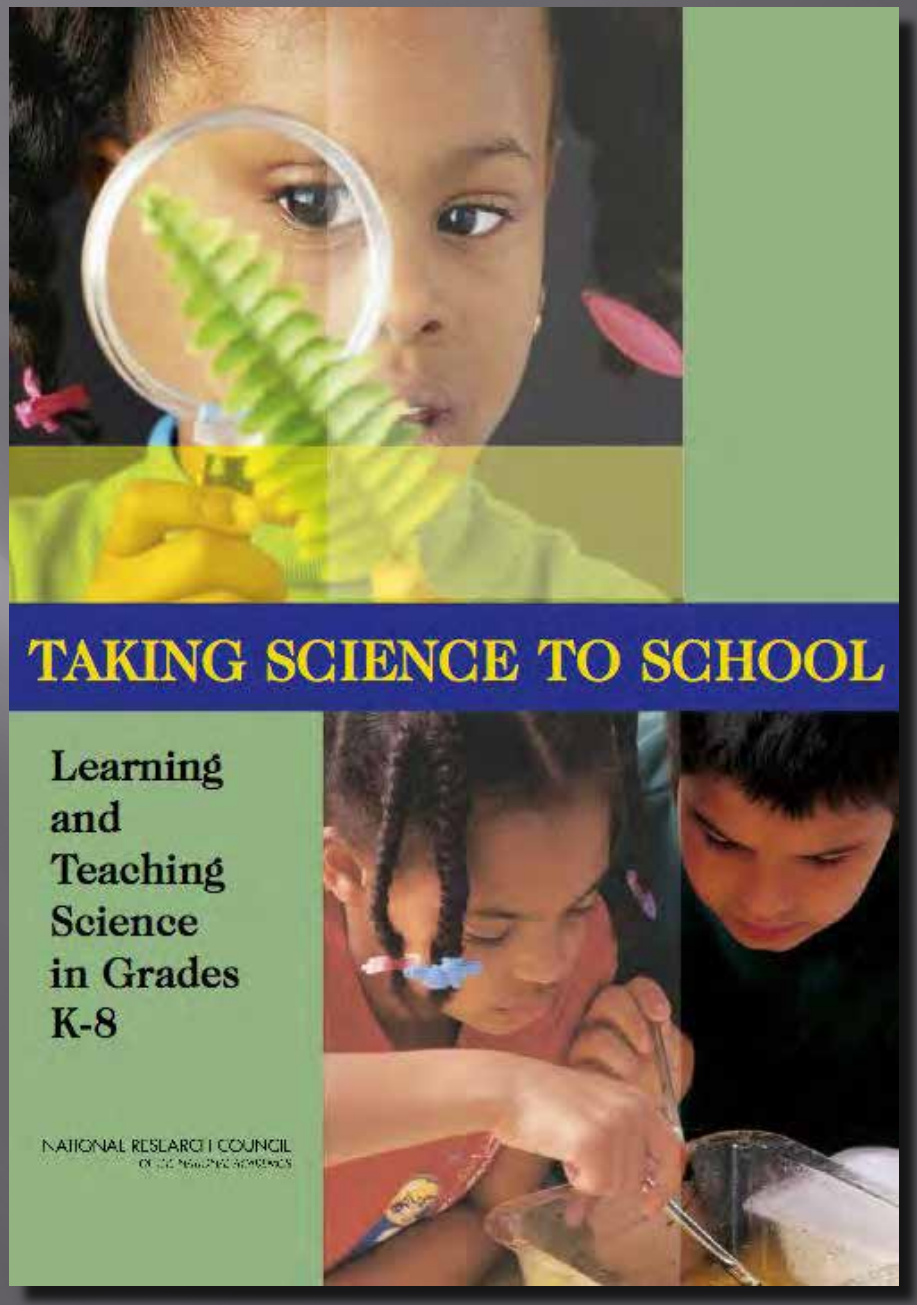
- **Epistemic Attempts**
- Crystalline Spheres Astronomy
- Catastrophist (Flood) Geology
- Phlogiston Theory of Chemistry
- Caloric Theory of Heat
- Vital Force Theory of Physiology
- Ether Theories of Electromagnetism and Optics
- Theories of Spontaneous Generation

