Lesson 2: Patterns in Organic Matter in Ecosystems

Overview

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Students use a simulation of a meadow ecosystem to view changes in the organic mass of populations of producers, herbivores, and carnivores from different initial population. They then compare their findings with different real ecosystems to highlight an important common pattern: *the organic matter pyramid.* In most terrestrial ecosystems, there is more organic matter in producers than in herbivores and more organic matter in herbivores than in carnivores. They will use carbon-transforming processes to explain this pattern in Lesson 3.

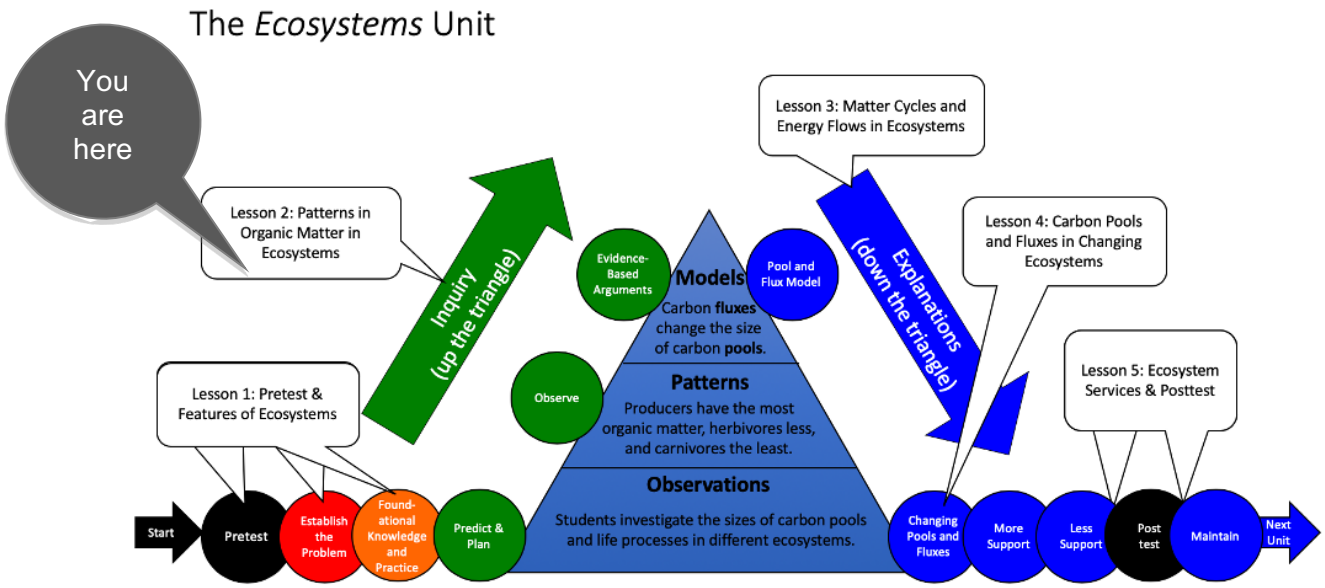
Guiding Question

What are the patterns in organic matter pools in ecosystems?

Activities in this Lesson

- Activity 2.1: Predictions and Planning for the Meadow Simulation (30 min)
- Activity 2.2: The Meadow Simulation (50 min)
- Activity 2.3: Evidence-Based Arguments for the Meadow Simulation (40 min)
- Activity 2.4: Organic Carbon Pools in Other Ecosystems (20 min)

Unit Map



Learning Goals

Target Performances

Activity	*Target Performance*
Lesson 2 – Patterns in Organic Matter in Ecosystems (students as investigators)	
Activity 2.1: Predictions and Planning for the Meadow Simulation	Students make predictions about changes in the mass of different populations in a meadow

Activity	*Target Performance*
	ecosystem and plans to maximize the fox population.
Activity 2.2: The Meadow Simulation	Students identify patterns in relationships among organic mass of populations at different trophic levels in a simulated meadow ecosystem (the organic matter pyramid).
Activity 2.3: Evidence-Based Arguments for the Meadow Simulation	Students develop arguments from evidence about possible patterns in relationships among mass of populations at different trophic levels in a simulated meadow ecosystem (the organic matter pyramid).
Activity 2.4: Organic Carbon Pools in Other Ecosystems	Students describe patterns in relationships among mass of populations at different trophic levels in a other ecosystems (the organic matter pyramid).

NGSS Performance Expectations

High School

- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-1. Use mathematical and or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

Middle School

- Interdependent Relationships in Ecosystems. MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- Matter and Energy in Organisms and Ecosystems. MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- Matter and Energy in Organisms and Ecosystems. MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Background Information

Three-dimensional Learning Progression

This Lesson includes three activities in which students begin to analyze ecosystems as systems that are constantly transforming matter and energy rather than as collections of plants and animals in a particular setting.

Key Ideas and Practices for Each Activity

In Activity 2.1 students make the transition from a picture of a meadow as a place where plants and animals live to a more abstract representation of the organic mass of populations of producers, herbivores, and carnivores in an ecosystem and make predictions about mass of each group in a meadow.

