Modeling Energy Flow and Matter Cycling: How the Curricular Approach Influences Students Development of Models

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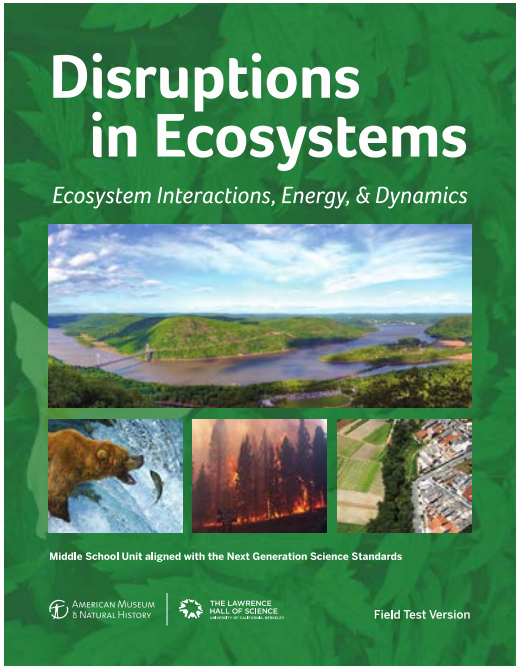
Project Overview

- Develop an NGSS-aligned middle school ecology curriculum unit and assessments
- Develop a professional development program to support teacher implementation
- Conduct development of and research on teacher measures

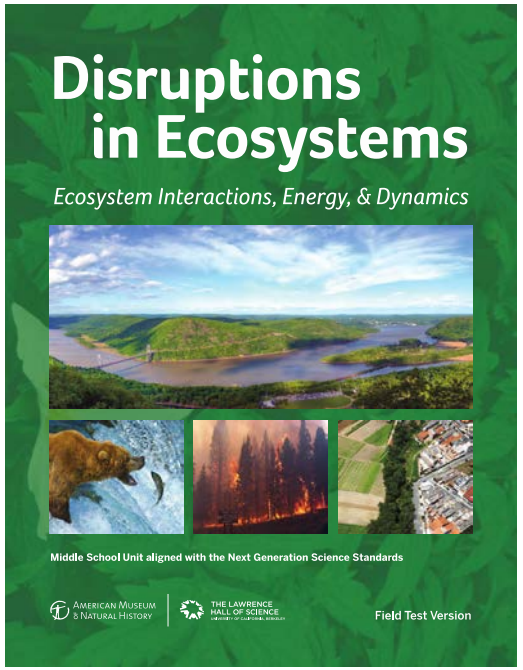
Disruptions in Ecosystems—Ecosystem Interactions, Energy, and Dynamics

- Based on a bundle of NGSS and related CCSS for ELA and Mathematics
  - MS-LS2: Ecosystems: Interactions, Energy, and Dynamics
  - MS-ESS3: Earth and Human Activity
  - MS-PS1: Matter & Its Interactions
- Uses the BSCS 5E Instructional Model (Bybee et al, 2006; Bybee, 2013)
  - Engage, Explore, Explain, Elaborate, Evaluate



Disruptions in Ecosystems—Ecosystem Interactions, Energy, and Dynamics

- Educative elements for teachers related to S-CK and S-PCK
- Embedded authentic assessments of 3D learning
- Supports for
  - Literacy & CC-ELA
  - Diverse learners
  - Development of science practices



Project Timeline

Timeframe	Milestones
September 2014 – July 2015	• Develop first field test instructional materials • Develop first field test PD model
August 2015 – February 2016	• 25 NYC teachers field test • Expert panel review
March 2016 – July 2016	• Revise materials and PD model for second field test
August 2016 – February 2017	• 25 NYC teachers field test • Second expert review
March 2017 – July 2017	• Revise materials and PD model for final field test
August 2017 – February 2018	• 25 NYC teachers field test • Further review if needed
March 2018 – August 2018	• Final revisions to materials and PD model

Curriculum Development and Design

Backward design approach

- Define learning goals
- Draft assessments
- Develop learning activities

Supported by use of the *Five Tools and Processes for NGSS* (developed by AMNH, BSCS, WestEd)

