Webinar:

NGSS Across the Sciences Curriculum

Organizers:
Susan Sullivan, CIRES, CU Boulder & NAGT Past President
Aida Awad, Einstein Distinguished Educator Fellow, Department of Energy
Ed Robeck, AGI
John McDaris, SERC/NAGT

Center for Geoscience & Society
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Webinar overview:

- ➢ Welcome and introductions
- ➢ Presenters
  - Dr. Jo Ellen Roseman, AAAS, American Association for the Advancement of Science
  - Dr. James Kessler, ACS, American Chemical Society
  - Dr. Aleeza Oshry, Science Education Fellow, Howard Hughes Medical Institute
- Discussion and Q&A
- ➢ Future Events

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Upcoming Events:

- **Webinars: 2nd Thursdays, 1p PT/4p ET**
  - September 14, 2017
    Achieve Resources and Tools for NGSS Implementation: Matt Krehbiel, Achieve, Inc

- August 1, 2017 Abstract submissions for Geological Society of America
  "Getting it done: Experiences of implementing the Framework and NGSS in Earth and space science"
  Seattle, WA October 22-25, 2017
- July 17-21, Earth Educators Rendezvous Round Table Discussion
  "Getting it done: Experiences of implementing the Framework and NGSS in Earth and space science"
  Albuquerque, NM
- Email list and archived webinars:
  http://nagt.org/nagt/profdev/workshops/ngss_summit/index.html

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Presenters

Jo Ellen Roseman

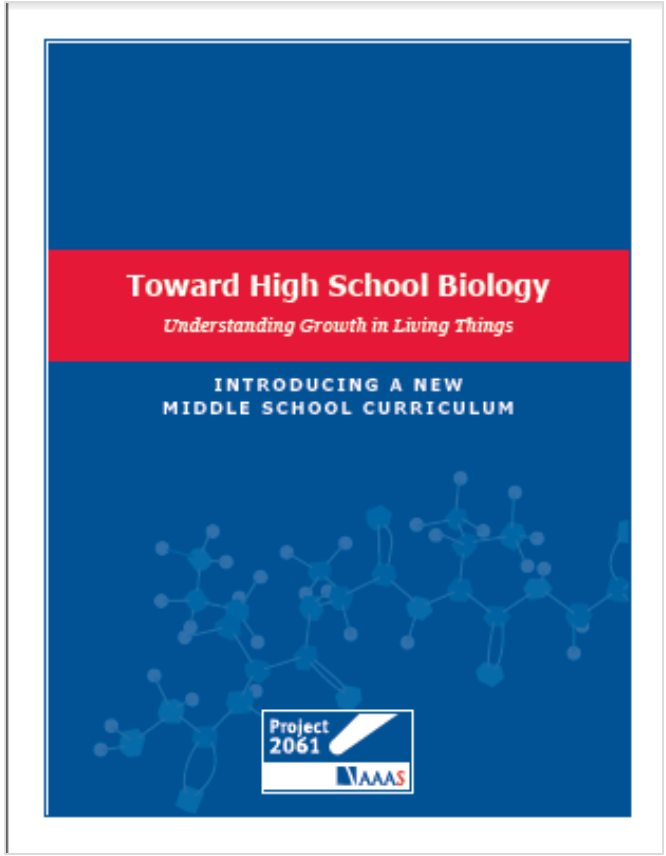
Jim Kessler

Aleeza Oshry

Toward High School Biology (THSB): Illustrating NGSS Across Physical and Life Science

Jo Ellen Roseman, Ph.D.
Director of Project 2061
American Association for the Advancement of Science

A New Middle School Curriculum Unit



- **Designed to support NGSS** 3D teaching and learning
- Tested for **classroom feasibility** in Colorado; Washington, DC; Maryland; and Massachusetts
- Results of a randomized control trial showed **significant learning gains** for a demographically diverse range of students using the new unit compared to those using their district curriculum
- **Available July, 2017** from NSTA Press

This work was funded by the Department of Education (Grant R305A100714)

Overarching Goal of the THSB Unit

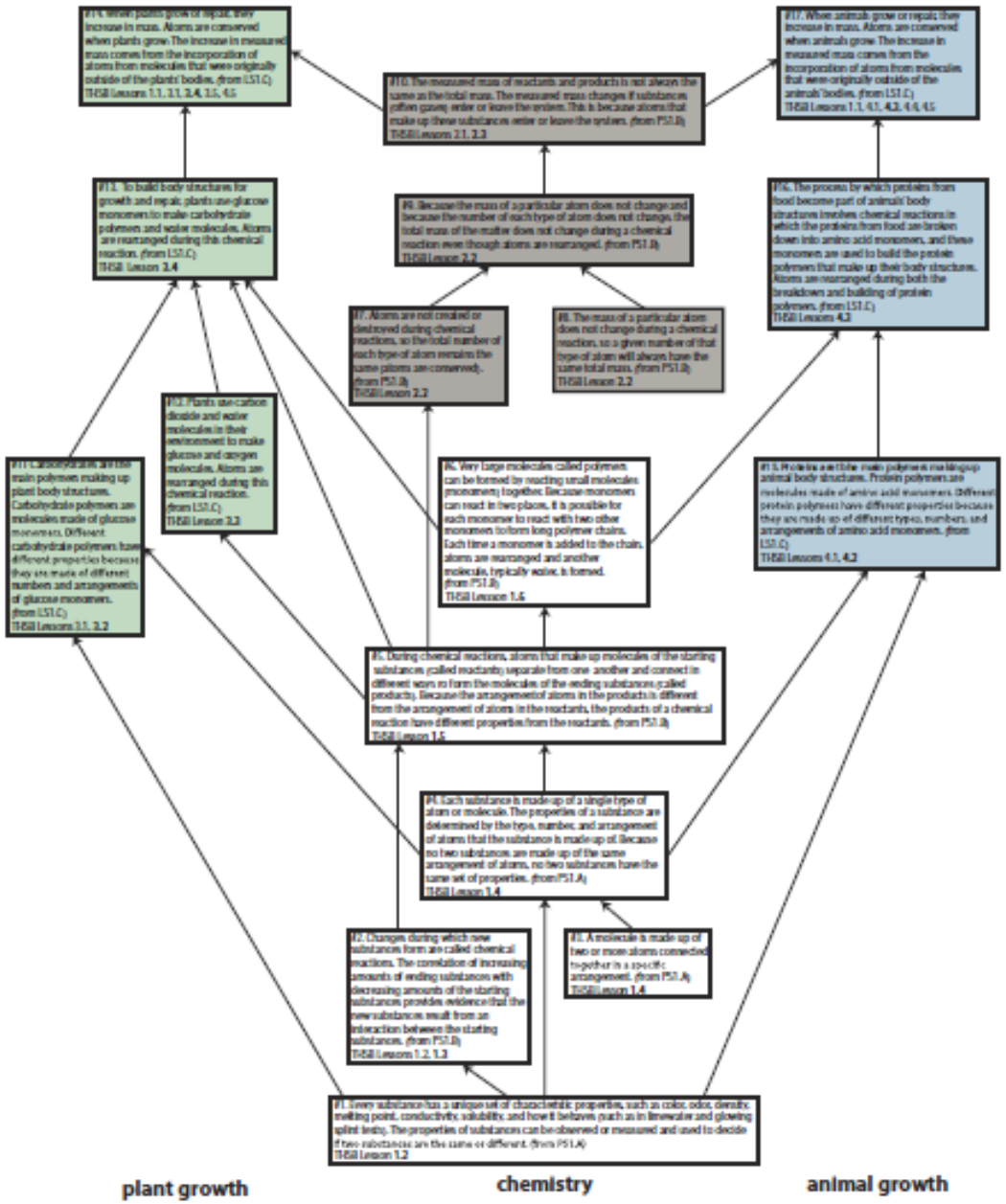
To support NGSS 3D learning by helping students make sense of phenomena related to plant and animal growth, using

- Disciplinary core ideas about **chemical reactions** in physical and life science,
- Crosscutting concept of **matter conservation** across physical and life science, and
- Science practices of **data analysis**, **modeling**, **explanation**, and **communication**.

Unit Design Draws on Learning Theory and Empirical Studies to Support NGSS

- **Coherent content storyline** of scientific ideas about atom rearrangement and conservation in chemical reactions in non-living and living systems
- **Phenomena** that can be explained with the science ideas
- **Models/modeling to** help students visualize underlying molecular mechanisms
- **Scaffolded explanation tasks** that accustom students to using evidence from data and logical reasoning from science ideas and models

Toward High School Biology (THSB)
Year 6 Content Storyline



Instructional Approach Supports NGSS Across Disciplines

- **Observing** materials/organisms at the **macroscopic level**
- **Relating** differences in **properties of substances** to differences in their **molecular composition**
- **Modeling atom rearrangement** involved in converting starting to ending substances during the chemical reaction
- **Accounting** for all the atoms involved
- **Connecting** the **evidence** gathered to **science ideas**
- Using evidence, science ideas, and modeling to **substantiate a claim**

Content Storyline: Conceptual Focus of Each Chapter

Chapter	Conceptual Focus
1	New substances form during chemical reactions because atoms rearrange to form new molecules.
2	Mass is conserved in chemical reactions because atoms are conserved.
3	Plant growth involves chemical reactions in which atoms rearrange and are conserved.
4	Animal growth involves chemical reactions in which atoms rearrange and are conserved.

Selecting and Sequencing Phenomena

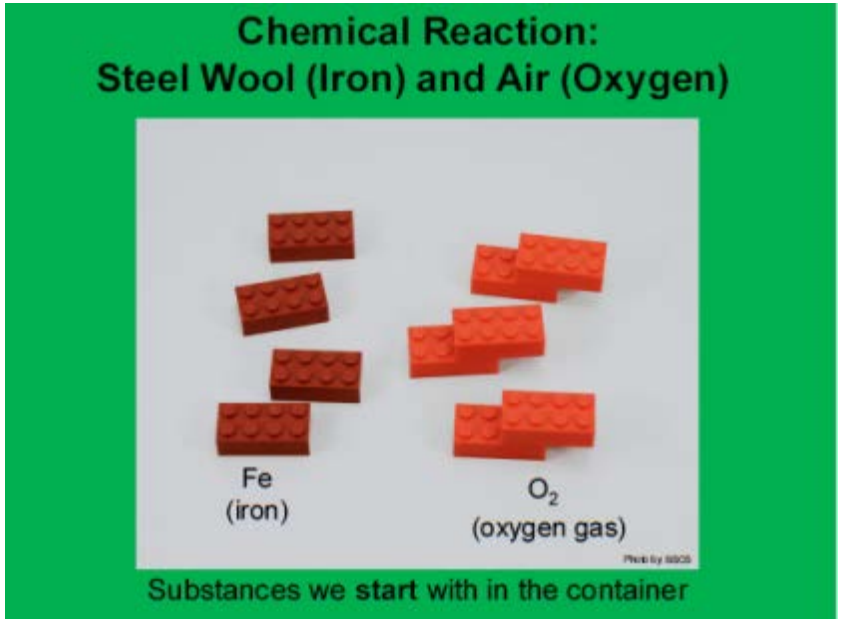
Conceptual Focus	What Students Experience
1: New substances form during chemical reactions because atoms rearrange to form new molecules.	Observing, modeling, and explaining how ending substances can form from starting substances when: • Vinegar is mixed with baking soda • Iron is exposed to air • Hexamethylene diamine is mixed with adipic acid
2: Mass is conserved in chemical reactions because atoms are conserved.	Observing, modeling and explaining how the measured mass of a system can change even though atoms aren't created or destroyed (same reactions used in Chapter 1)
3: Plant growth involves chemical reactions in which atoms rearrange and are conserved.	Observing, modeling, and explaining how plants produce carbohydrates for growth from substances in their environment and increase in mass without violating conservation principles when: • Plants produce $^{14}C_6H_{12}O_6$ from $^{14}CO_2$ • Plants produce $^{18}O_2$ not $C_6H_{12}{}^{18}O_6$ from $H_2{}^{18}O$ • Plants make more ^{14}C-cellulose without herbicide than with it
4: Animal growth involves chemical reactions in which atoms rearrange and are conserved.	Observing, modeling and explaining how animals produce proteins for growth that are different from what they eat and increase in mass without violating conservation principles when: • Snakes eat only eggs but can replace shed skin • Humans eat muscles but can make tendons • Fish eat ^{14}C-labeled brine shrimp and make ^{14}C-labeled body structures

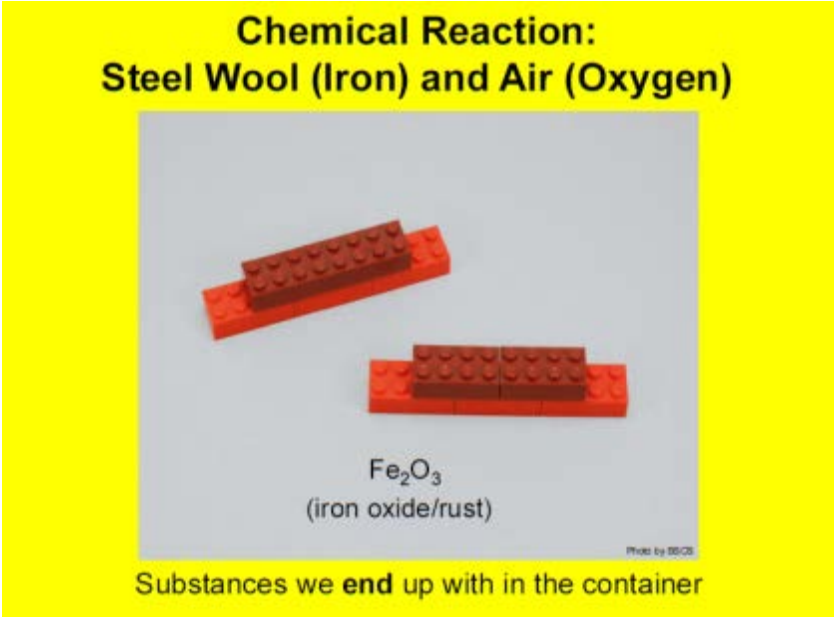
Macroscopic Phenomena: Rust forms when iron is exposed to air, and the amounts of both iron and air decrease as more rust forms.

