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
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
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](http://nagt.org/nagt/profdev/workshops/ngss_summit/index.html)
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

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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

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Conceptual Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New substances form during chemical reactions because atoms rearrange to form new molecules.</td>
</tr>
<tr>
<td>2</td>
<td>Mass is conserved in chemical reactions because atoms are conserved.</td>
</tr>
<tr>
<td>3</td>
<td>Plant growth involves chemical reactions in which atoms rearrange and are conserved.</td>
</tr>
<tr>
<td>4</td>
<td>Animal growth involves chemical reactions in which atoms rearrange and are conserved.</td>
</tr>
</tbody>
</table>
## Selecting and Sequencing Phenomena

<table>
<thead>
<tr>
<th>Conceptual Focus</th>
<th>What Students Experience</th>
</tr>
</thead>
</table>
| 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$_6$H$_{12}$O$_6$ from $^{14}$CO$_2$  
   - Plants produce $^{18}$O$_2$ not C$_6$H$_{12}^{18}$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

<table>
<thead>
<tr>
<th>State of Matter (at 25°C)</th>
<th>Color</th>
<th>Smell</th>
<th>Conductivity</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Iron</strong></td>
<td><strong>Solid</strong></td>
<td><strong>Metallic silver</strong></td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Oxygen</strong></td>
<td><strong>Gas</strong></td>
<td><strong>Colorless</strong></td>
<td>None</td>
<td>No</td>
</tr>
</tbody>
</table>

#### Ending Substances

<table>
<thead>
<tr>
<th></th>
<th>State of Matter</th>
<th>Color</th>
<th>Smell</th>
<th>Conductivity</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rust</strong></td>
<td><strong>Solid</strong></td>
<td><strong>Red orange</strong></td>
<td>None</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Examining Models of Molecules of Starting and Ending Substances

Chemical Reaction:
Steel Wool (Iron) and Air (Oxygen)

Substances we start with in the container:
- Fe (iron)
- O₂ (oxygen gas)

Substances we end up with in the container:
- Fe₂O₃ (iron oxide/rust)
### Relating Differences in Properties to Differences in Molecular Composition

<table>
<thead>
<tr>
<th>Substance Name</th>
<th>Properties</th>
<th>Molecular Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Metallic silver solid</td>
<td>Fe</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Colorless gas at 25°C</td>
<td>O₂</td>
</tr>
<tr>
<td>Rust (Iron Oxide)</td>
<td>Red-orange solid</td>
<td>Fe₂O₃</td>
</tr>
</tbody>
</table>
Modeling How a New Substance, Rust (Fe₂O₃), Could Form from the Starting Substances Iron (Fe) and Oxygen (O₂)
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

Chemical Reaction: Hexamethylenediamine and Adipic Acid

Substances we start with in the container:
- C₆H₁₄N₂ (hexamethylene diamine)
- C₉H₁₆O₄ (adipic acid)

Substances we end up with in the container:
- C₁₂H₂₄O₃N (nylon repeating unit)
- H₂O (water)
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.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Initial Mass (Age)</th>
<th>Final Mass (Age)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>.7 g (1 week)</td>
<td>896 g (13 weeks)</td>
</tr>
</tbody>
</table>
Examining Substances that Make Up Plant Body Structures

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

<table>
<thead>
<tr>
<th>Carbohydrate Molecule</th>
<th>Solubility in Water</th>
<th>Does it form fibers?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>Starch</td>
<td>Low</td>
<td>No</td>
</tr>
</tbody>
</table>

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)?

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Starting Substances (Reactants)</th>
<th>Ending Substances (Products)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\text{CO}_2$</td>
<td>$\text{H}_2\text{O}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 2</th>
<th>Starting Substances (Reactants)</th>
<th>Ending Substances (Products)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\text{CO}_2$</td>
<td>$\text{H}_2\text{O}$</td>
</tr>
</tbody>
</table>

Effects of the Herbicide Triazofenamide on Cellulose Production from Glucose

<table>
<thead>
<tr>
<th>Group</th>
<th>Amount of Labeled C Atoms in Cellulose (dpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>11,200</td>
</tr>
<tr>
<td>Experimental (herbicide)</td>
<td>1,900</td>
</tr>
</tbody>
</table>
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.