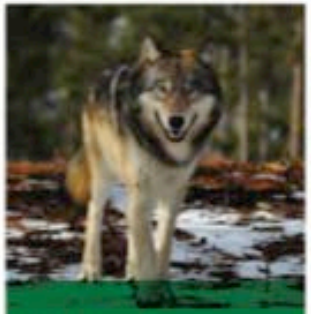
Types of Interactions

Predator-prey interactions, competition, and symbiosis are all interactions between living factors. A **predator-prey** interaction involves a feeding relationship between two animals. The **predator** is the animal that kills and consumes another animal, called the **prey**. In the photo below the bear is the predator and the fish is the prey.

Context

Disruptions in Ecosystems

Ecosystem Interactions, Energy, & Dynamics



CHAPTER 1

Wolves in Yellowstone

CHAPTER 2

Ecosystem Models

CHAPTER 3

Interactions between Populations & Resources

CHAPTER 4

Zebra Mussels

CHAPTER 5

Designing Solutions

Developing the Modeling Practice

- Focus of Chapter 2: Ecosystem Models
- Content: flow of energy and cycling of matter
- Six activities
- Context: Yellowstone National Park ecosystem
- Particular attention to common misconceptions around energy and matter

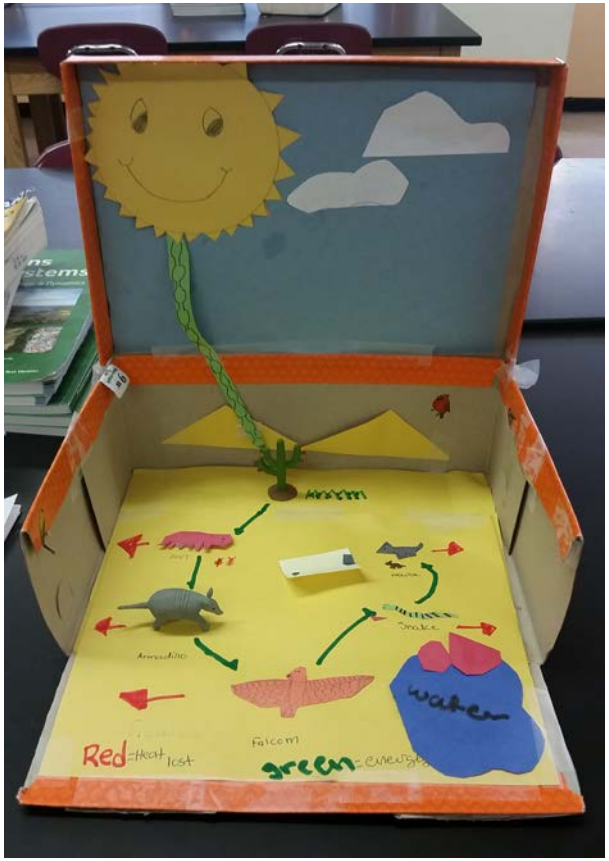
Chapter 2: Ecosystem Models
First Field Test

Activity	5E Phase	Description
A Living Model of an Ecosystem	Engage/Explore	Analyze statements on energy and matter; set up ecosystem model (bottles)
Energy Flow in Ecosystems	Explain	Reading with anticipation guide
Energy Pyramid	Explore/Explain	Develop a model of an energy pyramid
Matter in Ecosystems	Explore/Explain	Ecosystem model exploration (Act 1); Reading
Fire in Yellowstone	Elaborate	Card sort with succession after fire and in a pond, with captions
Modeling Energy Flow and Matter Cycling in an Ecosystem	Evaluate	Develop a 3-d model that shows food web, cycling of matter, and flow of energy