Observing Properties of Starting Substances and Ending Substances

Starting Substances					
	State of Matter (at 25°C)	Color	Smell	Conductivity	Solubility
Iron	Solid	Metallic silver	None	Yes	No
Oxygen	Gas	Colorless	None	No	Yes
Ending Substances					
Rust	Solid	Red orange	None	No	No

Examining Models of Molecules of Starting and Ending Substances





Relating Differences in Properties to Differences in Molecular Composition

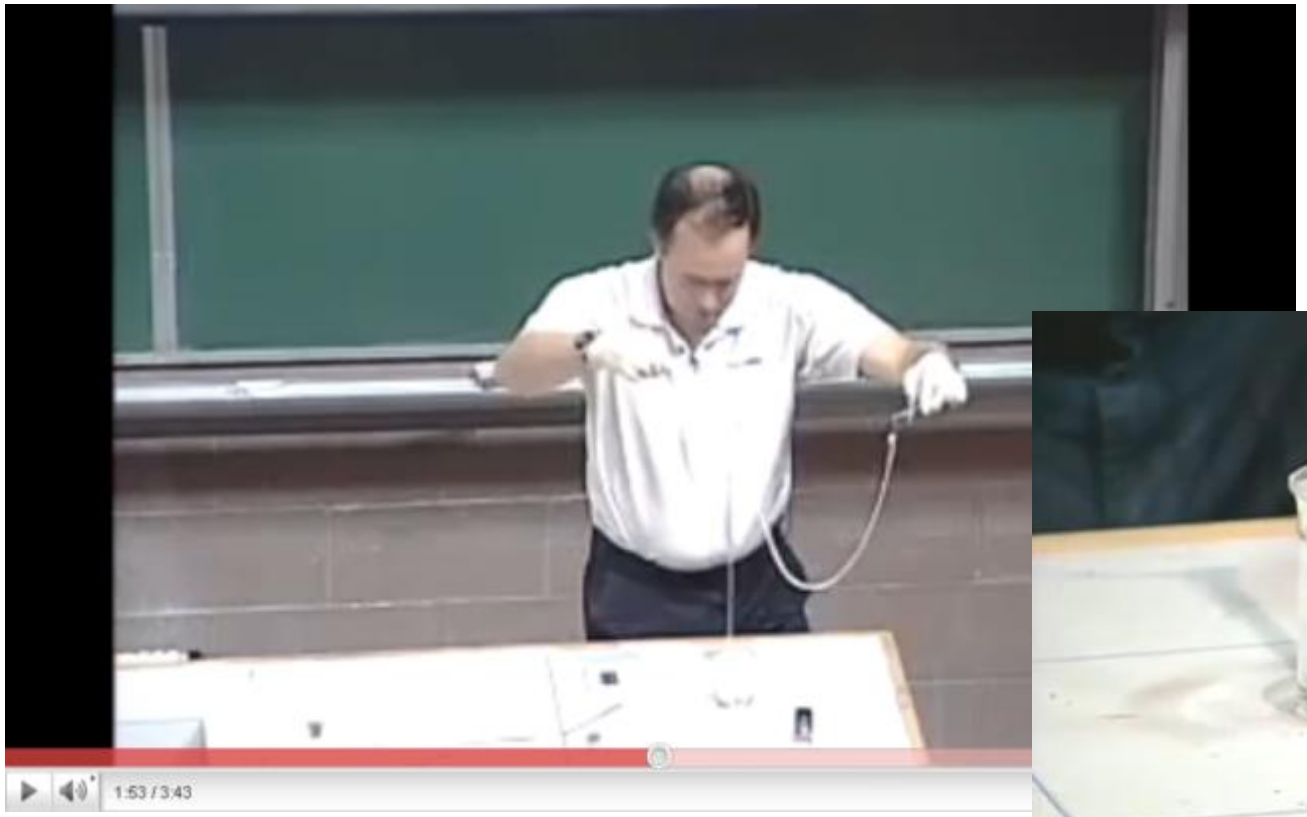
Substance Name	Properties	Molecular Composition
Iron	Metallic silver solid	Fe
Oxygen	Colorless gas at 25°C	O_2
Rust (Iron Oxide)	Red-orange solid	Fe_2O_3

Modeling How a New Substance, Rust (Fe_2O_3), Could Form from the Starting Substances Iron (Fe) and Oxygen (O_2)

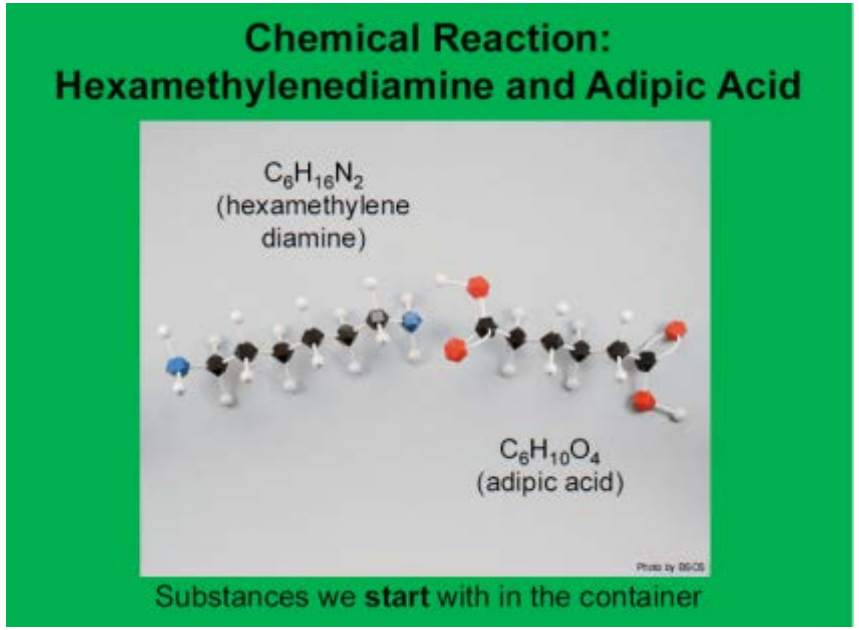
Science Idea #5

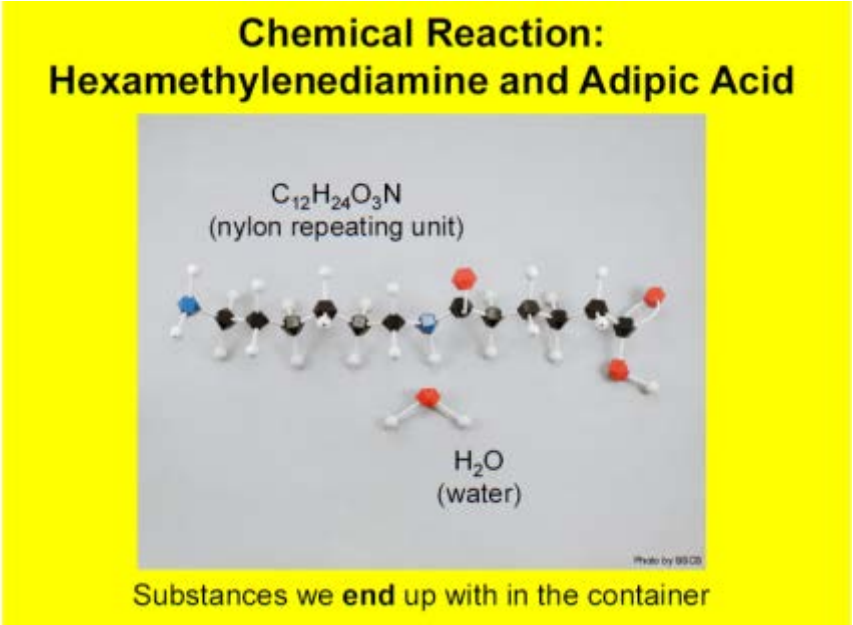
During chemical reactions, atoms that make up molecules of the starting substances (called reactants) disconnect from one another and connect in different ways to form the molecules of the ending substances (called products). Because the arrangement of atoms in the products is different from the arrangement of atoms in the reactants, the products of a chemical reaction have different properties from the reactants.

Macroscopic Phenomena: Nylon forms when hexamethylenediamine is mixed with adipic acid, and the amount of product increases as the amounts of the reactants decrease.



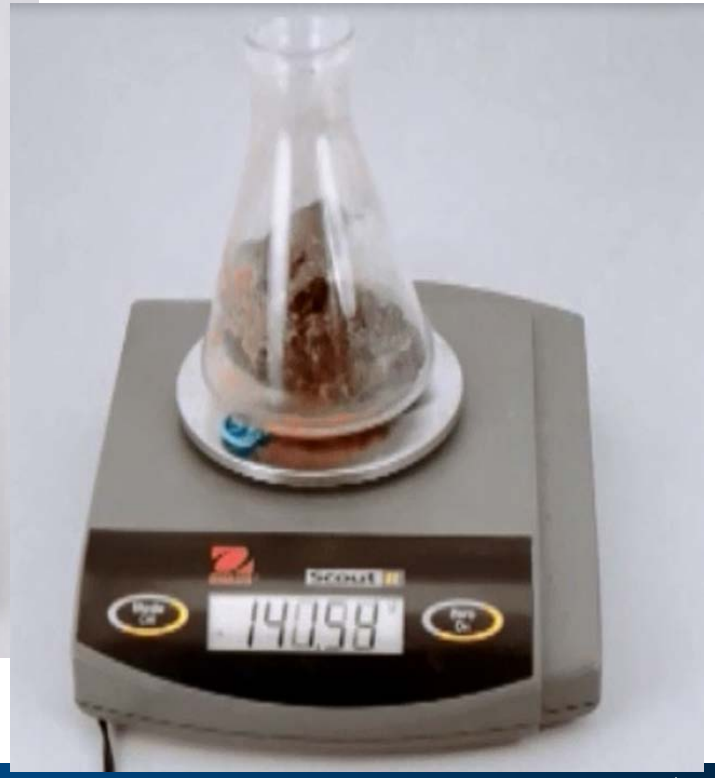
Examining Models of Molecules of Starting and Ending Substances





Modeling How a New Substance, Nylon (polymer), Could Form from Hexamethylenediamine and Adipic Acid (monomers)

Macroscopic Phenomenon: The measured mass increases as iron reacts with oxygen to form iron oxide in an open system.

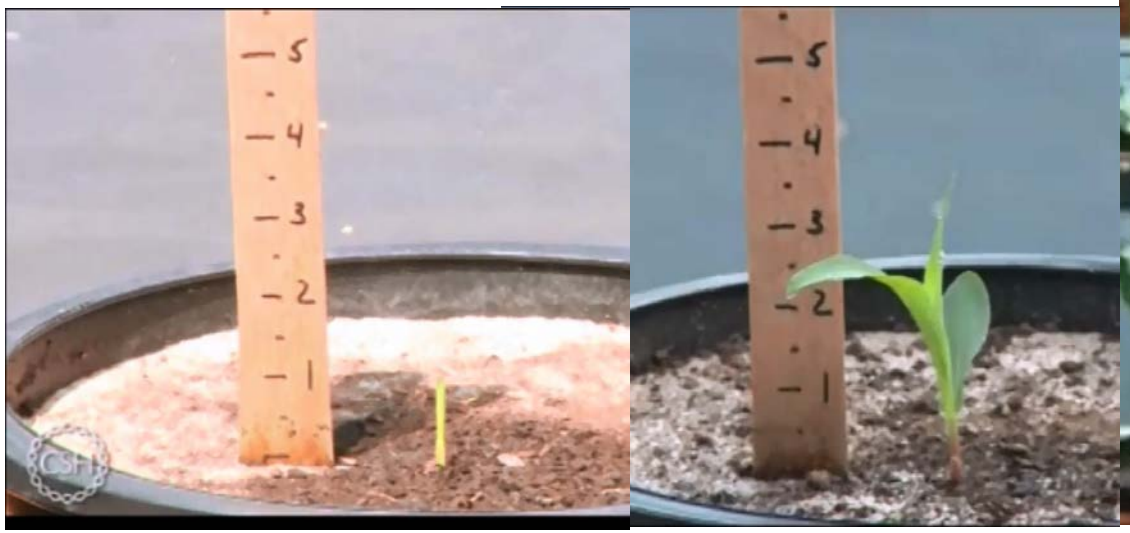


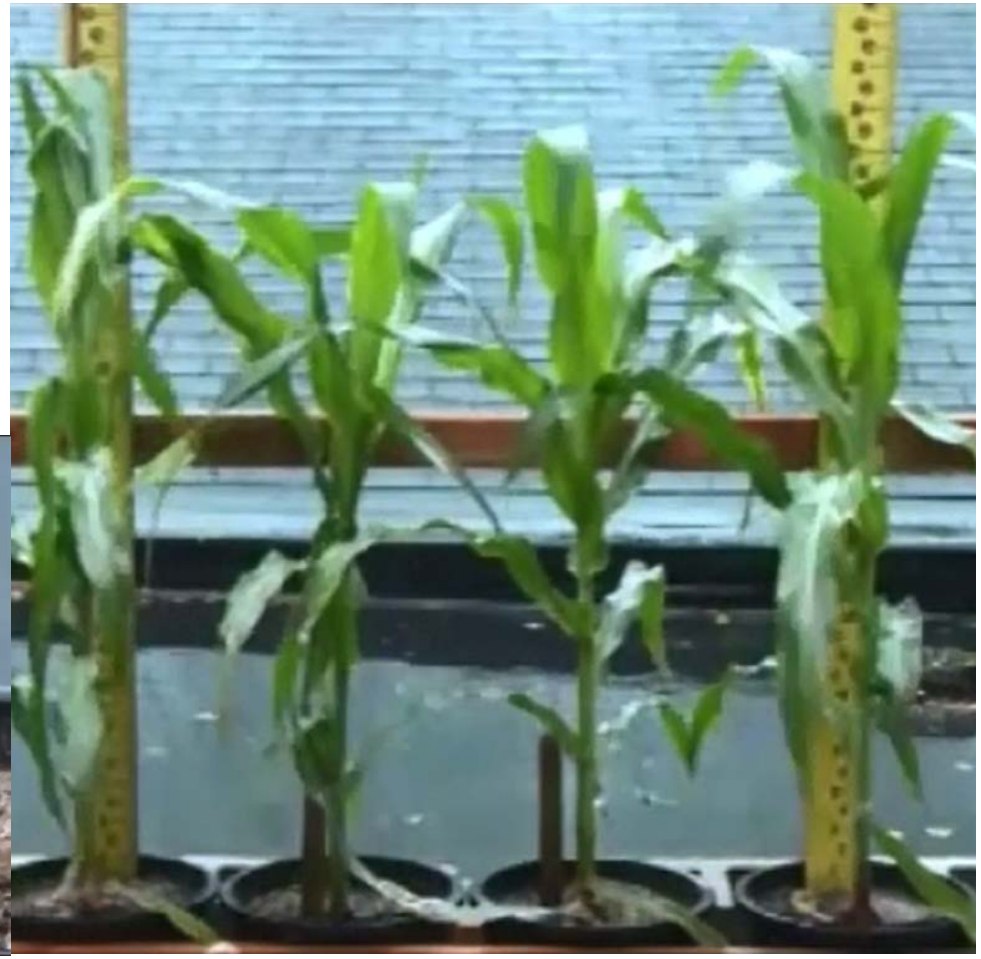
Modeling What Happens to the Mass in Closed and Open Containers

and why measured mass increases even though atoms are conserved.

Macroscopic Phenomena: Over several weeks maize increase in size/mass and produce new body structures.

Plant	Initial Mass (Age)	Final Mass (Age)
Corn	.7 g (1 week)	896 g (13 weeks)





Examining Substances that Make Up Plant Body Structures

Structure	Plant	Carbohydrates (per 100 g)	Fats (per 100 g)	Proteins (per 100 g)
Root	Carrot	8.24	0.13	0.64
	Potato	17.00	0.10	2.00
Stem	Bamboo shoot	5.20	0.30	2.60
	Celery	2.97	0.17	0.69
Leaf	Spinach	3.63	0.39	2.86
	Lettuce	2.87	0.15	1.36
Flower	Broccoli	5.24	0.35	2.98
	Cauliflower	4.97	0.28	1.92
Fruit	Strawberry	7.68	0.30	0.67
	Tomato	3.89	0.20	0.88
Seed	Snap beans	6.97	0.22	1.83
	Kidney beans	4.10	0.50	4.20

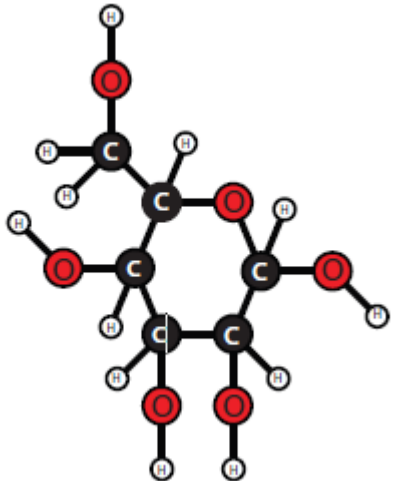
Examining Properties of Those Substances

Carbohydrate Molecule	Solubility in Water	Does it form fibers?
Glucose	High	No
Cellulose	Low	Yes
Starch	Low	No

and considering which carbohydrate could give celery its stringiness

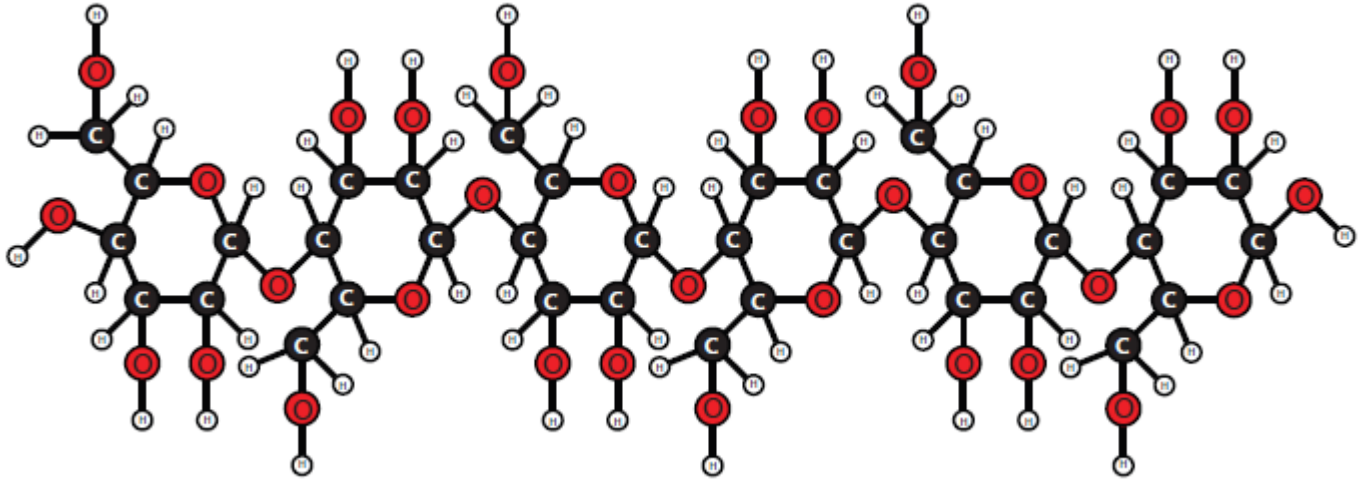
Examining Molecular Structures of Carbohydrates

Glucose



and noticing that cellulose appears to be made up of glucose monomers

Cellulose



Examining Data from Experiments Using "Labeled" Atoms

Can plants make glucose from carbon dioxide (and water)?