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
Macroscopic Phenomenon: Over seven months a puppy grows into an adult German shepherd.
### Examining Substances That Make Up Animal Body Structures

<table>
<thead>
<tr>
<th>Animal</th>
<th>Protein Molecules (per 100g)</th>
<th>Fat Molecules (per 100g)</th>
<th>Carbohydrate Molecules (per 100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchovy fish</td>
<td>65.3</td>
<td>7.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Brine shrimp</td>
<td>58.4</td>
<td>4.0</td>
<td>29.3</td>
</tr>
<tr>
<td>Cow</td>
<td>60.0</td>
<td>8.9</td>
<td>15.1</td>
</tr>
<tr>
<td>Chicken</td>
<td>42.3</td>
<td>37.8</td>
<td>10.5</td>
</tr>
<tr>
<td>Crayfish</td>
<td>42.3</td>
<td>37.8</td>
<td>10.5</td>
</tr>
<tr>
<td>Hamster</td>
<td>49.8</td>
<td>34.6</td>
<td>8.1</td>
</tr>
<tr>
<td>Herring fish</td>
<td>72.7</td>
<td>8.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Human</td>
<td>48.0</td>
<td>38.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Locust</td>
<td>22.1</td>
<td>3.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Squid</td>
<td>74.8</td>
<td>8.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Worm</td>
<td>56.4</td>
<td>7.8</td>
<td>19.6</td>
</tr>
</tbody>
</table>
# Examining Properties of Those Substances

<table>
<thead>
<tr>
<th>Protein Name</th>
<th>Body Structures</th>
<th>Solubility in Water</th>
<th>Fibrous or Globular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein</td>
<td>Milk</td>
<td>High</td>
<td>Globular</td>
</tr>
<tr>
<td>Collagen</td>
<td>Tendons, skin</td>
<td>Low</td>
<td>Fibrous</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>Blood</td>
<td>High</td>
<td>Globular</td>
</tr>
<tr>
<td>Keratin</td>
<td>Skin, scales, hair</td>
<td>Very low</td>
<td>Fibrous</td>
</tr>
<tr>
<td>Myosin</td>
<td>Muscle</td>
<td>Low</td>
<td>Globular</td>
</tr>
<tr>
<td>Actin</td>
<td>Muscle</td>
<td>Low</td>
<td>Fibrous</td>
</tr>
<tr>
<td>Ovalbumin</td>
<td>Egg white</td>
<td>High</td>
<td>Globular</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Location</th>
<th>% of labeled carbon atoms found 24 hours after feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestive system</td>
<td>7</td>
</tr>
<tr>
<td>Rest of body (excluding digestive system)</td>
<td>20</td>
</tr>
<tr>
<td>Water (outside the fishes’ bodies)</td>
<td>73</td>
</tr>
</tbody>
</table>
Examining Models of Starting and Ending Substances

Chemical Reaction #1: Breaking down a piece of a protein into amino acids

Reactants (starting substances)

Products (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
Middleschoolchemistry.com and the NGSS

Jim Kessler
ACS Office of K-8 Science
Welcome to the Next Generation Science Standards (NGSS)
Start with the Disciplinary Core Ideas

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.
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

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®
Implementing NGSS with Systems Connect

Integrating Investigations & Action
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
How?

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

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

➢ building explicit conceptual links
➢ developing a deep, comprehensive understanding of the systems and processes of our planet
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*
Components of Systems Connect include:

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- **A Systems Planning Guide** for developing or revising learning progressions, scope and sequence and integrating resources to be responsive to **NGSS**
Broadly applicable method for integrating investigations & action into curriculum

Environmental Literacy Model (ELM): More information @ www.melpeducation.org
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

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

… 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

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
- Pollutants & waste
- Temperature
- Burning of fossil fuels
- Greenhouse gases
- Renewable energy

knowledge:

@gapingvoid
Integrating Investigations & Action
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*
Systems Planning Guide

- Curriculum Anchor
- Issues Investigation
- Civic Action

- Academic Connections
- Exploration through Inquiry
- Application of Information
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

<table>
<thead>
<tr>
<th>Resource</th>
<th>Earth system connections</th>
<th>Available data</th>
<th>Focal questions for exploration</th>
</tr>
</thead>
</table>
### Academic Connections: Earth System Topic & Context

#### Exploration through Inquiry: Investigation of Change

**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

<table>
<thead>
<tr>
<th>Resource</th>
<th>Measurable changes to build conceptual links</th>
<th>Available data</th>
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Academic Connections: Earth System Topic & Context

Exploration through Inquiry: Investigation of Change

Application of Information: Cause & 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.

<table>
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<tr>
<th>Case study/Resource</th>
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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

Development of action plan:
- 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
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

Learning Lesson: What-a-cycle

Global Climate Change and Sea Level Rise
# 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

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<tr>
<td>- Water reservoirs Water, water everywhere (NOAA) <a href="http://www.srh.noaa.gov/srh/jetstream/atmos/ll_water.html">http://www.srh.noaa.gov/srh/jetstream/atmos/ll_water.html</a></td>
<td>Clouds, water vapor (greenhouse gas), precipitation, snow and ice cover are all a part of the water reservoirs.</td>
<td>Model of relative size of water reservoirs</td>
<td>Where do we find water?</td>
</tr>
<tr>
<td>- Water cycle game What-a-cycle (NOAA) <a href="http://www.srh.noaa.gov/jetstream/atmos/ll_whatacycle.html">http://www.srh.noaa.gov/jetstream/atmos/ll_whatacycle.html</a></td>
<td>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.</td>
<td>Model of the cycling of water in the Earth system</td>
<td>How does water move? How does water get into and out of the ocean?</td>
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</table>
## Exploration through Inquiry: Investigation of Change

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.