Next Generation Science Standards

Taking Science to School (TSTS)

Ready, Set Science! (RSS)

National Research Council 2007



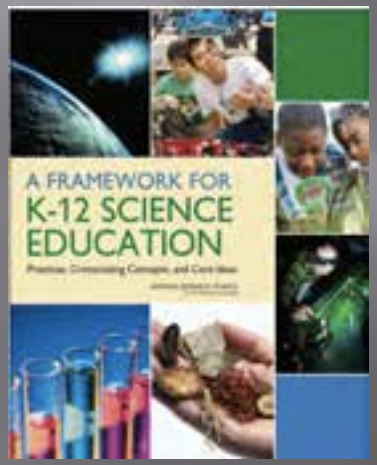
Building on the Past; Preparing for the Future

1990s

Phase I

Phase II

1990s-2009



1/2010 - 7/2011

NEXT GENERATION SCIENCE STANDARDS
For States, By States

7/2011 – March 2013

Read It For Yourself

"Don't believe everything you read on the Internet just because there's a picture with a quote next to it."

—Abraham Lincoln

NEXT GENERATION STANDARDS

What's Different about the Next Generation Science Standards?

Conceptual Shifts in the NGSS

1. K-12 Science Education Should Reflect the Interconnected Nature of Science as it is Practiced and Experienced in the Real World.
2. The Next Generation Science Standards are student performance expectations – NOT curriculum.
3. The science concepts build coherently from K-12.
4. The NGSS Focus on Deeper Understanding of Content as well as Application of Content.
5. Science and Engineering are Integrated in the NGSS from K–12.
6. NGSS content is focused on preparing students for the next generation workforce.
7. The NGSS and Common Core State Standards (English Language Arts and Mathematics) are Aligned.

NEXT GENERATION STANDARDS

NEXT GENERATION SCIENCE STANDARDS
For States, By States

Earth Space Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
ESS1.A The universe and its stars	Patterns of movement of the sun, moon and stars as seen from Earth can be observed, described and predicted	Stars range greatly in size and distance from Earth and this can explain their relative brightness	The Big Bang describes the origin of the universe; the Earth is part of one galaxy among many	a) Light spectra are used to describe characteristics of stars; b) The sun will burn out over a life span of about 10 billion years; c) Stars and galaxies are abundant in the universe; d) The development of technologies has provided the observable astronomical data that are the empirical evidence of the Big Bang theory
ESS1.B Earth and the solar system		The Earth's orbit and rotation, and the orbit of the moon around the Earth cause observed patterns of movement of celestial objects as seen from Earth	The solar system can be modeled to predict tides, eclipses and the apparent motion of planets seen in the sky from Earth. The Earth's tilt cause seasons	a) Kepler's laws describe common features of the motions of orbiting objects; b) Ice ages and other gradual climatic changes are caused by gradual changes in Earth's orbit and changes in Earth's axial tilt
ESS1.C The history of planet Earth	Some events on Earth occur in cycles while some are discrete events, any of which can occur over varying time scales	Earth has changed over time; the history of local landscapes can be inferred. Certain features can be used to order events that have occurred in a landscape	Rock strata and the fossil record can be used as evidence to organize the relative occurrence of major historical events in Earth's history	Radioactive-decay lifetimes and isotopic content can be used to fix the scale of geologic time; the rock record resulting from tectonic and other geoscience processes as well as objects from the solar system can provide evidence of Earth's early history and the relative ages of major geologic formations
ESS2.A Earth materials and systems	The materials and resources found in association with landforms provide homes for plants and animals	Four major Earth systems interact to affect materials and processes on Earth's surface	Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources; Plate tectonics is one result of these processes	Feedback effects exist within and among Earth's systems;
ESS2.B Plate tectonics and large-scale system interactions	Wind and water carry natural materials that influence landforms and what can live in a location	Earth's physical features occur in patterns, as do earthquakes and volcanoes; Maps can be used to locate features and predict location of those events	Plate tectonics is the unifying theory that explains movements of rocks at Earth's surface and geological history; Maps are used to display evidence of plate movement	Radioactive decay and residual heat of formation within Earth's interior contribute to thermal convection in the mantle