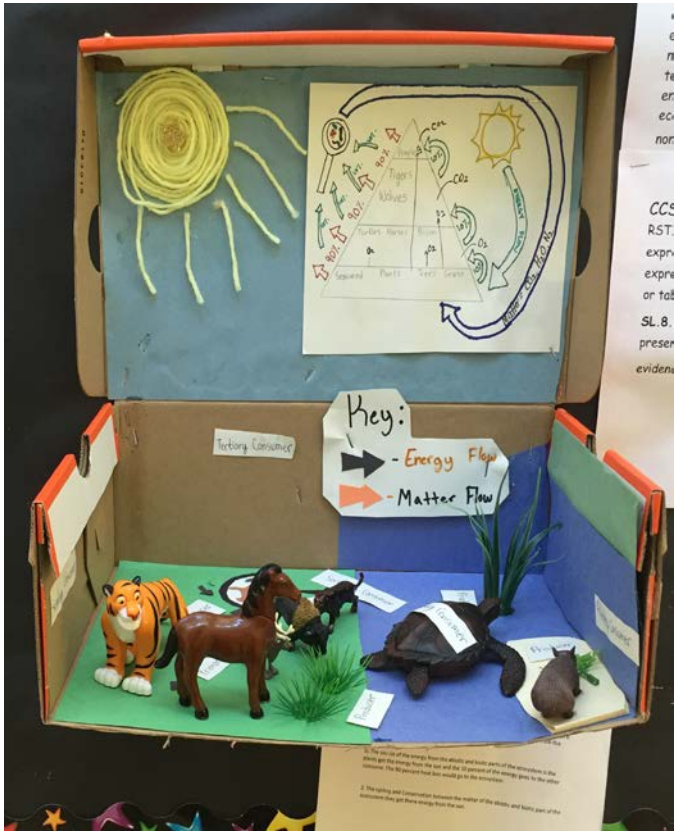
Curriculum Evaluation – Year 1

- Feedback from 25 NYC field test teachers teachers
  - Surveys by activity, chapter, unit
  - Focus groups
  - Feedback during final PD day
  - Student work samples
- Expert panel meeting and written review

Evaluate Activity Results - Dioramas



6th Grade



8th Grade

Analysis Item #1

Imagine that a science museum is making a very large version of your model (the diorama) for a museum display. Write three captions explaining the model for members of the public who will view the display. The captions should describe:

- interactions between living organisms
- the cycling and conservation of matter between abiotic and biotic parts of the ecosystem
- the source, flow, and loss of energy from abiotic and biotic parts of the ecosystem

Sample Answers

- 6th Grade: “a. All living organism eat each other except trees. (grass←rabbit←coyote). b. When an animal or human grows bigger and older the matter it has or we have is cycling to withstand the new body. However abiotic organism matter cycles but doesn’t change or grow. c. The sun provides energy for producers so that they can produce food. When an biotic factor eat’s another, 10% goes to the scavenger who eat’s it and 90% goes to the decomposers.”
- 8th Grade: “a. predator and prey. competition. mutualism. parasitism. and comensalism. b. Air cycles from trees to animals, but food transfers from the sun to the plants which gets retained into the animals that eat the plant. Now it could get transferred into plants again if the animal dies by itself, but if the animal is killed by another some energy goes to that animal. c. When an animal is killed 10% of the energy goes to the killer or the plants if it died by itself.”

Analysis Item #2

A large volcano erupts. A thick cloud of volcanic ash blocks sunlight from reaching the surrounding ecosystem for several months. Predict how the flow of energy and the cycling of matter would be affected by the ash cloud and explain how this would affect the organisms in your model.

Sample Answers

- 6th Grade: “The energy and matter will eventually die out because there is no sunlight. It will affect my ecosystem because no sunlight will kill the producer and then the primary consumers will die, then the secondary consumers will die which will cause the tertiary consumer to die.”

- 8th Grade: “The flow of energy will be less because of less sunlight through ashes less organisms/consumers because of lack of plants. The cycling and matter would be limited becauses of lack of animals. So this could cause a decreases in producers and consumers.”

Teacher Feedback – Chapter 2

- "3D learning is present!"
- "Most engaging chapter."
- "Needs larger emphasis on matter."
- "Students mastered flow of energy but matter was still somewhat confusing."
- "Can say energy flows and matter cycles, but don't actually understand. 8th graders did understand matter."
- "Wasn't explicit enough specifically about atoms cycling repeatedly."