	Starting Substances (Reactants)		Ending Substances (Products)	
Experiment 1	CO_2	H_2O	$C_6H_{12}O_6$	O_2

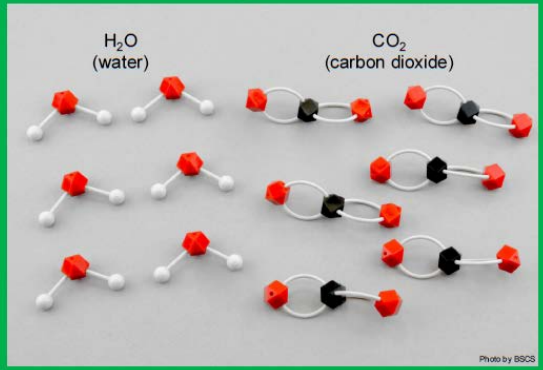
	Starting Substances (Reactants)		Ending Substances (Products)	
Experiment 2	CO_2	H_2O	$C_6H_{12}O_6$	O_2

Effects of the Herbicide Triazofenamide on Cellulose Production from Glucose

Group	Amount of Labeled C Atoms in Cellulose (dpm)
Control	11,200
Experimental (herbicide)	1,900

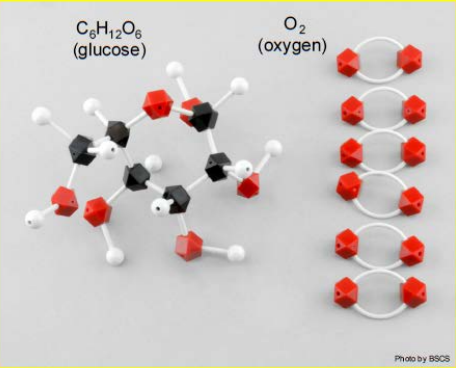
Modeling How Plants Can Produce New Body Structures from Carbon Dioxide and Water

Chemical Reaction: Making Glucose



Starting Substances (Reactants)

Chemical Reaction: Making Glucose

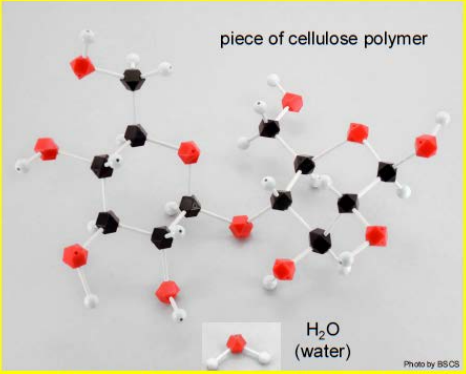


Ending Substances (Products)

Chemical Reaction: Making Cellulose

Starting Substances (Reactants)

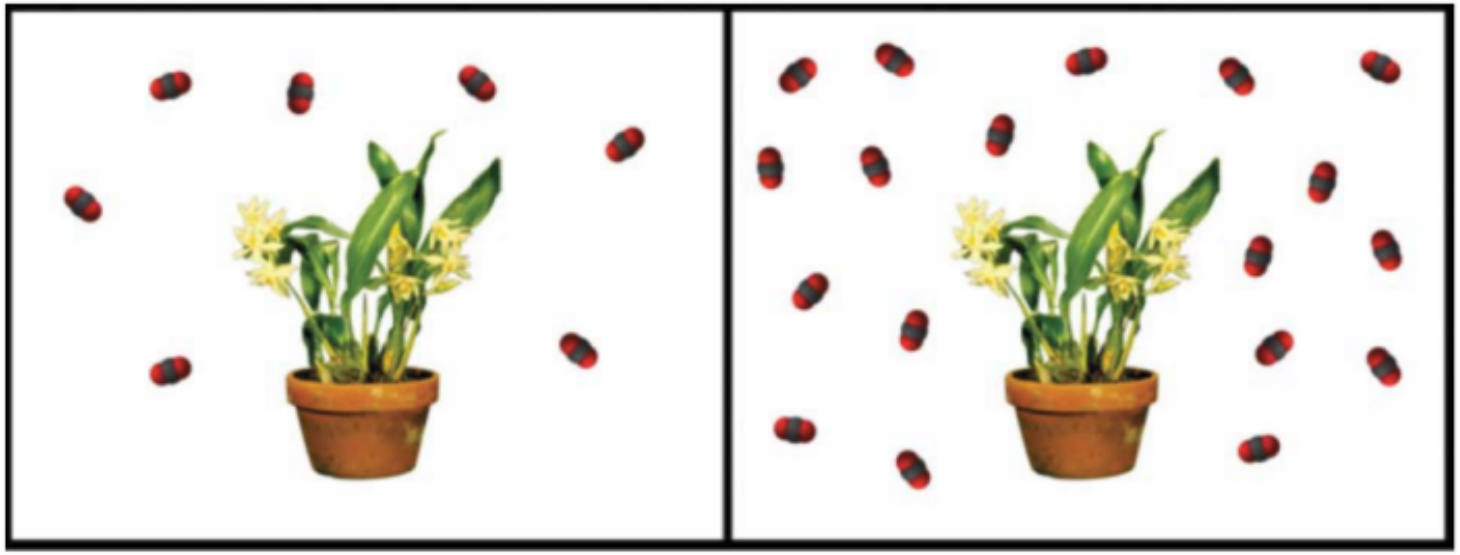
Chemical Reaction: Making Cellulose



Ending Substances (Products)

Using Evidence, Science Ideas, and Models to Support a Claim

3. The owner of a plant store wanted to see if the amount of carbon dioxide in the air would affect how her plants grow. She set up two identical rooms, Room 1 and Room 2, in her greenhouse. She put one plant in each room. Both plants were the same size and mass, and both were given plenty of water. Room 1 had normal air with the normal level of carbon dioxide in it. Room 2 was filled with air that had extra carbon dioxide in it.



Room 1 **Room 2**

Figure 2.4 Plants exposed to different amounts of carbon dioxide

Three months later, the store owner measured each of the plants. Do you think one plant was bigger than the other? Explain your answer using science ideas, evidence, and models. Check to be sure that your explanation meets the Explanation Quality Criteria.

Using Evidence, Science Ideas, and Models to Support a Claim

		Soil		Willow tree
Day 1	=	200.0 lbs	+	5.0 lbs
Five years later	=	199.9 lbs	+	169.2 lbs
Difference		-0.1 lbs		+164.2 lbs

Macroscopic Phenomenon: Over seven months a puppy grows into an adult German shepherd.

Examining Substances That Make Up Animal Body Structures

Animal	Protein Molecules (per 100g)	Fat Molecules (per 100g)	Carbohydrate Molecules (per 100g)
Anchovy fish	65.3	7.1	4.4
Brine shrimp	58.4	4.0	29.3
Cow	60.0	8.9	15.1
Chicken	42.3	37.8	10.5
Crayfish	42.3	37.8	10.5
Hamster	49.8	34.6	8.1
Herring fish	72.7	8.5	0.8
Human	48.0	38.7	1.5
Locust	22.1	3.0	4.3
Squid	74.8	8.8	4.9
Worm	56.4	7.8	19.6

Examining Properties of Those Substances

Protein Name	Body Structures	Solubility in Water	Fibrous or Globular
Casein	Milk	High	Globular
Collagen	Tendons, skin	Low	Fibrous
Hemoglobin	Blood	High	Globular
Keratin	Skin, scales, hair	Very low	Fibrous
Myosin	Muscle	Low	Globular
Actin	Muscle	Low	Fibrous
Ovalbumin	Egg white	High	Globular

Macroscopic Phenomenon: Are brine shrimp a suitable food source for farmed herring fish?

Photo by Jiri Bohdal

?

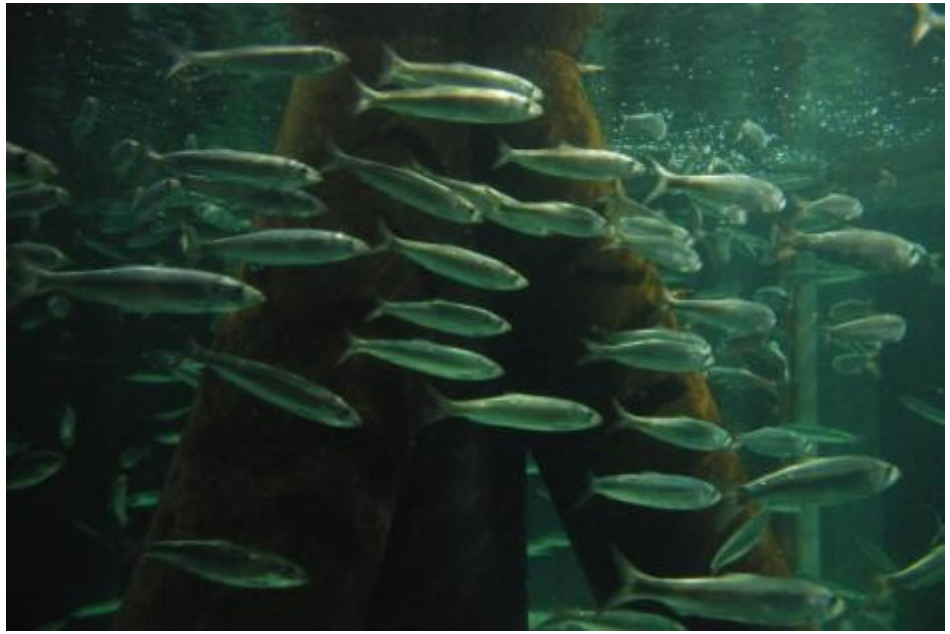
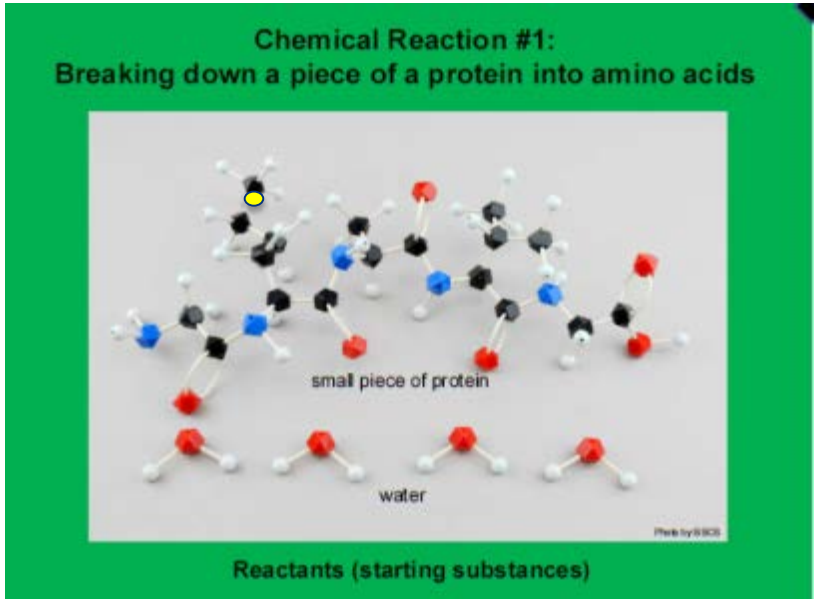


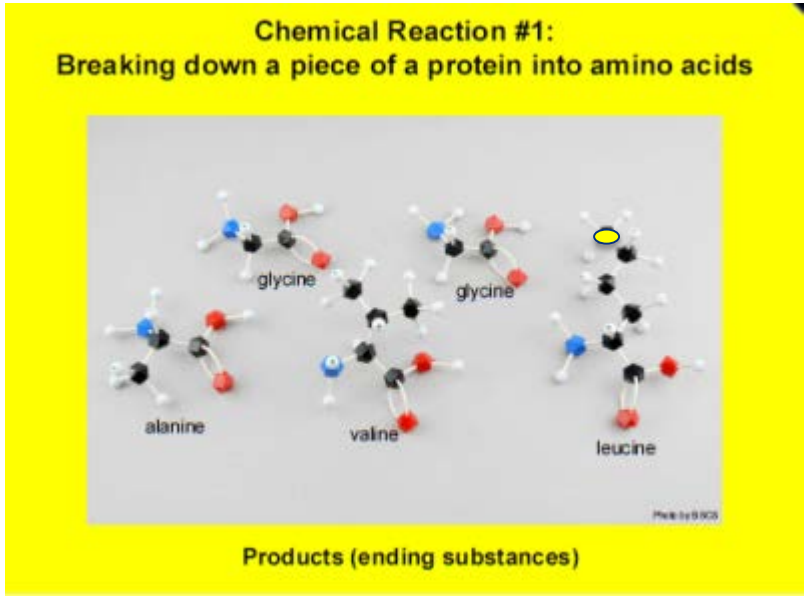
Photo by Uli Harder

Examining Data from Experiments Using "Labeled" Atoms

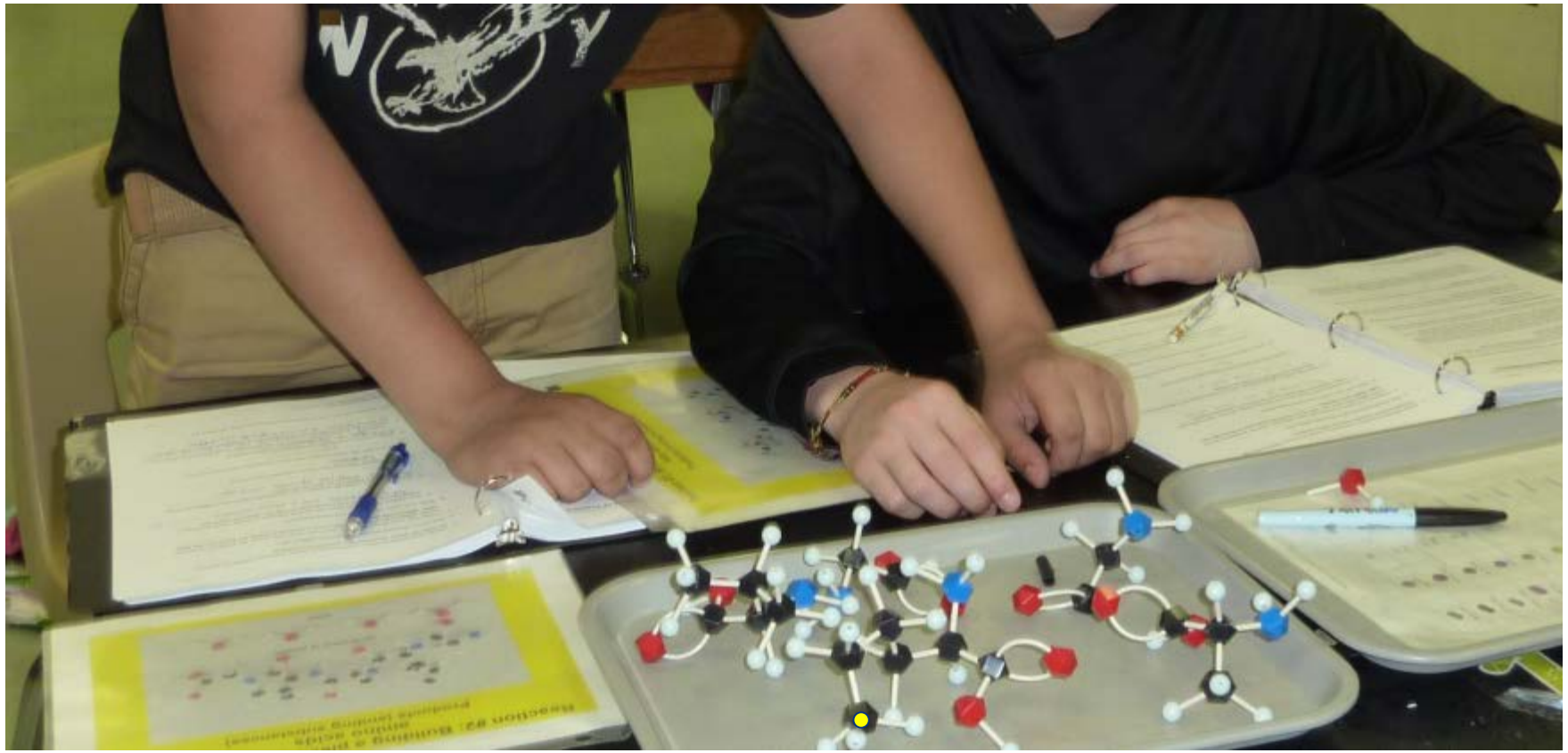
Location	% of labeled carbon atoms found 24 hours after feeding [6]
Digestive system	7
Rest of body (excluding digestive system)	20
Water (outside the fishes' bodies)	73

Examining Models of Starting and Ending Substances





Modeling How Brine Shrimp Proteins Could Become Herring Fish Proteins



Using Evidence, Science Ideas, and Models to Explain How Egg-Eating Snakes Replace Shed Skin

How THSB Supports NGSS by Connecting Physical and Life Science

- Both physical and life science ideas in **same unit**
- Takes the **same instructional approach** , i.e., from macroscopic phenomena to underlying molecular events
- Provides **data on the same properties** (e.g., solubility, fibrous/globular)
- Uses the **same models/modeling** of atom rearrangement and conservation during polymer formation
- Science Ideas across disciplines use **same language**
- **Students identify similarities** across physical and life science phenomena and Science Ideas

American Chemical Society

Middleschoolchemistry.com and the NGSS

Jim Kessler

ACS Office of K-8 Science

Welcome to the Next Generation Science Standards (NGSS)

MS.Structure and Properties of Matter

MS.Structure and Properties of Matter

Students who demonstrate understanding can:

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.]