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<tr>
<td>Global Climate Change and Sea Level Rise (California Academy of Sciences) <a href="http://www.calacademy.org/educators/lesson-plans/global-climate-change-and-sea-level-rise">http://www.calacademy.org/educators/lesson-plans/global-climate-change-and-sea-level-rise</a></td>
<td>Changes in temperature cause the water cycle, including melting of snow and ice cover. Melting ice from land causes sea level rise.</td>
<td>Creating a model of sea ice and land ice melt</td>
<td>Could there ever be more water in the ocean than there is today?</td>
</tr>
<tr>
<td>How Global Warming Works Video (UC Berkeley) <a href="http://www.howglobalwarmingworks.org/">http://www.howglobalwarmingworks.org/</a></td>
<td>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.</td>
<td>Interpreting graphs of temperature forcings (greenhouse gases, volcanoes, Sun, etc) from NASA datasets.</td>
<td>What makes Earth’s average temperature rise and ice melt?</td>
</tr>
<tr>
<td>Global Climate Change: Vital Signs of the Planet (NASA) <a href="https://climate.nasa.gov/evidence/">https://climate.nasa.gov/evidence/</a></td>
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**Application of Information: Cause & 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.

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<td>Students will interpret visualizations of sea level rise using Sea Level Rise Viewer (NOAA) <a href="https://coast.noaa.gov/digitalcoast/tools/slr">https://coast.noaa.gov/digitalcoast/tools/slr</a></td>
<td>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.</td>
<td>How quickly could sea level rise happen?</td>
</tr>
<tr>
<td>Students will read and summarize local news articles on locations and construction that will be impacted by sea level rise</td>
<td>Habitat loss/restoration can help mitigate the effects of sea level rise.</td>
<td>What parts of SF will be most impacted by sea level rise?</td>
</tr>
<tr>
<td>San Francisco Public Press <a href="http://sfpublicpress.org/searise">http://sfpublicpress.org/searise</a></td>
<td>Sea level rise will result in the displacement of human populations.</td>
<td>How can we protect coastal areas from sea level rise?</td>
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<tr>
<td>Students will make recommendation on how to mitigate the effects of sea level rise locally</td>
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Ecosystem Impact Unit Question: How are ecosystems impacted when the environment changes?
Academic Connections: Earth System Topic & Context

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.

Essential/Driving Question:

How are ecosystems impacted when the environment changes?

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

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<td>EarthViewer</td>
<td>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.</td>
<td>Historic data for carbon dioxide concentrations, temperature, biodiversity, climate, wildlife, patterns of human settlement and agriculture</td>
<td>How has climate changed in earth’s geologic past and how might these changes affect ecosystems?</td>
</tr>
<tr>
<td>BiomeViewer</td>
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<td>How are changes in the past similar/different than more recent changes?</td>
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<td>What factors and variables should be studied to understand how a system (ecosystem, biome, etc) functions and the species living in it?</td>
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### Academic Connections: Earth System Topic & Context

#### Exploration through Inquiry: Investigation of Change

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.

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<td>Creating Chains and Webs to Model Ecological Relationships</td>
<td>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.</td>
<td>Creating, manipulating and comparing different models of species relationships and energy flow through a system: food chain, energy pyramid and food web</td>
<td>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?</td>
</tr>
<tr>
<td>Niche Partitioning and Species Coexistence</td>
<td>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.</td>
<td>Identification of species habits, behaviors and relationships to determine role and function in ecosystem; how species interactions inform health and resiliency of ecosystem</td>
<td>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?</td>
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Academic Connections: Earth System Topic & Context

Exploration through Inquiry: Investigation of Change

Application of Information: Cause & 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.**

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<td><strong>Conserving and Restoring Ecosystems</strong></td>
<td>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.</td>
<td>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?</td>
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<tr>
<td><strong>Restoring Mozambique’s National Treasure</strong></td>
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<tr>
<td><strong>A Science-Based Approach to Restoring Gorongosa’s Wildlife</strong></td>
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<td><strong>Gorongosa National Park Interactive Map</strong></td>
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**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

**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
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**Conserving and Restoring Ecosystems**

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

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

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

**Gorongosa Resources also address local community needs:**

**Conserving and Restoring Ecosystems**

**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...”

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
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](http://nagt.org/nagt/profdev/workshops/ngss_summit/index.html)
Thank you!

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