Standards Comparison: Structure and Properties of Matter

Current State Middle School Science Standard

a. Distinguish between atoms and molecules.
b. Describe the difference between pure substances (elements and compounds) and mixtures.
c. Describe the movement of particles in solids, liquids, gases, and plasmas states.
d. Distinguish between physical and chemical properties of matter as physical (i.e., density, melting point, boiling point) or chemical (i.e., reactivity, combustibility).
e. Distinguish between changes in matter as physical (i.e., physical change) or chemical (development of a gas, formation of precipitate, and change in color).
f. Recognize that there are more than 100 elements and some have similar properties as shown on the Periodic Table of Elements.
g. Identify and demonstrate the Law of Conservation of Matter.

NEXT GENERATION STANDARDS

Standards Comparison: Structure and Properties of Matter

NGSS Middle School Sample

a. Develop molecular-level models of a variety of substances, comparing those with simple molecules to those with extended structures.
b. Design a solution that solves a practical problem by using characteristic chemical and physical properties of pure substances.*
c. Develop a molecular level model that depicts and predicts why either temperature change and/or change of state can occur when adding or removing thermal energy from a pure substance.
d. Develop molecular models of reactants and products to support the explanation that atoms, and therefore mass, are conserved in a chemical reaction.
e. Analyze and interpret the properties of products and reactants to determine if a chemical reaction has occurred.
f. Gather and communicate information that people's needs and desires for new materials drive chemistry forward, and that synthetic materials come from natural resources and impact society.*
g. Design, construct, and test a device that either releases or absorbs thermal energy by chemical processes.*

NEXT GENERATION STANDARDS

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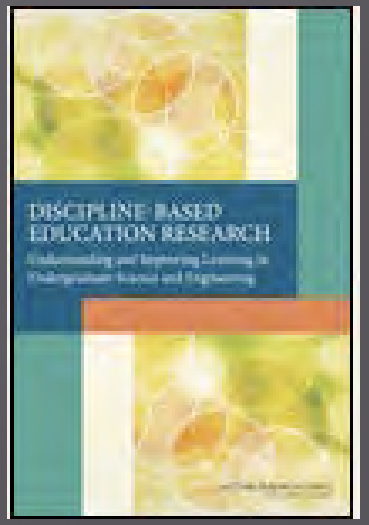
NEXT GENERATION STANDARDS

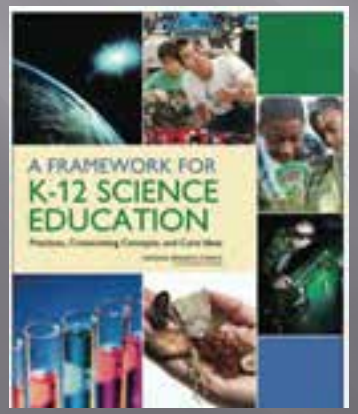
Grand Challenges in Environmental Sciences (NRC 2001)

- Biogeochemical cycles: understanding how human activity is perturbing the six nutrient cycles of carbon, oxygen, hydrogen, nitrogen, sulfur, and phosphorus which has impacts on climate change, CO2 concentrations, acid rain, and chlorofluorocarbons (CFC).
- Biological diversity and ecosystem functioning: understanding the regulation and functional consequences of biological diversity which has impacts on rates of species extinction, threats to biological diversity, and controls on biological diversity.
- Hydrological forecasting: understanding and predicting changes in freshwater resources and the environment caused by floods, droughts, sedimentation, and contamination which threatens freshwater ecosystems.

Opportunities for Better K-16 Alignment

- A Framework for K-12 Science Education and the Next Generation Science Standards
- New AP Biology Curriculum
- NSF/AAAS Vision and Change in Undergraduate Biology Education (PULSECommunity.org)





NEXT GENERATION SCIENCE STANDARDS
For States, By States

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Thank You