Chapter 2 Revisions

- Simplify and reduce overall number of models
- Better reflect 5E model
- Prevent student misconceptions by having students create initial model which is revised throughout the chapter

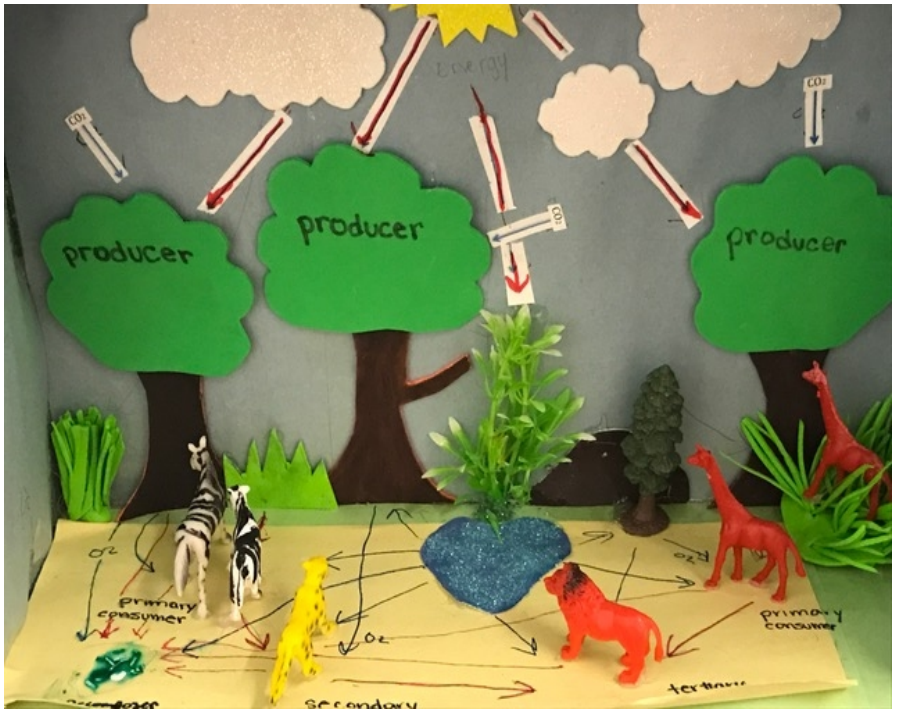
Chapter 2: Ecosystem Models
Second Field Test

Activity	5E Phase	Description
Ecosystem Changes	Engage	Analyze & discuss ecosystems (illustration) & ecosystem disruptions; composting
Life and Death in an Ecosystem	Explore	Develop Yellowstone ecosystem model (YEM); analyze model of change in ecosystem over time
Matter in Ecosystems	Explain	Analyze scientific findings about matter in ecosystems; develop a model for cycling of matter
Energy Flow in Ecosystems	Explain	Add flow of energy to YEM; read about photosynthesis; model revision
Energy Tracking	Elaborate	Analyze existing models re energy; develop energy pyramid model; YEM revision
Modeling Energy Flow and Matter Cycling in an Ecosystem	Evaluate	Develop a 3-d model that shows food web, cycling of matter, and flow of energy