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.
- Develop a model to predict and/or describe phenomena. (MS-PS1-1),(MS-PS1-4)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.
- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-PS1-3)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-2.)*
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-3) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-2 and MS-PS1-5.)*

PS3.A: Definitions of Energy
- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(secondary to MS-PS1-4)*

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

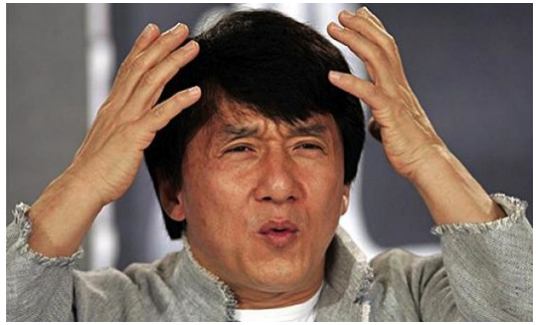
Scale, Proportion, and Quantity
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Structure and Function
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)

Influence of Science, Engineering and Technology on Society and the Natural World
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and differences in such factors as clim resources, and economic condition



Start with the Disciplinary Core Ideas

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PS1.A: Structure and Properties of Matter
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-2.)*
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

PS1.B: Chemical Reactions
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-3) *(Note: This Disciplinary Core Idea is also addressed by MS-PS1-2 and MS-PS1-5.)*

PS3.A: Definitions of Energy
- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. *(secondary to MS-PS1-4)*

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity
- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Structure and Function
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3)

Influence of Science, Engineering and Technology on Society and the Natural World
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and differences in such factors as climate, natural resources, and economic conditions.

Be practical:

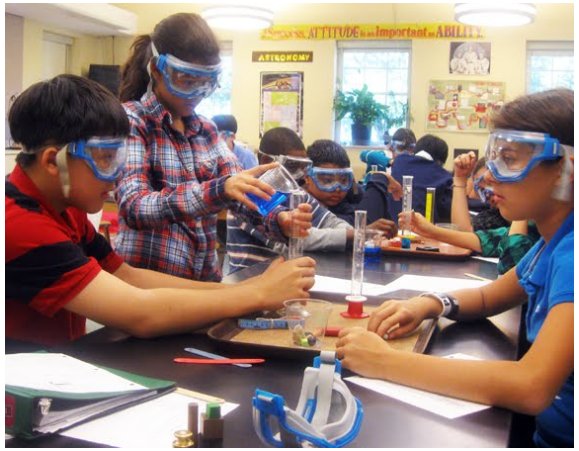
- Start with the core ideas students need to learn.
- Look at the practices and crosscutting concepts in the foundation boxes as a guide writing the lesson.
- Think about what phenomena students could observe, interact with, and investigate to develop an understanding of the core ideas using the practice.

Use Phenomena as the Basis for Engaging in Practice and Learning Core Idea

- **Asking a Question**: A basic practice of the scientist is formulating empirically answerable questions about phenomena.
- **Planning and Carrying Out Investigations**: A major practice of science is planning and carrying out systematic investigations (about phenomena).
- **Developing and Using Models**: Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena.
- **Constructing Explanations**: The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.

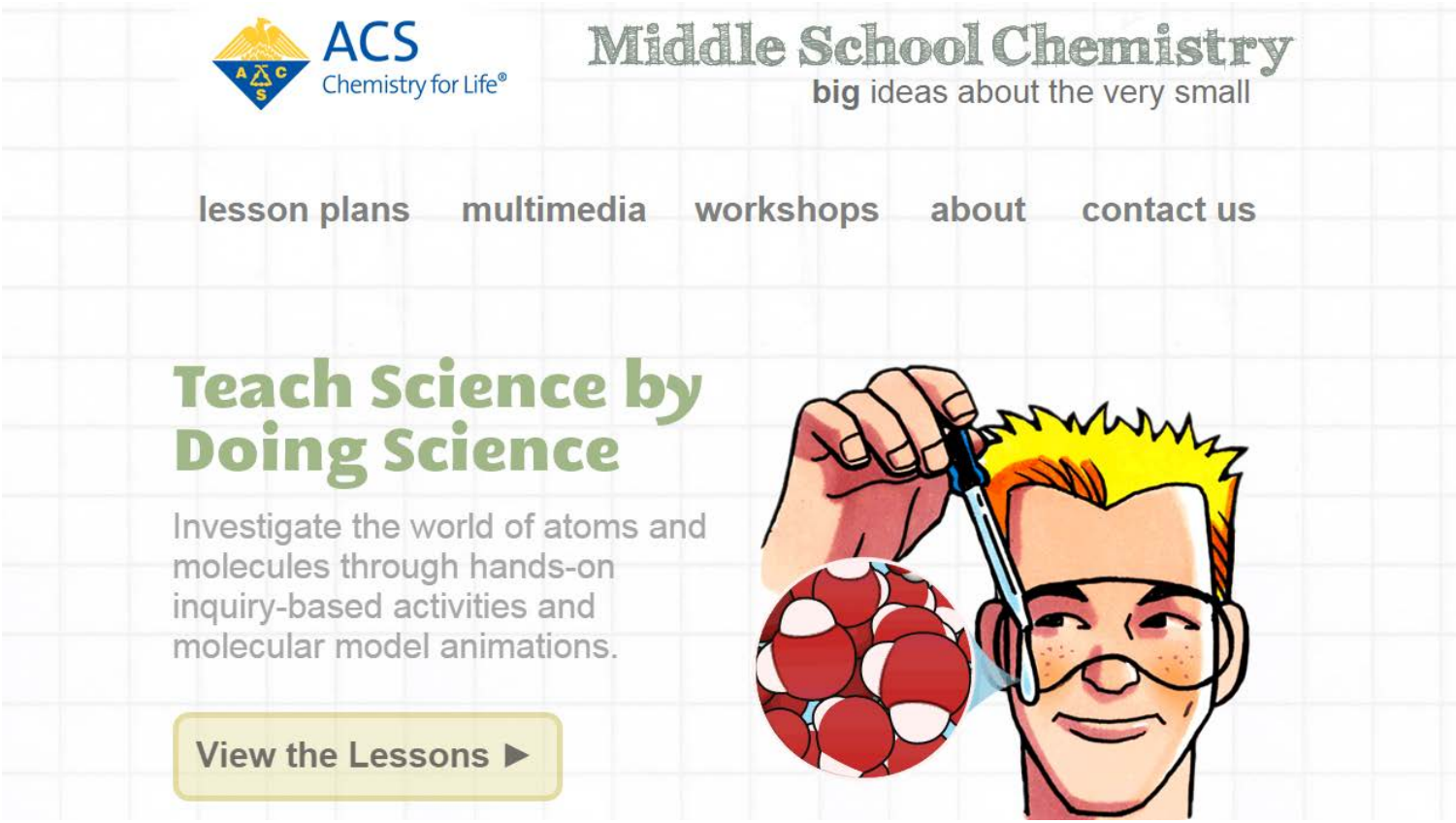
So What Should a Lesson Look Like?

Students use science practices to investigate phenomena in order to understand and explain core ideas and crosscutting concepts.



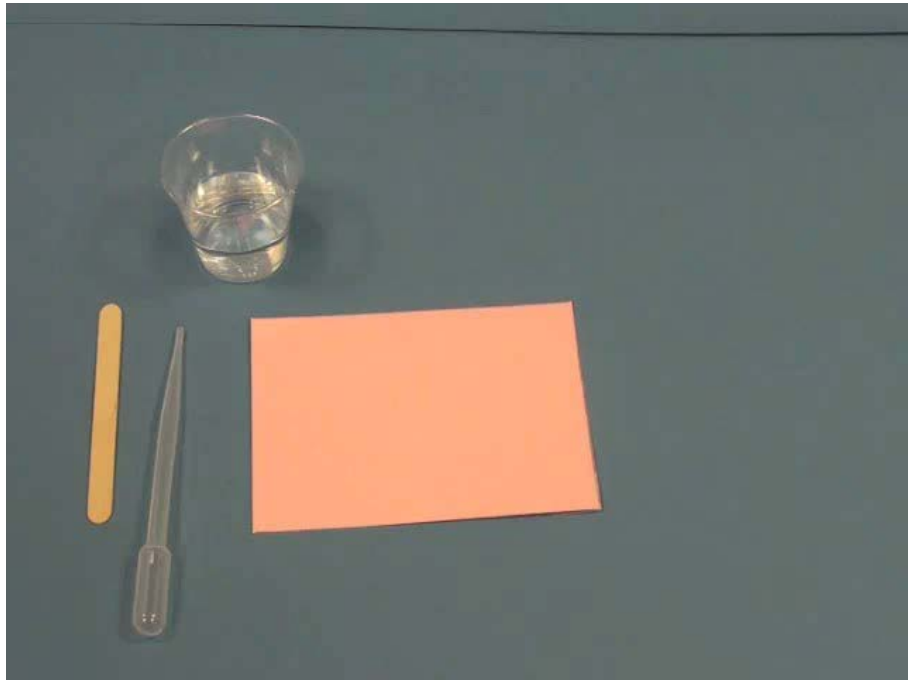
Tackling NGSS MS-PS1- 4

Middleschoolchemistry.com - Chapters 1 and 2



Attractions between Water Molecules

Engage → **Explore** → Explain → Evaluate → Extend



Students observe water on wax paper.

Does the water drop stay together or come apart easily?

If water was made of tiny particles (molecules), would you say they are attracted to each other or not?

The Motion of Water Molecules

Engage → **Explore** → Explain → Evaluate → Extend

What else can we learn about the particles that make up water?

Why do you think the food coloring spread out?

If the food coloring is also made of particles, how could the water molecules help to spread them out?

Heating and Cooling Water

Students see the coloring move faster and mix more quickly in hot water than in cold water.

Guide students to use their observations to think about why this happens on the molecular level.

Ask students what their observations tell them about the speed of molecules in hot and cold water.

Help students come to the conclusion that heating water increases the speed of water molecules and that cooling water decreases the speed.

Questions

ACS

Chemistry for Life®

American Chemical Society

Implementing NGSS with Systems Connect

Why a systems planning guide for NGSS implementation?

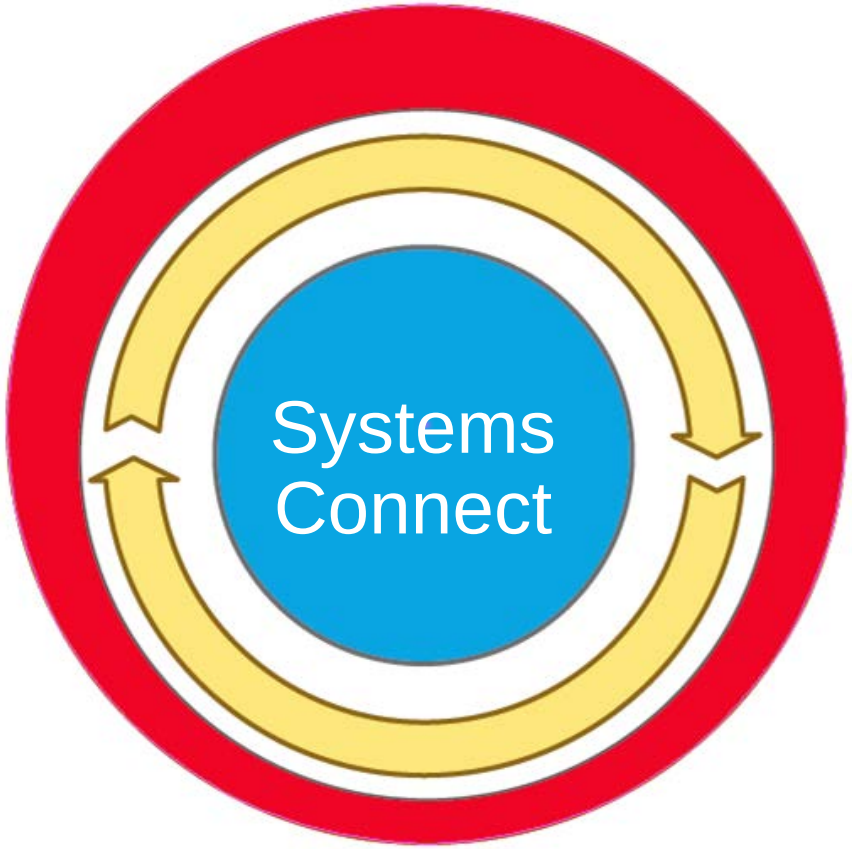
- Broadly applicable approach for incorporating relevant, real-world investigations and action into curriculum
- Responsive to academic standards & learning outcomes
- Incorporates authentic research and data into learning progressions
- Maximal adoption and ease of use by large numbers of educators

Unfortunately, Larry had always approached from the side that wasn't posted, and a natural phenomenon was destroyed before anyone could react.

How?

- building explicit conceptual links
- developing a deep, comprehensive understanding of the systems and processes of our planet

Systems Thinking



- building explicit conceptual links
- developing a deep, comprehensive understanding of the systems and processes of our planet

Integrating Investigations & Actions into curriculum using Systems Connect

Components of Systems Connect include:

- A **framework** for teaching global change topics that gives context and organization to interdisciplinary content (*NGSS Disciplinary Core Ideas*)

- **Conceptual models** for building an understanding of Earth system interactions and feedbacks (*NGSS Science and Engineering Practices and Crosscutting Concepts*)

- A **Systems Planning Guide** for developing or revising learning progressions, scope and sequence and integrating resources to be responsive to **NGSS**

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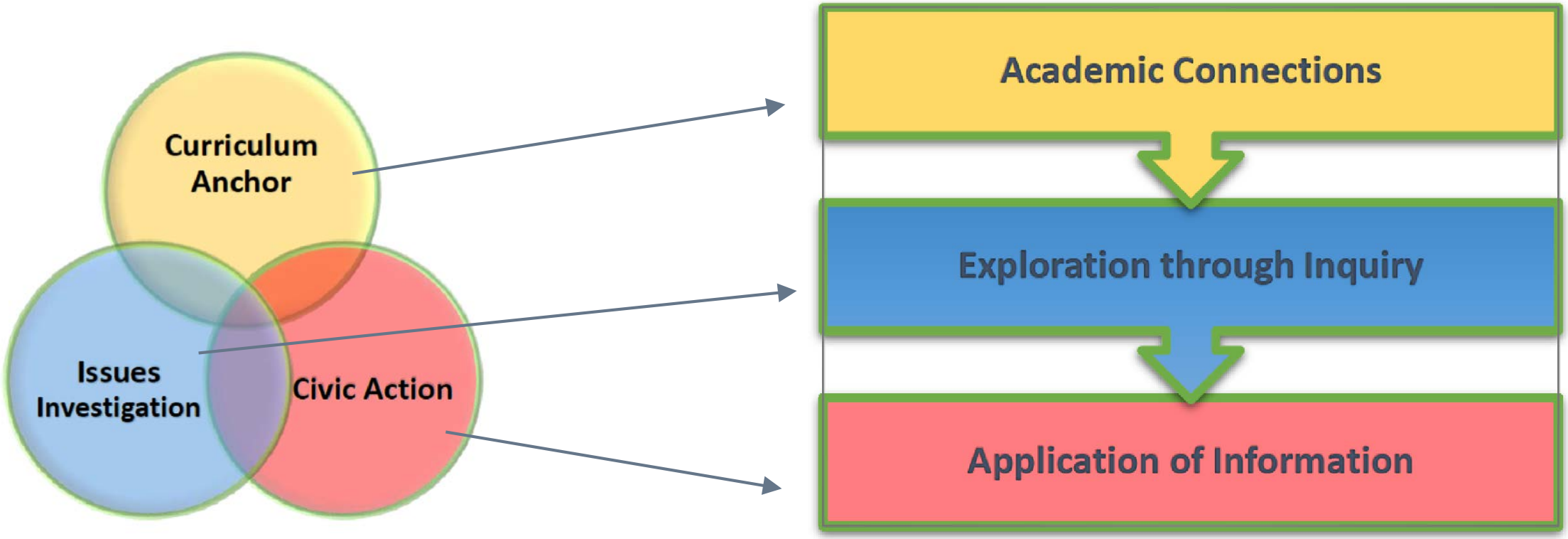
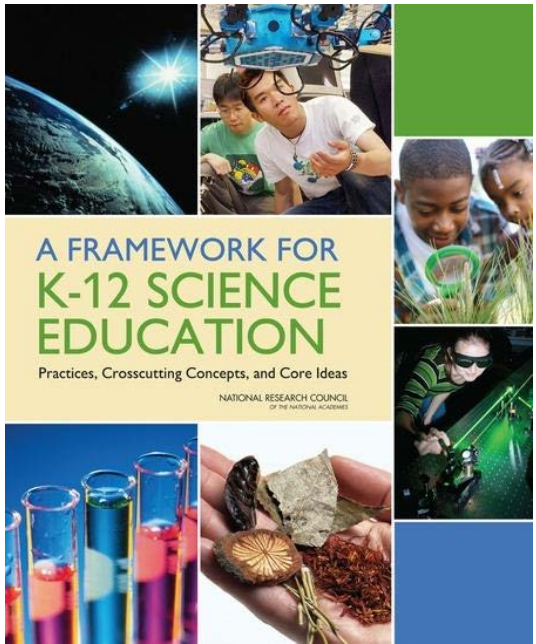
Broadly applicable method for integrating investigations & action into curriculum



a learning model for student achievement

Students learning outcomes:

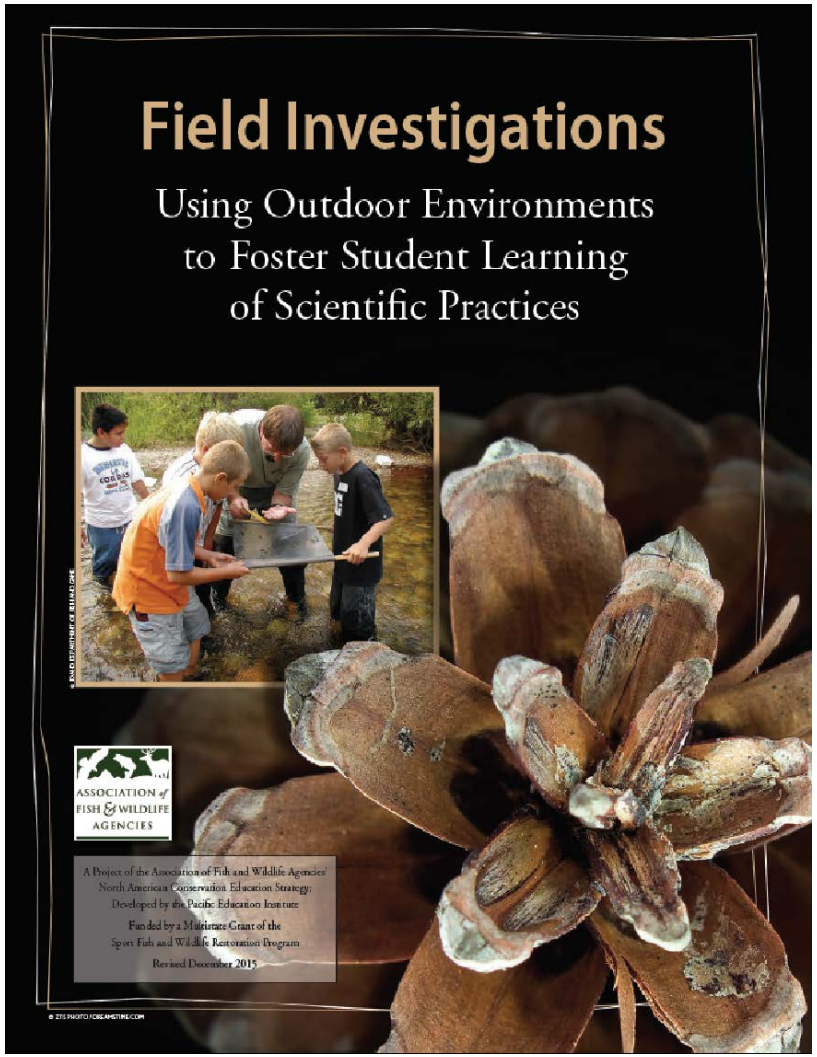
- Appreciation of the beauty and wonder of science/nature
- Possess sufficient knowledge … to engage in public discussions
- Are careful consumers of … information related to their everyday lives
- Are able to continue to learn … outside of school
- Have the skills to enter careers of their choice



2012 A Framework for K-12 Science Education, The National Academies, Washington, D.C.

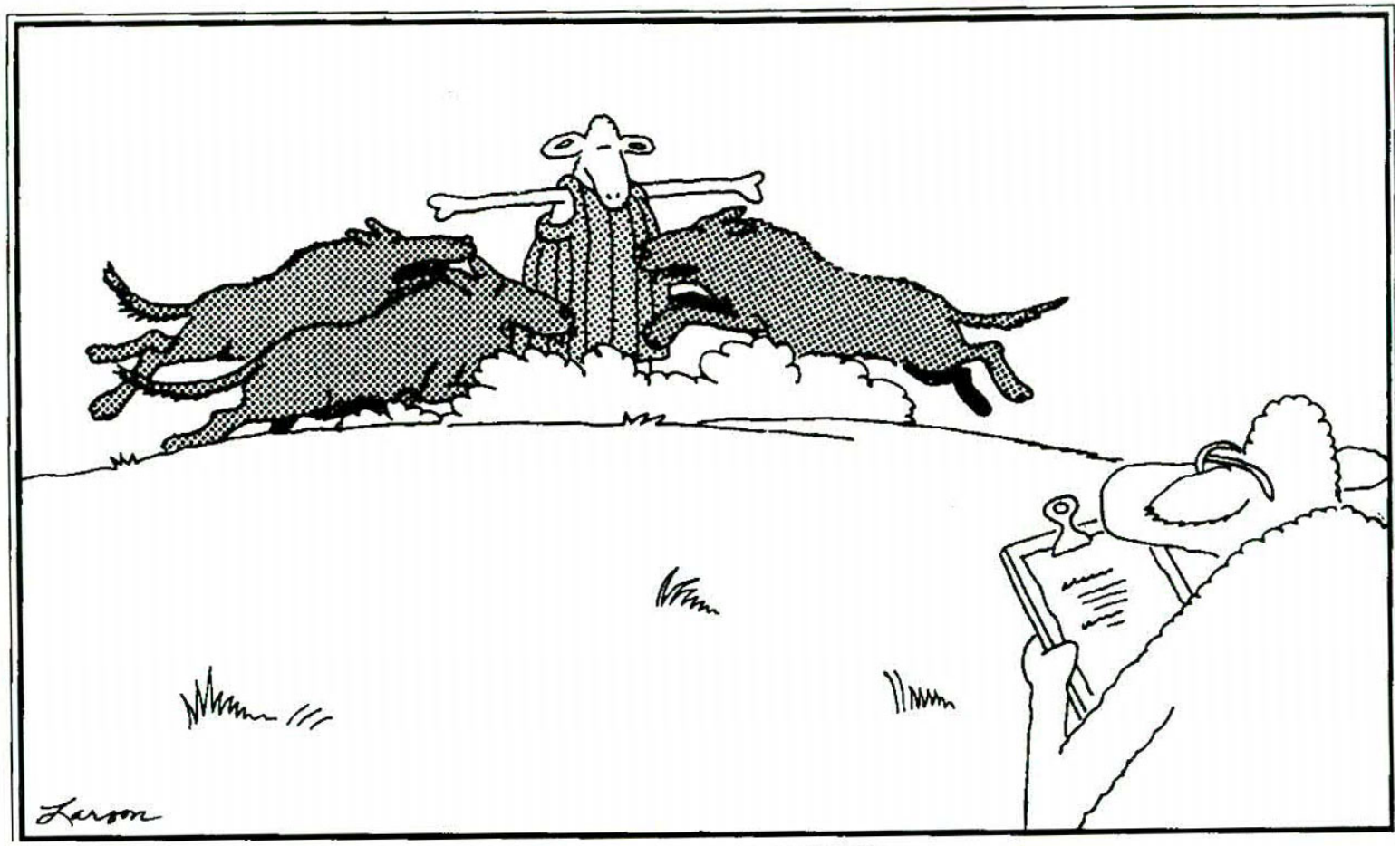
Exploration through Inquiry

- Investigations integrate **scientific practices** with real world content through **crosscutting concepts** that practicing field scientists and engineers tackle in their role as professionals.
- Scientific investigations are essential to the study of the natural world and provide valuable information for **problem solving** …

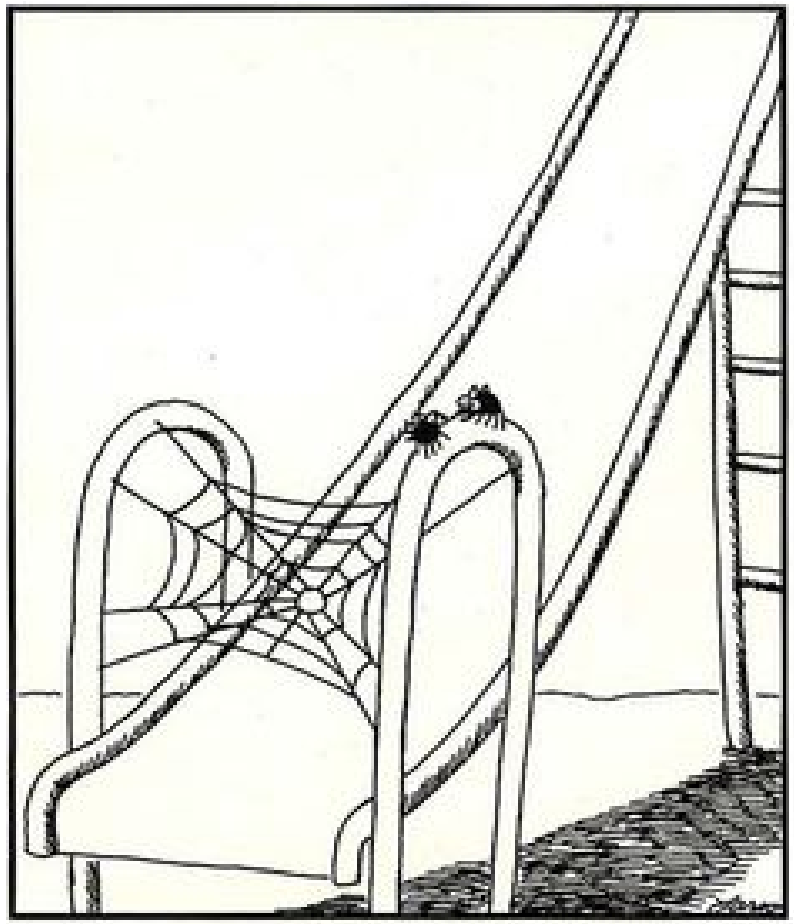


[1]***Field Investigations: Using Outdoor Environments to Foster Student Learning of Scientific Practices***, Pacific Education Institute, revised 2015

“The expectation is that students generate and interpret evidence and develop explanations of the natural world through sustained investigations.” [1]



Testing the carnivore-proof vest



“If we pull this off, we’ll eat like kings.”

[1] 2012 A Framework for K-12 Science Education, The National Academies, Washington, D.C.

Application of Information

… to be able to tackle environmental issues that currently confront society.

"Instruction throughout K-12 education is likely to develop science **proficiency** if it provides students with opportunities for a range of scientific activities...: **inquiry and investigation**, collection and analysis of evidence, logical reasoning, and **communication and application of information."**[1]

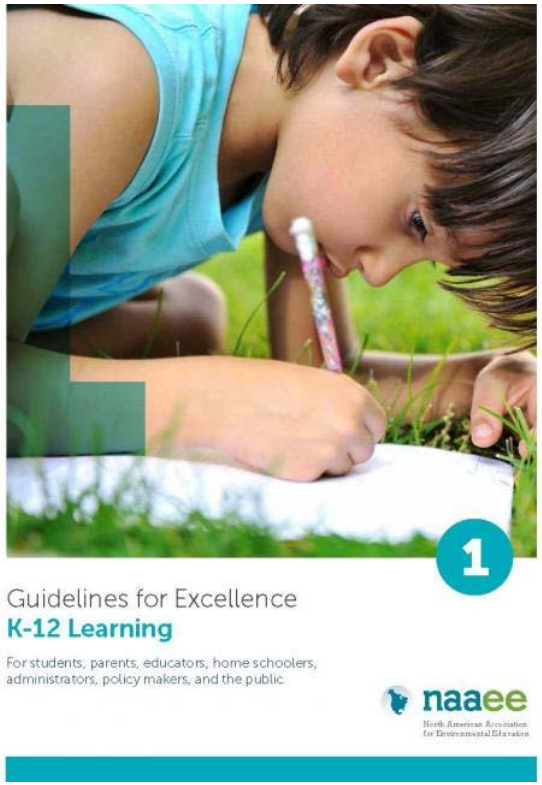
[1] 2012 A Framework for K-12 Science Education, The National Academies, Washington, D.C.