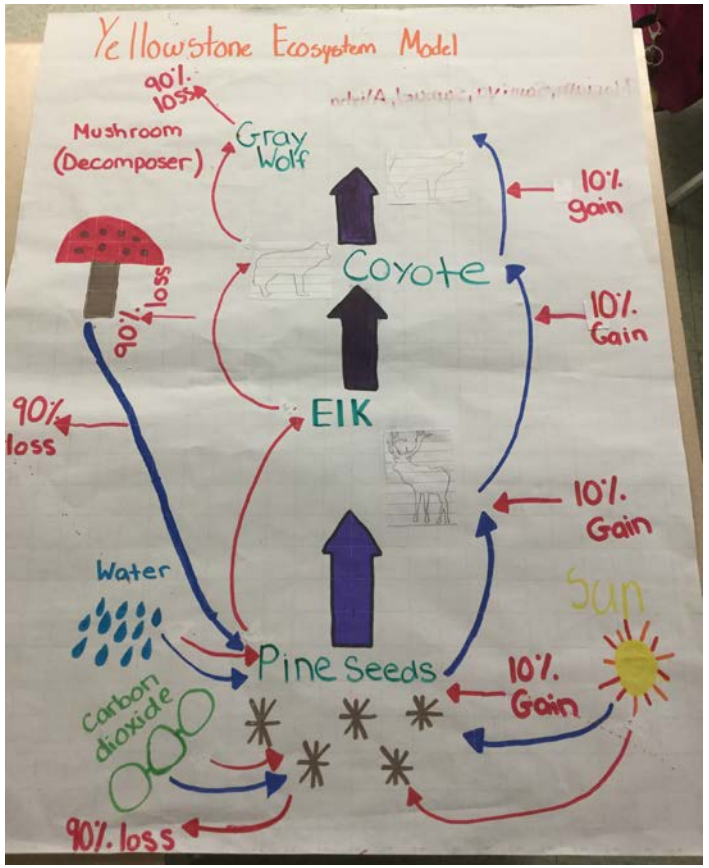
Curriculum Evaluation – Year 2

- Feedback from 25 NYC field test teachers teachers
  - Surveys by chapter and unit
  - Focus groups
  - Feedback during final PD day
  - Student work samples
- Expert review

Evaluate Activity Results - Dioramas



6th Grade



8th Grade

Analysis Item #1

Imagine that a science museum is making a very large version of your model [the diorama] for a museum display. Write three captions explaining the model for members of the public who will view the display. The captions should describe:

- interactions between living organisms
- the cycling and conservation of matter between abiotic and biotic parts of the ecosystem
- the source, flow, and loss of energy from abiotic and biotic parts of the ecosystem
- *what would happen if a disease killed off the top level of your ecosystem*

Sample Answers

- 8th Grade: a) The interactions between living organisms can be the grasses to the bison. For example, the bison eats the grasses. b) Matter cycles between the abiotic and the biotic parts of the ecosystem. For example, the matter can cycle from the grasses to rain and back to the grasses because the grasses die without water and then when it rains the the grasses gets the matter back because they water helps the grasses grow and stay alive. c) When the plants die the 90% of the energy goes into the environment and the rest of the energy which is 10% goes to the next consumer which is the animal that ate the plant in the first place. d) If a disease kills off the top of your ecosystem then the population of the consumer that the top animal ate before will increase and then the population of the primary consumer will decrease and then the population of the producer ill increase as well.
- 6th Grade: a) The interactions between living organisms is they spred energy but some other interactions are predator prey and mutualism, but also commensalism with competition. b) abiotic is when an organism or something is not real not living. In other words, biotic is something that is real and living. c) Some sources are heat, some sources of biotic things are grass, H2O wich is (water). d) what would happen is the ecosystem would get contaminated and most of the living things/organisms would get killed.

Analysis Item #2

Using the *Explanation Tool*, construct a scientific explanation for the following. A landslide occurs along the side of a mountain that causes the forest at the bottom to be covered with 20 meters of rocks and soil. Predict how the flow of energy and the cycling of matter would be affected both in the short term and in the long term. Use the steps below to guide you as you use the Explanation Tool.

- Question: Record the question "How would a landslide affect the flow of matter, cycling of energy, and organisms in an ecosystem?"
- Evidence: Use evidence from this chapter that helps you to answer this question.
- Science Concepts: List any science concepts that are connected to the evidence and might help answer the question.
- Scientific Reasoning: Describe the scientific reasoning that connects the evidence and science concepts to the question you are trying to answer.
- Claim: Based on the evidence of patterns in the data and on your scientific reasoning, state your claim about the effects of the landslide on matter, energy, and organisms in the ecosystem.

Sample Answer 6th Grade

"The ecosystem will disappear then be resilient and come back again. Energy just flows not cycle and matter cycles in an ecosystem. When an ecosystem dies the plants come first, then the animals. Photosynthesis is the process of using water and carbon dioxide to make sugars. The source of all energys is the sun. Energy flows in one direction matter cycles in an ecosystem. The ecosystem will disappear then be resilient and come back. Photosynthesis is the process of using water and carbon dioxide to make sugars. The source of all energy is the sun. Energy flows in one direction, mater cycles in an ecosystem. Energy just flows not cycle. Matter cycles. First the plants come back then the animals come."