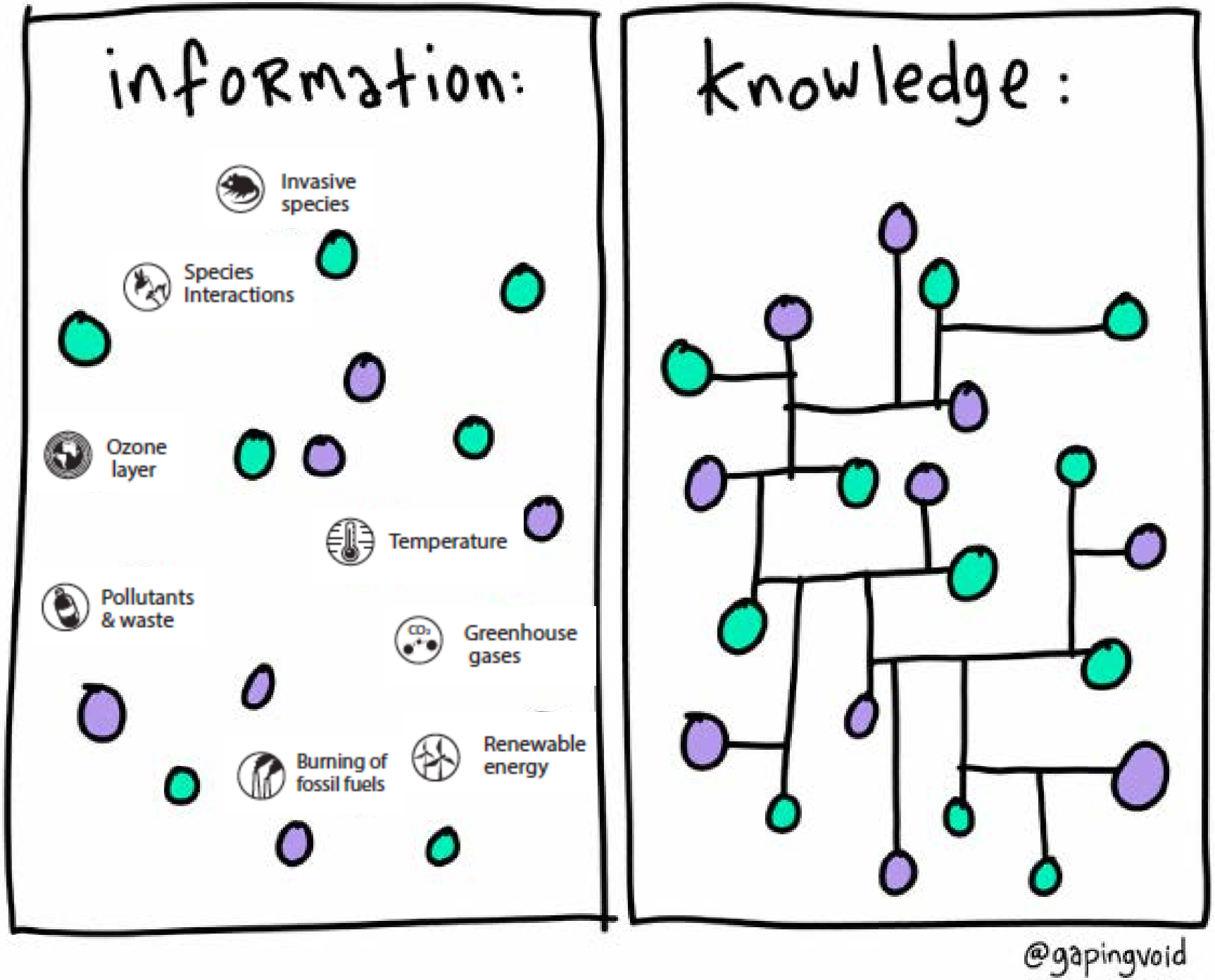
Connecting experience to curricula

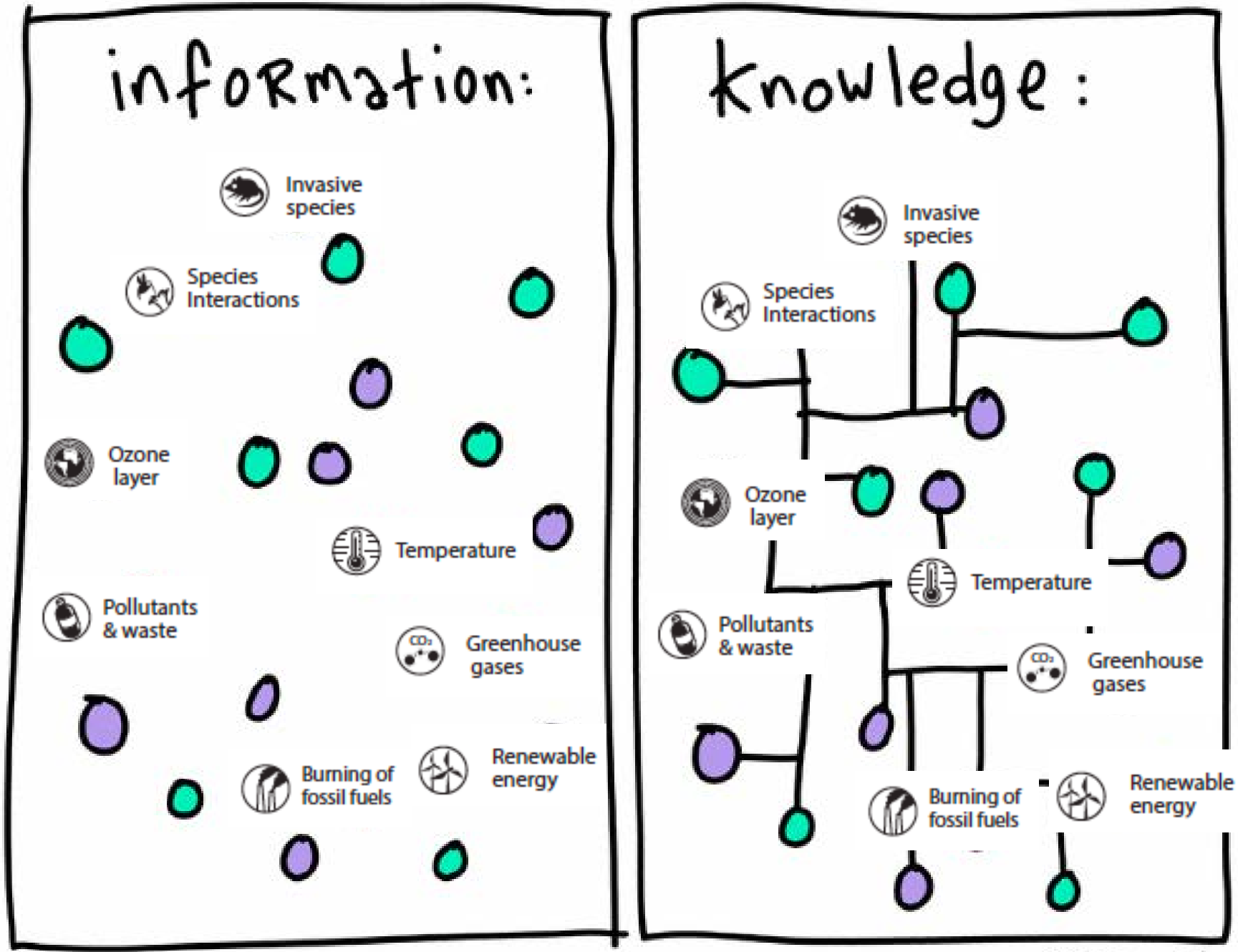
Integration of experiential programs and real-world connections into curricula is important for proficiency and deeper understanding of content, **replacing stand-alone experiences**.

Examples of resources for integrating experiential learning:

- Environmental and/or sustainability learning standards
- Environmental Literacy Plans (ELPs)
- Inter-disciplinary “cross-walks”
- Topical field investigations/experiences




information:
Invasive species
Species Interactions
Ozone layer
Temperature
Pollutants & waste
Greenhouse gases
Burning of fossil fuels
Renewable energy
knowledge:
@gapingvoid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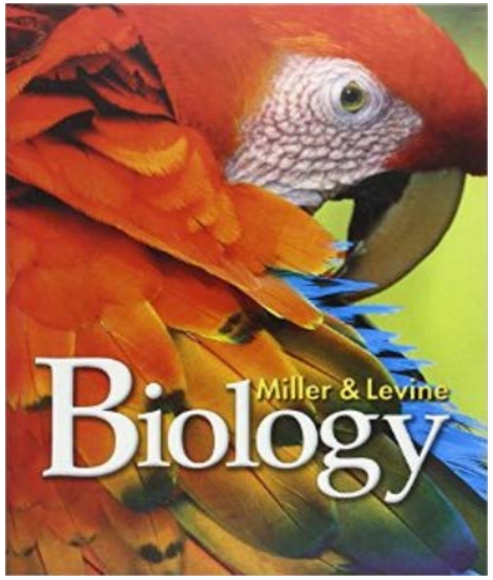
Burning of fossil fuels
Renewable energy
@gapingvoid

hhmi Howard Hughes Medical Institute

Smithsonian National Museum of Natural History

Integrating Investigations & Action



NASA

CALIFORNIA ACADEMY OF SCIENCES

Berkeley UNIVERSITY OF CALIFORNIA

UCMP

Understanding Science how science *really* works

Understanding Evolution your one-stop source for information on evolution

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION UNITED STATES DEPARTMENT OF COMMERCE

BSCS A SCIENCE EDUCATION CURRICULUM STUDY

Integrating Investigations & Actions into curriculum using Systems Connect

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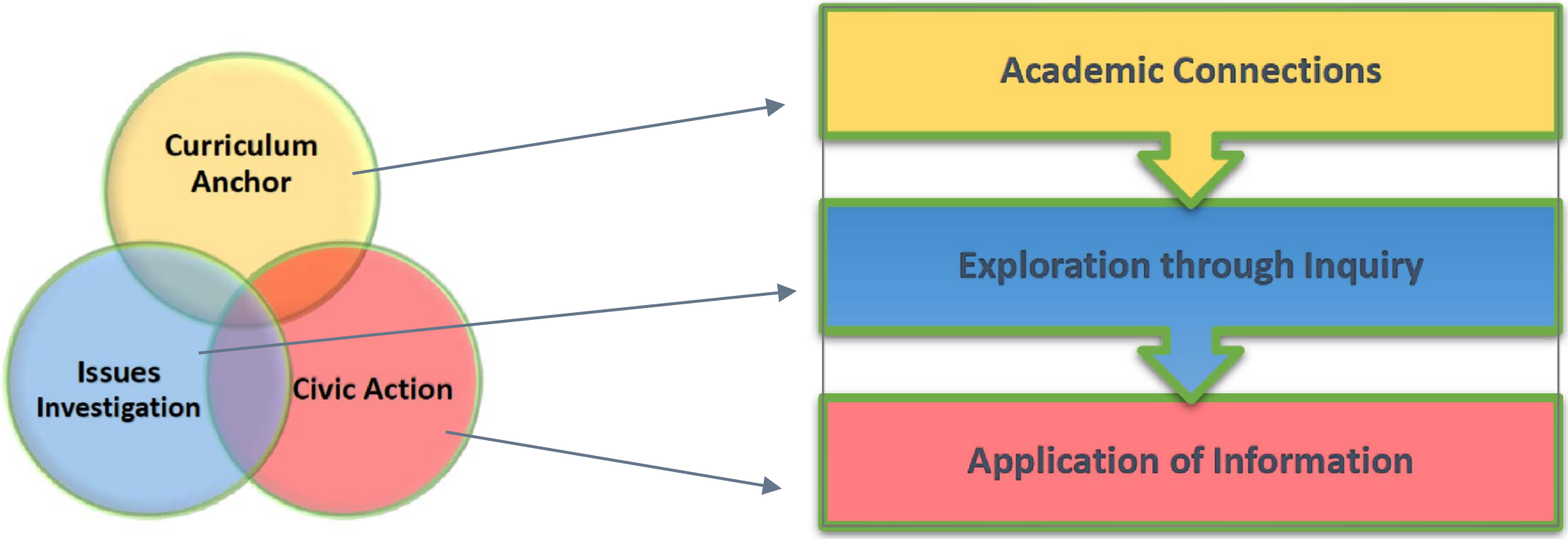
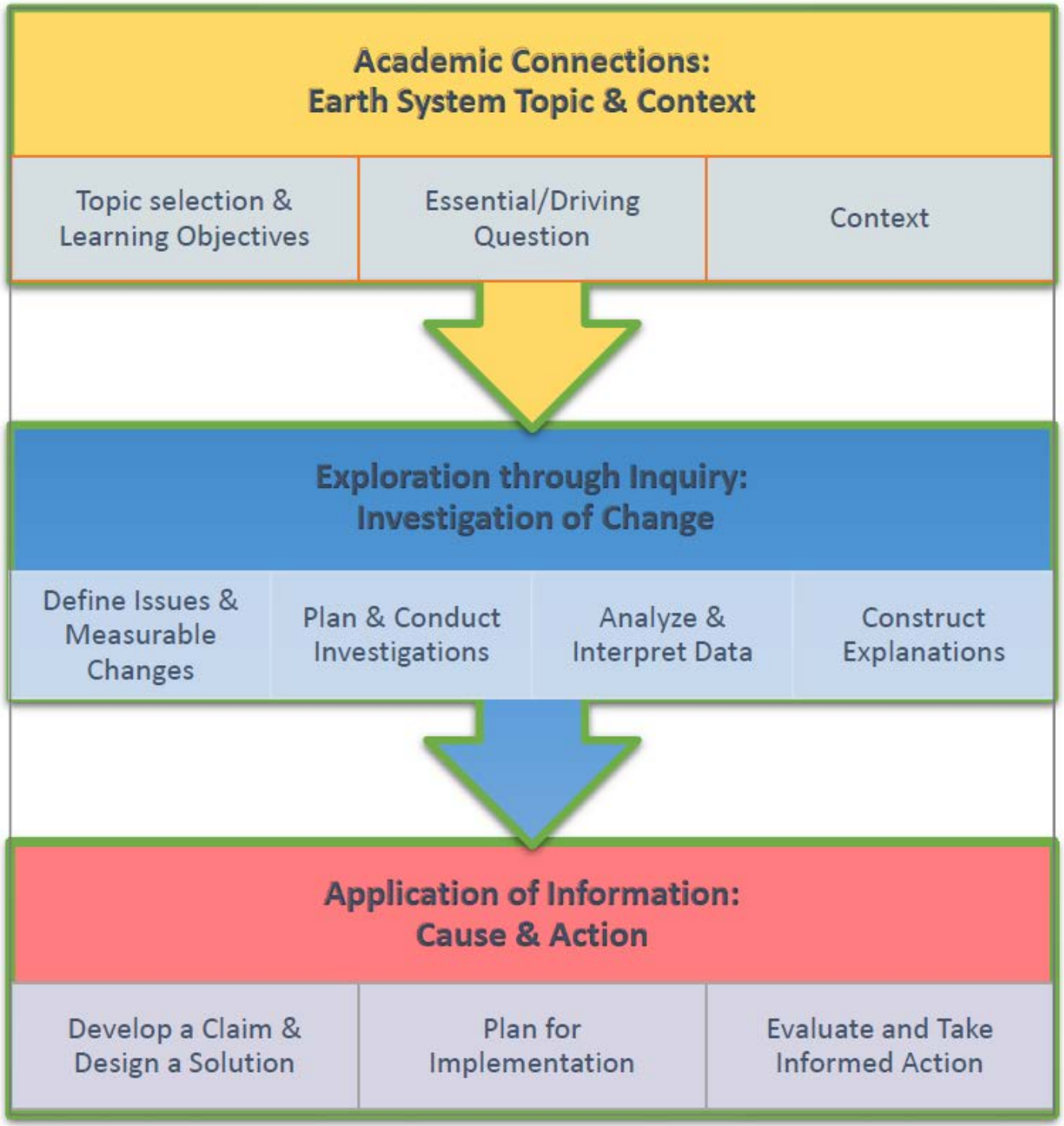
Systems Planning Guide




Academic Connections:
Earth System Topic & Context
Topic selection & Learning Objectives
Essential/Driving Question
Context
Exploration through Inquiry:
Investigation of Change
Define Issues & Measurable Changes
Plan & Conduct Investigations
Analyze & Interpret Data
Construct Explanations
Application of Information:
Cause & Action
Develop a Claim & Design a Solution
Plan for Implementation
Evaluate and Take Informed Action

SYSTEMS PLANNING GUIDE TEMPLATE

Resource criteria*:

Connecting topics to curriculum standards, performance expectations, and/or learning objectives

Overarching standards- based statement to guide inquiry, investigations and development of explanations and claims

Establishes relevancy, initiates conceptual links and connections to phenomena

Elicits questions, prompts investigation(s), supports inquiry, informs development of actionable claims

Academic Connections: Earth System Topic & Context

Topic Selection & Learning Objectives

Referencing disciplinary standards, select the related UGC Framework icons to create a topic "word bank"

Essential/Driving Question

Devise a broad, open-ended question or statement, aligned with the identified content standards and topics above, to guide the inquiry for the investigation(s), development of explanations and design of solutions

Context

Selection of resources or activities to establish connection and life-relevancy of topic to Earth Systems, initiate the building of conceptual links, and elicit questions which establish the need for further investigation

Resource	Earth system connections	Available data	Focal questions for exploration

SYSTEMS PLANNING GUIDE TEMPLATE

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Exploration through Inquiry: Investigation of Change

Resource criteria*:

Define issue for investigation and identify change variables to measure

Select resources for investigations that:

- *establish relationships between variables*
- *make predictions*
- *define protocols to measure/ collect/ select sources of data*
- *research authenticity and reliability of information*
- *evaluate, analyze and interpret information through modeling and graphical representations*
- *construct explanations and develop evidence-based conclusions*