Sample Answer 8th Grade

“Landslide’s affect the flow of energy, cycling of matter, and of organisms in that ecosystem because of disruption in a food web since disrupting one part of a ecosystem messes up everything. The evidence I use was from my KWL chart and it said when you disrupt one part of the ecosystem the rest of it messes up or collapse. The science concept disruption in a food web and the evidence I just stated about how mess up one part of the ecosystem makes it all collapse connects. They connect because if a landslide disrupts a ecosystem then there won’t be no flow of energy or cycle of matter because some animals would die or leave the ecosystem and the non-living things in the ecosystem would get mess up.”

Findings – Year 2

Feedback on Changes to Chapter 2

- More successful in developing deep understanding of matter and energy
- Teachers have better understanding of matter and energy
- Still a difficult topic!

Teacher Feedback

I learned how important it is to incorporate models in a curriculum. I learned that most students struggle to understand what is matter. I learned a great way to teach how matter and energy connect to one another. Usually students learn what is matter and what is energy but they do not connect the two. I feel this chapter really addressed that. (Stiles, 2017)

Teacher Feedback

- “Energy and matter are both difficult concepts.”
- “The findings in Activity 2.3 were challenging.”
- “The literacy supports were helpful.” (anticipation guide, graphic organizers, use of diagrams/models)
- “Final assessment, especially if students make 3-D models, was time consuming.”

Findings – Year 2

Chapter 2 Specific Revisions

- Deepening teacher support
- Simplifying material that students are analyzing (e.g. fewer scientific findings)
- Increasing support for analyzing materials (e.g. graphic organizer to guide analysis)

Chapter 2 Revisions

- Fewer number of models
- Some analysis of existing models
- Increase opportunities to develop and revise their models over the course of several activities

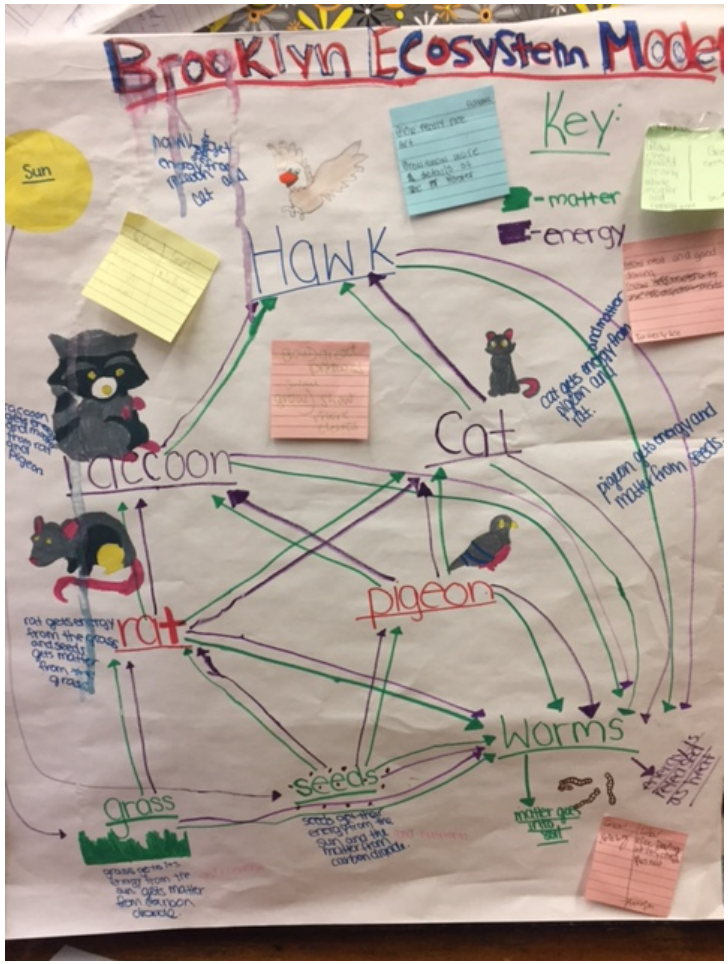
Chapter 2: Ecosystem Models
Third Field Test