Define Issues and Measurable Changes

- *Identify the topics (variables) to measure and select the resources for the investigations and activities*
- *Use the storyboard to develop a concept map of the earth system topic and measurable changes*
- *Use the chart below to develop a sequence for the investigations and activities*

Resource	Measurable changes to build conceptual links	Available data	Investigative questions

SYSTEMS PLANNING GUIDE TEMPLATE

Academic Connections: Earth System Topic & Context

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Application of Information: Cause & Action

Resource criteria*:

Develop evidence-based claims from investigations about cause of change

Design a solution/model a theory to address claim and mitigate/remediate measurable impact

Plan for implementation, identify phases, stakeholders and timetable for action

Collaborate and communicate to verify effectiveness of solution and take informed action

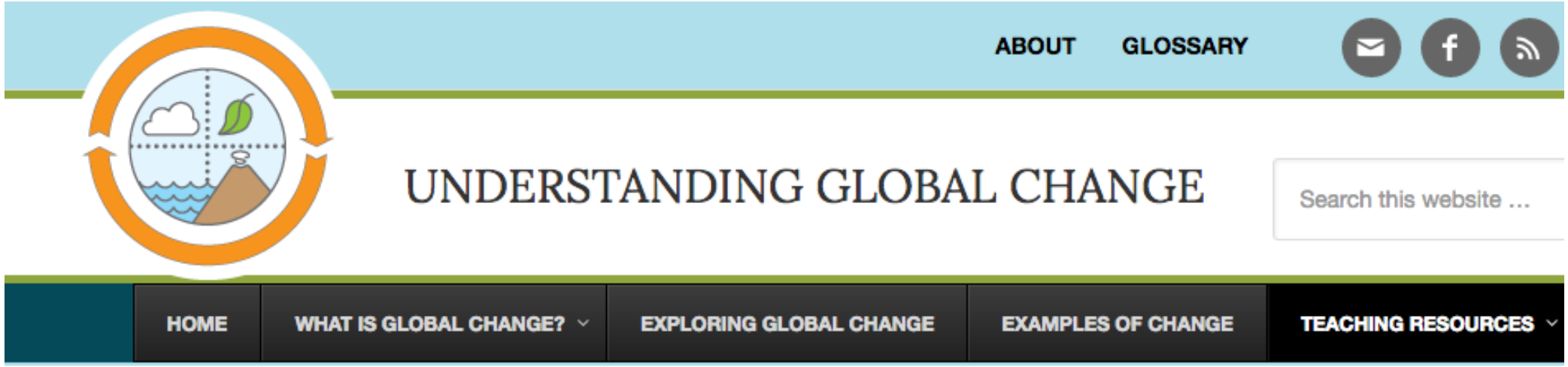
Develop a Claim and Design a Solution

Students will develop a claim about the causes of changes in earth systems and design a directly related actionable and implementable solution to manage/reduce impact to the earth system and improved quality of life/environment

Case study/Resource	Causes of change	Questions addressed by actionable claims/solutions

Examples using the **Systems Connect Planning Guide** to build curricular units

- University of California Museum of Paleontology (UCMP)
  - Sea level rise
- BioInteractive (HHMI)
  - Ecosystem impact

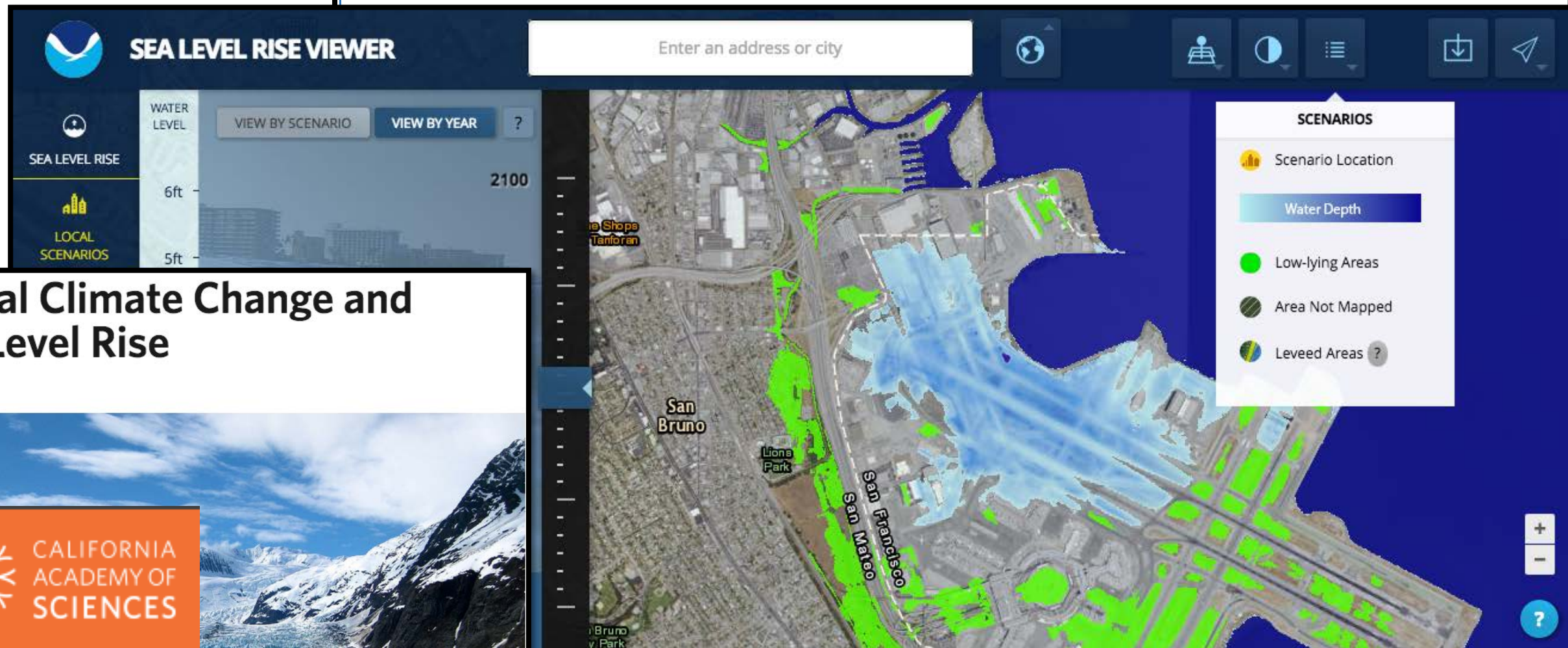


Sea Level Rise Unit Question: Will parts of the San Francisco Bay Area be under water in the next 100 years?

Linking Resources

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Learning Lesson: What-a-cycle



Global Climate Change and Sea Level Rise

CALIFORNIA ACADEMY OF SCIENCES

Resource criteria:*

Connecting topics to curriculum standards, performance expectations, and/or learning objectives

Overarching standards- based statement to guide inquiry, investigations and development of explanations and claims

Establishes relevancy, initiates conceptual links and connections to phenomena

Elicits questions, prompts investigation(s), supports inquiry, informs development of actionable claims

Academic Connections: Earth System Topic & Context

Earth System Topics: Sea Level Rise, Water Cycle, Greenhouse Effect

NGSS Performance Expectations:

5- ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Essential/Driving Question:

Will parts of the San Francisco Bay Area be under water in 100 years?

Context: Students will use resources to conceptualize earth systems functions and changes

Resource	Earth system connections	Available data	Focal questions for exploration
• Water reservoirs Water, water everywhere (NOAA) http://www.srh.noaa.gov/srh/jetstream/atmos/ll_water.html	Clouds, water vapor (greenhouse gas), precipitation, snow and ice cover are all a part of the water reservoirs.	Model of relative size of water reservoirs	Where do we find water?
• Water cycle game What-a-cycle (NOAA) http://www.srh.noaa.gov/jetstream/atmos/ll_whatacycle.html	Water cycles as it transforms between a solid, liquid, and gas due to energy from solar radiation. Clouds, water vapor (greenhouse gas), precipitation , freshwater quality and availability, freshwater use, and snow and ice cover are all a part of the water cycle.	Model of the cycling of water in the Earth system	How does water move? How does water get into and out of the ocean?

Exploration through Inquiry: Investigation of Change

Resource criteria:

Define issue for investigation and identify change variables to measure

Select resources for investigations that:

- *establish relationships between variables*
- *make predictions*
- *define protocols to measure/ collect/ select sources of data*
- *research authenticity and reliability of information*
- *evaluate, analyze and interpret information through modeling and graphical representations*
- *construct explanations and develop evidence-based conclusions*

Students will use selected resources to plan & conduct investigations about measurable changes in earth systems, analyze data and construct evidence-based explanations about how environmental changes can impact ecosystems

Resource	Measurable changes to build conceptual links	Available data	Investigative questions
Global Climate Change and Sea Level Rise (California Academy of Sciences) http://www.calacademy.org/educators/lesson-plans/global-climate-change-and-sea-level-rise	Changes in temperature cause the water cycle, including melting of snow and ice cover. Melting ice from land causes sea level rise.	Creating a model of sea ice and land ice melt	Could there ever be more water in the ocean than there is today?
How Global Warming Works Video (UC Berkeley) http://www.howglobalwarmingworks.org/ Global Climate Change: Vital Signs of the Planet (NASA) https://climate.nasa.gov/evidence/	When solar radiation reaches the Earth, light is absorbed or reflected. When light is absorbed, it is reradiated as heat. The greenhouse effect happens when greenhouse gases reradiate heat in the atmosphere, which increases the temperature of the Earth's atmosphere and oceans. Since the industrial age, greenhouse gases have increased significantly. Human activities, such as burning of fossil fuels, cement production, agricultural activities, and deforestation all increase the levels of greenhouse gases in the atmosphere.	Interpreting graphs of temperature forcings (greenhouse gases, volcanoes, Sun, etc) from NASA datasets.	What makes Earth's average temperature rise and ice melt?
Thermal expansion of water (University of Central Florida) http://sciences.ucf.edu/biology/noss/wp-content/uploads/sites/171/2013/05/Sea-Level-Rise-Lesson-Series.pdf	As global temperatures of the atmosphere and ocean rise, thermal expansion of water will also contribute to sea level rise.	Collecting data from heating water experiment	How do rising global temperatures affect sea level?

Application of Information: Cause & Action

Resource criteria:

Develop evidence-based claims from investigations about cause of change

Design a solution/model a theory to address claim and mitigate/remediate measurable impact

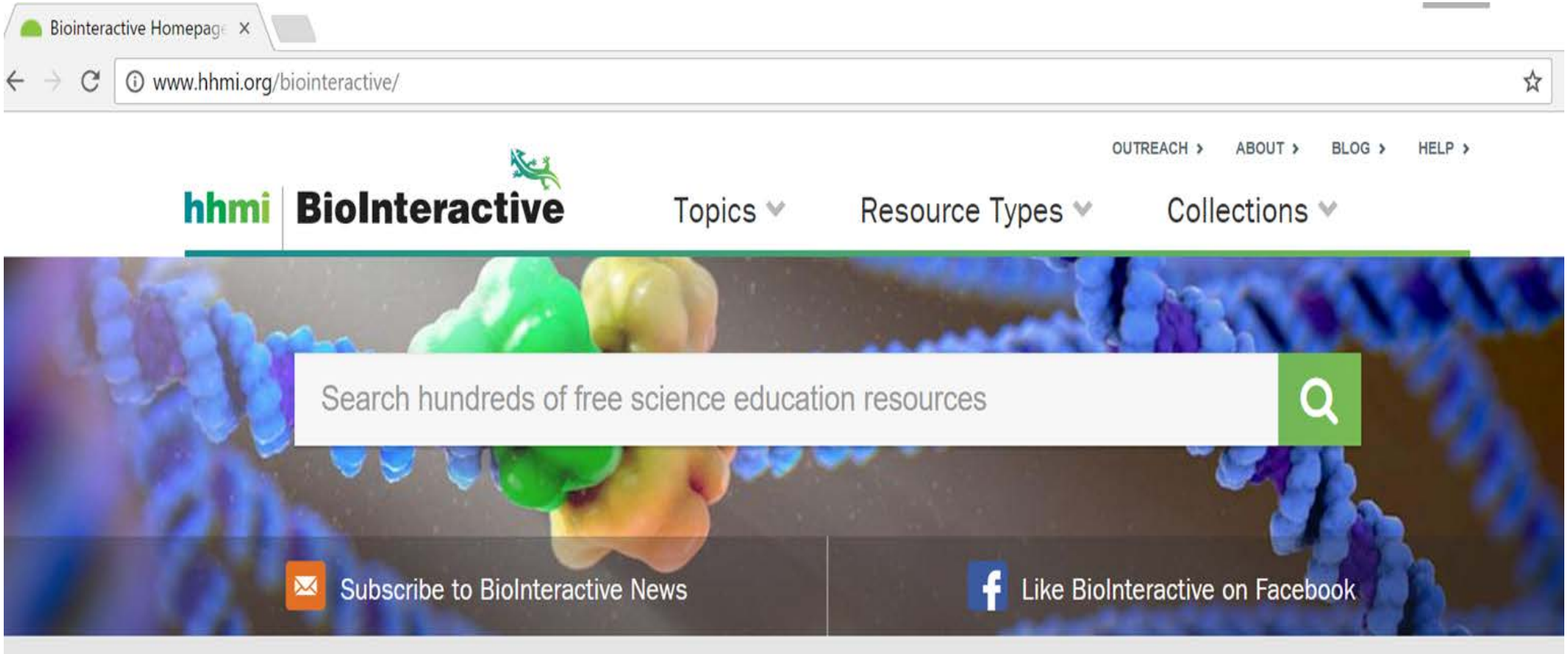
Plan for implementation, identify phases, stakeholders and timetable for action

Collaborate and communicate to verify effectiveness of solution and take informed action

Students will develop a claim about the causes of changes in earth systems and design an actionable and implementable solution to manage/reduce impact to ecosystems for conservation, preservation and improved quality of life

Case study/Resource	Causes of change	Questions addressed by actionable claims/solutions
Students will interpret visualizations of sea level rise using Sea Level Rise Viewer (NOAA) https://coast.noaa.gov/digitalcoast/tools/slr Students will read and summarize local news articles on locations and construction that will be impacted by sea level rise San Francisco Public Press http://sfpublicpress.org/searise Students will make recommendation on how to mitigate the effects of sea level rise locally	Human activities, such as burning of fossil fuels, cement production, agricultural activities, and deforestation all increase the levels of greenhouse gases in the atmosphere, causing temperatures to rise. Habitat loss/restoration can help mitigate the effects of sea level rise. Sea level rise will result in the displacement of human populations.	How quickly could sea level rise happen? What parts of SF will be most impacted by sea level rise? How can we protect coastal areas from sea level rise?

Ecosystem Impact Unit Question: How are ecosystems impacted when the environment changes?



SYSTEMS PLANNING GUIDE 〉 BIOINTERACTIVE

Academic Connections: Earth System Topic & Context

Resource criteria:*

Connecting topics to curriculum standards, performance expectations, and/or learning objectives

Earth System Topic: Ecosystems

NGSS Disciplinary Core Idea: LS2.C Ecosystem Dynamics, Functioning & Resilience

NGSS Performance Expectations: (HS-LS2-6) Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Overarching standards- based statement to guide inquiry, investigations and development of explanations and claims

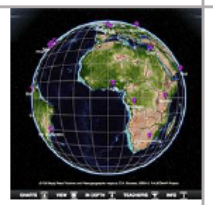
Essential/Driving Question:

How are ecosystems impacted when the environment changes?

Establishes relevancy, initiates conceptual links and connections to phenomena

Context: Students will use resources to conceptualize earth systems functions and changes

Elicits questions, prompts investigation(s), supports inquiry, informs development of actionable claims

Resource	Earth system connections	Available data	Focal questions for exploration
EarthViewer Click & Learn, App, activities  and BiomeViewer interactive 	**Plate tectonics** determines the movement of landmasses and **distribution of continents and oceans** across the globe influence **atmospheric and ocean circulation** patterns. Different latitudes receive variable amounts of **solar radiation** that is **reflected and absorbed** through time due to the spin, **tilt, and orbit of the Earth.** Differential heating of the Earth's surface results in **climate** zones and **ecosystems** that determine **species ranges, productivity and biomass,** and **population** sizes.	Historic data for carbon dioxide concentrations, temperature, biodiversity, climate, wildlife, patterns of human settlement and agriculture	How has climate changed in earth's geologic past and how might these changes affect ecosystems? How are changes in the past similar/different than more recent changes? What factors and variables should be studied to understand how a system (ecosystem, biome, etc) functions and the species living in it?

SYSTEMS PLANNING GUIDE 〉 BIOINTERACTIVE

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Elicits questions, prompts investigation(s), supports inquiry, informs development of actionable claims

Exploration through Inquiry: Investigation of Change

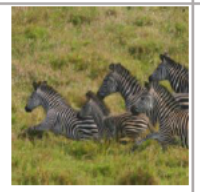
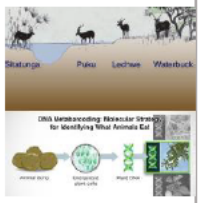
Resource criteria*:

Define issue for investigation and identify change variables to measure

Select resources for investigations that:

- *establish relationships between variables*
- *make predictions*
- *define protocols to measure/ collect/ select sources of data*
- *research authenticity and reliability of information*
- *evaluate, analyze and interpret information through modeling and graphical representations*
- *construct explanations and develop evidence-based conclusions*

Students will use selected resources to plan & conduct investigations about measurable changes in earth systems, analyze data and construct evidence-based explanations about how environmental changes can impact ecosystems

Resource	Measurable changes to build conceptual links	Available data	Investigative questions
Creating Chains and Webs to Model Ecological Relationships 	The stability of **populations** in an **ecosystem** is determined by the distribution of **biomass** across the **ecosystem.** Variation in **biomass and productivity** can impact **species interactions** and **species ranges.** Disruptions to **climate** systems due to **weather events**, **fire**, drought, soil formation/erosion or human activities (deforestation, habitat loss, agricultural activities, population growth) can cause changes in **population sizes** and lead to **extinction or diversification.**	Creating, manipulating and comparing different models of species relationships and energy flow through a system: food chain, energy pyramid and food web	What is the energy flow through an ecosystem? What is the relationship and interaction between species in an ecosystem? What happens to the flow of energy and interrelationship of species when there is a disturbance?
Niche Partitioning and Species Coexistence  and Niche Partitioning Activity 	How **populations** use resources in an **ecosystem** is determined by **species interactions**, such as competition or facilitation. Stresses on **productivity and biomass** can impact the number of individuals that can survive in a **population**, and alter **species ranges** and **diversity**. If **population** sizes and the **species ranges** are small, **extinction** can occur.	Identification of species habits, behaviors and relationships to determine role and function in ecosystem; how species interactions inform health and resiliency of ecosystem	How do species coexist and share the resources in an ecosystem? How do we know if species are competing for resources? Can ecosystems support many of the same kinds of species and maintain ecosystem health?

SYSTEMS PLANNING GUIDE 〉 BIOINTERACTIVE

Academic Connections: Earth System Topic & Context

Resource criteria*:

Connecting topics to curriculum standards, performance expectations, and/or learning objectives

Overarching standards- based statement to guide inquiry, investigations and development of explanations and claims

Establishes relevancy, initiates conceptual links and connections to phenomena

Elicits questions, prompts investigation(s), supports inquiry, informs development of actionable claims

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Application of Information: Cause & Action

Resource criteria*:

Develop evidence-based claims from investigations about cause of change

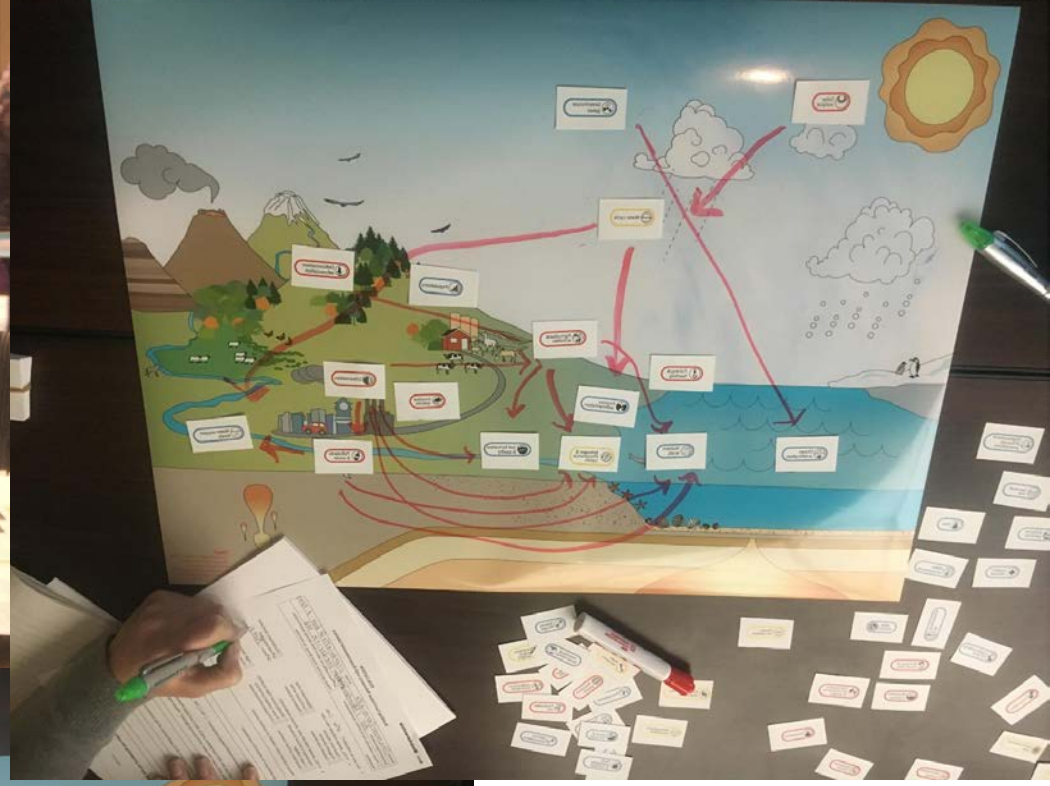
Design a solution/model a theory to address claim and mitigate/remediate measurable impact

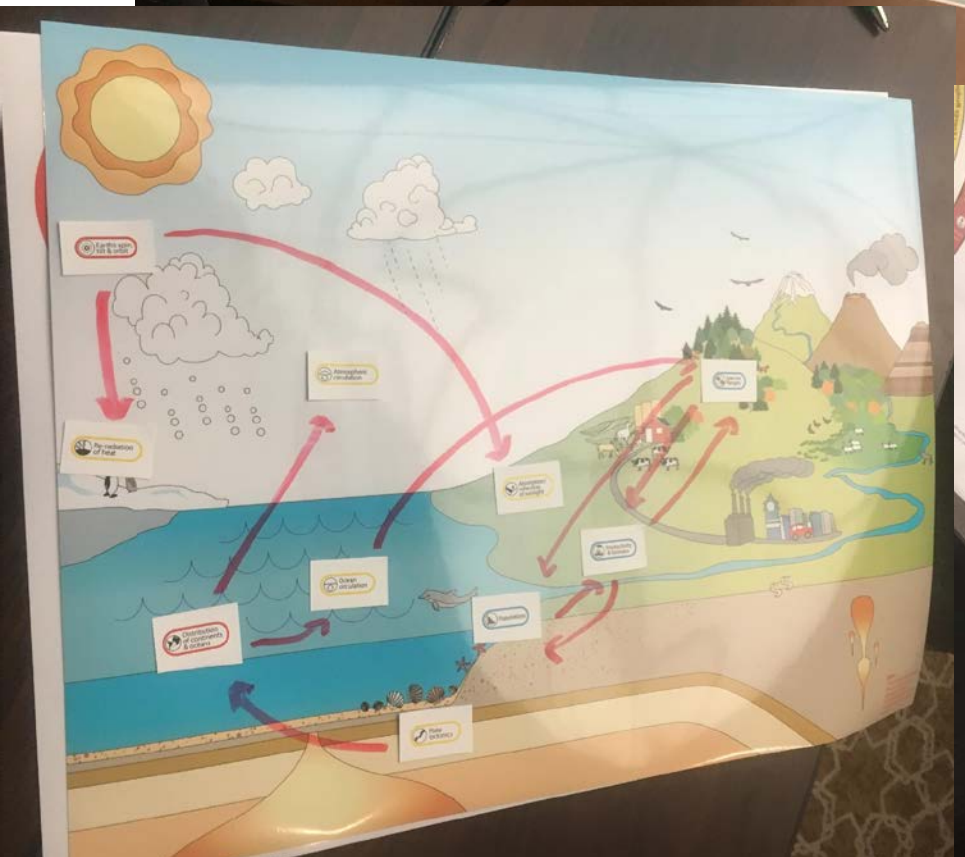
Plan for implementation, identify phases, stakeholders and timetable for action

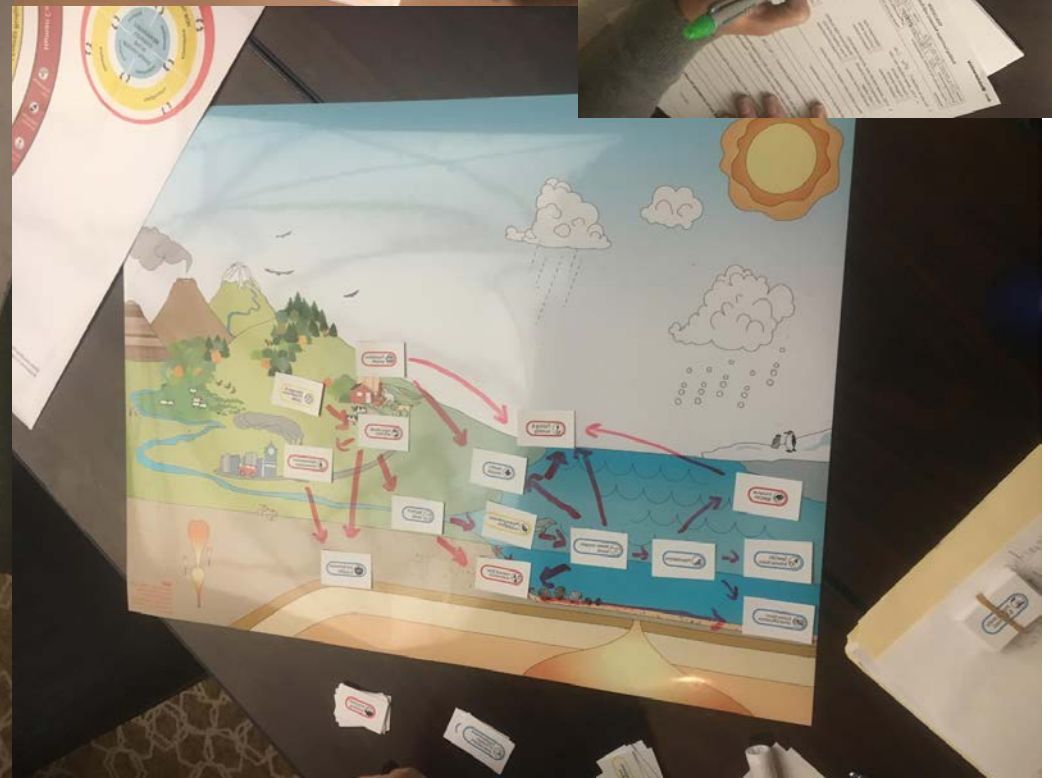
Collaborate and communicate to verify effectiveness of solution and take informed action

Students will develop a claim about the causes of changes in earth systems and design an actionable and implementable solution to manage/reduce impact to ecosystems for conservation, preservation and improved quality of life

	Case study/Resource		Causes of change	Questions addressed by actionable claims/solutions
GORONGOSA RESOURCES Restoration and conservation efforts and strategies in Gorongosa National Park also address local community needs	Conserving and Restoring Ecosystems		The effects of war and **population growth** have disrupted the **ecosystems** in Gorongosa National Park: Sections of rainforest were **deforested** to make room for **agricultural activities** to increase **food availability/nutrition** for the **population,** which caused **erosion** of topsoil and impacted **freshwater availability**, affecting the **productivity/biomass** of the **ecosystem. Species ranges** were impacted due to **habitat loss**, limiting food availability. **Hunting** and poaching have led to the near **extinction** of several species. A large-scale **restoration** effort utilizing ingenuity and **innovation** is underway in Gorongosa to both conserve the local **ecosystems** and to improve the **quality of human life** for the Mozambican people.	How do we conserve ecosystems? When we try to restore damaged ecosystems, what state do we restore them? At what point might they recover on their own? Who are the stakeholders who can collaborate to mitigate/remediate environmental changes? How do we evaluate the effectiveness of conservation efforts?
	Restoring Mozambique's National Treasure			
	A Science-Based Approach to Restoring Gorongosa's Wildlife			
	Gorongosa National Park Interactive Map			





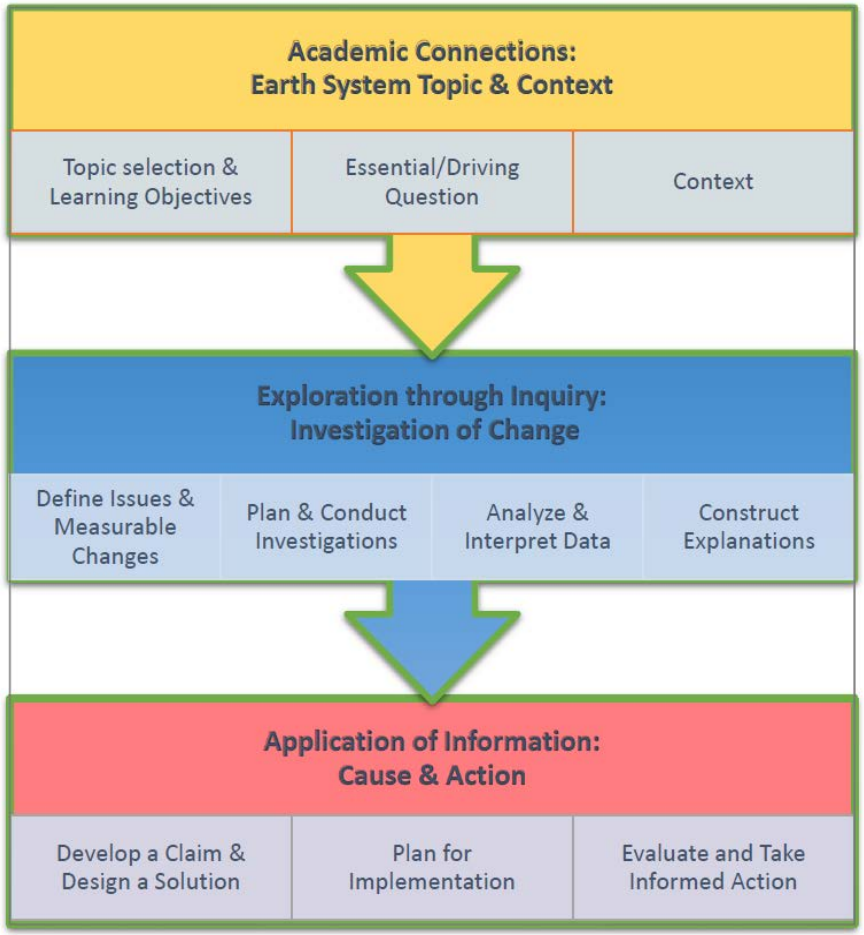


"…students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry…" [1]

Carl Sagan as a kid

[1] 2012 A Framework for K-12 Science Education, The National Academies, Washington, D.C.

The Systems Connect Planning Guide



- Defines the curricular scope and sequence for instruction, student learning and engagement
- Constructs relevant conceptual links & relationship between topics
- Provides a roadmap for NGSS implementation

For more information:

- *Aleeza Oshry, HHMI: oshrya@hhmi.org*
- *Jessica Bean, UCMP: jrbean@berkeley.edu*

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UCMP

Upcoming Events:

- **Webinars: 2nd Thursdays, 1p PT/4p ET**
  - September 14, 2017
    Achieve Resources and Tools for NGSS Implementation: Matt Krehbiel, Achieve, Inc

- August 1, 2017 Abstract submissions for Geological Society of America
  "Getting it done: Experiences of implementing the Framework and NGSS in Earth and space science"
  Seattle, WA October 22-25, 2017
- July 17-21, Earth Educators Rendezvous Round Table Discussion
  "Getting it done: Experiences of implementing the Framework and NGSS in Earth and space science"
  Albuquerque, NM
- Email list and archived webinars:
  http://nagt.org/nagt/profdev/workshops/ngss_summit/index.html

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Thank you!

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