Activity	5E Phase	Description
Energy and Matter in Ecosystems	Engage	Analyze & discuss ecosystems (illustration) & ecosystem disruptions; composting
Life and Death in an Ecosystem	Explore	Develop Yellowstone ecosystem model (YEM)
Matter in Ecosystems	Explain	Analyze scientific findings about matter in ecosystems; develop a model for cycling of matter (include captions)
Energy Flow in Ecosystems	Explain	Add flow of energy to YEM; choice of pre-drawn models; read about photosynthesis; model revision (abiotic factors & 10% rule)
Disruptions and Food Webs	Elaborate	Analyze disruption in model
Modeling Energy Flow and Matter Cycling in an Ecosystem	Evaluate	Develop a 3-d model that shows food web, cycling of matter, and flow of energy

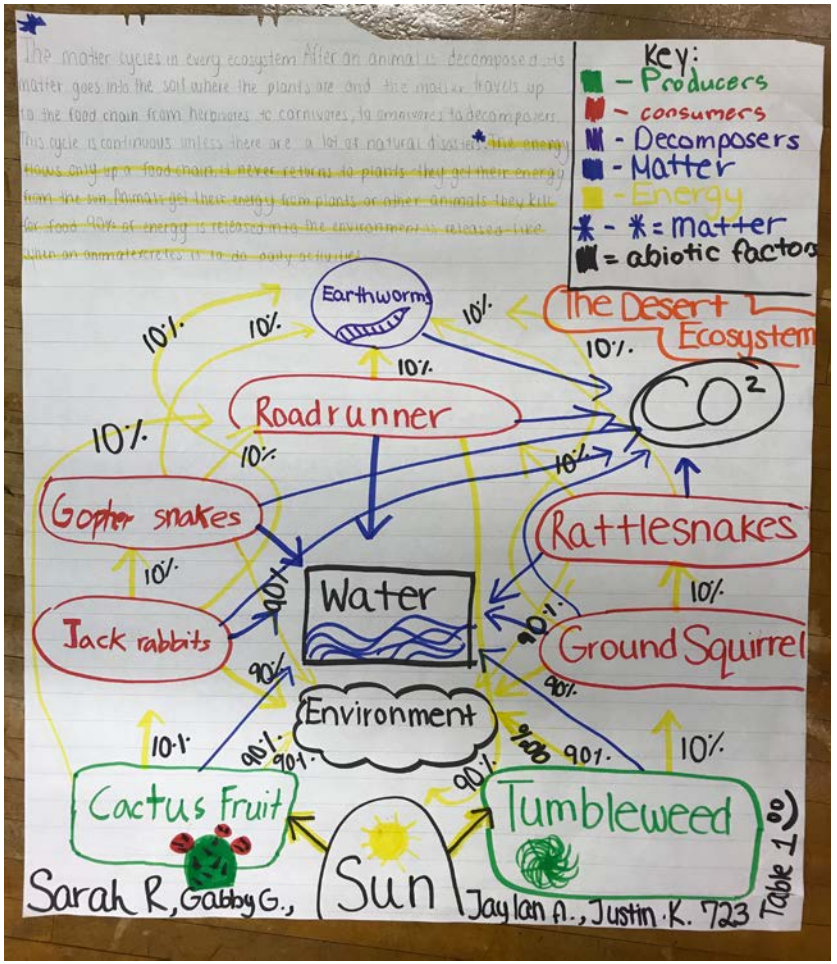
Curriculum Evaluation – Year 3

- Feedback from 25 NYC field test teachers teachers (still being collected)
  - Surveys by chapter and unit
  - Focus groups
  - Feedback during final PD day
  - Student work samples

Evaluate Activity Results - Dioramas



6th Grade



7th Grade

Analysis Item #1

Imagine that a science museum is making a very large version of your model [the diorama] for a museum display. Write three captions explaining the model for members of the public who will view the display. The captions should describe:

- interactions between living organisms
- the cycling and conservation of matter between abiotic and biotic parts of the ecosystem
- the source, flow, and loss of energy from abiotic and biotic parts of the ecosystem
- ~~*what would happen if a disease killed off the top level of your ecosystem*~~

Sample Answers

- 8th Grade: a) The living organisms interact with each other because they live together and they will help each other out. In addition they will eat each other. b) The biotic and abiotic parts how matter flowing because when a biotic thing dies on something abiotic the matter is left there. c) The flow and loss of energy in the abiotic and biotic factors don't work together because when a biotic factor dies the energy flow is stopped.
- 7th Grade: a) Each organism is a source of matter (food) for the other animal. Since there is more than 1 consumer they are in competition with each other for food. In an ecosystem the decomposers get to eat the leftover animal. b) The matter starts at the producers and goes all the way to the decomposers. The decomposers turn the matter to water and CO_2 to help the plants grow. The level 1 producers (usually plants) give off oxygen which is food for the organisms. c) The main source of energy in the ecosystem is the sun. Energy flows through the ecosystem by giving the producers energy to grow. The loss of energy is that 90% of the energy goes to the ecosystem.

Analysis Item #2

Using the Explanation Tool, construct a scientific explanation for the following. *A disease kills off the consumers in the top level of your ecosystem.* Predict how the flow of energy and the cycling of matter would be affected both in the short term and in the long term. Use the steps below to guide you as you use the Explanation Tool.

- Question: Record the question "How would a disease that kills off consumers in the tip level of your ecosystem affect the flow of matter, cycling of energy, and organisms in an ecosystem?"
- Evidence: Use evidence from this chapter that helps you to answer this question.
- Science Concepts: List any science concepts that are connected to the evidence and might help answer the question.
- Scientific Reasoning: Describe the scientific reasoning that connects the evidence and science concepts to the question you are trying to answer.
- Claim: Based on the evidence of patterns in the data and on your scientific reasoning, state your claim about the effects of the landslide on matter, energy, and organisms in the ecosystem.

Sample Answer 7th Grade ELL

"The scientific question is how would a disease that kills off the consumers in the top level of our ecosystem affect the cycling of matter, flow of energy and organisms in the ecosystem? My claim is that the jellyfish and Narwhal will increase if the polar bears decrease. Then the rest of the food chain will be unstable and a smaller circle. My evidence is that the top level consumer is the polar bear eats the narwhals and jellyfish. My concepts is the amount of jellyfish and Narwhal is affected by the polar bears. My scientific reasoning is how since the polar bears are the top level consumer the jellyfish and Narwhal will increase. Also the cycle of energy will be smaller. If the polar bears get killed by a disease the decomposers that decompose it might be infected and might infect the rest of the food chain. This is what I think will happen if the top level consumers die."

Sample Answer 8th Grade

“The scientific question is “How would a disease that kills off consumers in the top level of your ecosystem affect the flow of energy, cycling of matter, and the organisms in the ecosystems?” Our claim is, the population of organisms other than the top species will roller coaster or go up and down, therefore the matter will cycle through less and more organisms and the energy will flow through different levels of population. Since the top consumer died, the organisms in the ecosystem will thrive, momentary, because the consumer is a predator. So the population of other animals will go up. But then, the second level consumers will start to eat up all of the first level consumers. Therefor the population of the organisms will rollor coaster or up and down. So the matter and the energy will follow the level of the population.”

Findings – Year 2

General Initial Feedback

- Need more non-written assessments to differentiate for all learners (esp ELLs)
- Good, NGSS-aligned curriculum is key, supportive PD makes it even better

Next steps

- Finish analyzing teacher feedback (when complete)
- Minimal student book revisions
- Teacher guide revisions focused on supporting diverse learners, especially ELLs

Overall Findings/Observations

- Continual revisions of student-generated models is key
- Structures to support model generation, revision process, and explanations helps all students
- Don’t overdo it!

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Slides & Paper: sepuplhs.org/news.html

Curriculum: (2nd Field Test Ed) available on nextgenscience.org (search for Disruptions in Ecosystems)

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