In Activity 2.2 students use an online simulation to investigate the relative sizes of the organic mass of populations of producers, herbivores, and carnivores and how they change over time.

The Meadow Simulation allows students to run multiple scenarios adjusting initial populations of grasses, rabbits, and foxes to observe changes in the mass of the populations over a 100-year period.

Through the online simulations students will need to notice two patterns: 1) the mass of the populations of producers, herbivores, and carnivores changes over time and 2) over time a consistent pattern emerges: The mass in the rabbit population is smaller than the grass biomass, and mass in the fox population is always the smallest. Different initial mass of grasses, rabbits and foxes lead to different patterns of change, but the foxes can survive only if the grass mass stays large.

In Activity 2.3 students complete the Evidence-Based Arguments Tool for the patterns of change in carbon pools that they observed in the Meadow Simulation. In addition to describing the pattern that they have observed—the organic matter pyramid—they formulate questions about why that pattern emerges for many different original settings. They will answer these questions in Lesson 3.

In Activity 2.4, students are introduced to the amount of organic carbon in different ecosystems. They observe the same pattern in producers, herbivores, and carnivores in four different types of ecosystems that have different amounts of total organic matter. They also see that in most terrestrial ecosystems, the largest organic matter pool is soil carbon. (Ecologists would say that the organic matter pyramid should more accurately be applied to production—the rate of biosynthesis at each trophic level—rather than biomass. There are aquatic ecosystems where the producers—phytoplankton—grow very fast and are eaten very fast, so there is more mass stored in consumers. This is not an important point for this Unit.)

Content Boundaries and Extensions

Activity 2.1: Predictions and Planning for the Meadow Simulation (30 min)

Overview and Preparation

Target Student Performance

Students make predictions about changes in the mass of different populations in a meadow ecosystem and plans to maximize the fox population.

Resources Provided

- 2.1 Predictions and Planning for the Meadow Simulation PPT
- 2.1 Predictions and Planning Tool for the Meadow Simulation (1 per student)
- 2.1 Assessing Predictions and Planning Tool for the Meadow Simulation

Setup

Open the 2.1 Predictions and Planning for the Meadow Simulation PPT and project it. Prepare enough copies of the 2.1 Predictions and Planning Tool for the Meadow Simulation for each student to have one.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 2.1 Predictions and Planning for the Meadow Simulation PPT.

2. Introduce the activity.

Use Slide 3 to remind students about meadows.

3. Discuss changes in organic matter pools.

Use Slide 4 to introduce the Meadow Simulation as a way to study change over time in organic matter pools.

- Use Slide 5 to review the organic matter pools in a meadow and to introduce the three pools in the Meadow Simulation (grasses, rabbits, and foxes).

4. Introduce the Meadow Simulation.

Use Slides 6 and 7 to point out the key features of the online simulation. Explain that they will use the simulation in the next lesson to investigate patterns in organic matter in the meadow ecosystem.

5. Have students record their predictions about changes in the meadow ecosystem.

Pass out the 2.1 Predictions and Planning Tool for the Meadow Simulation and give students 5 – 10 minutes to answer the questions individually.

6. Have students discuss their predictions in pairs and as a class.

When students have completed their Predictions and Planning Tools, divide students into pairs and tell them to compare and contrast their predictions with each other and to look for differences and similarities. Give students 2-3 minutes to compare their predictions.

- Display Slide 8 and ask students to share their ideas for the mass of each population after 100 years. Type their predictions in the table on the slide. Try to elicit a range of predictions

and help students look for similarities and differences in the predictions and reasoning that they share.
- Display Slide 9 and ask students to share their predictions about what initial settings will result in the greatest mass of foxes at the end of the 100 year-simulation. Type the predictions for three different groups on the slide (try to get a range of different ideas represented). Help students look for similarities and differences in the predictions and reasoning.

Tell students that they will revisit their ideas after the investigation to see how their ideas changed over time.

Assessment

Ideally, the discussion about the Predictions and Planning Tool in this activity will reveal a range of student ideas. Level 4 students will realize that the mass of producers must be much larger than the mass of herbivores, which, in turn will be much larger than the mass of carnivores. Level 2 and 3 students may assume that the mass of producers, herbivores, and carnivores may be more equal or have other ideas about organic matter patterns in ecosystems. Use the 2.1 Assessing Predictions and Planning Tool for the Meadow Simulation to assess students' ideas.

Differentiation & Extending the Learning

Differentiation

- Refer back to past Predictions and Planning Tools from other units as a model
- Strategic grouping with strong speakers
- Provide sentence stems for discussion and filling in the Predictions and Planning Tool.
- Keep student predictions and plans in a safe place (notebook or class file)
- Have students work in pairs from the beginning rather than individually

Modifications

Activity 2.2: The Meadow Simulation (50 min)

Overview and Preparation

Target Student Performance

Students identify patterns in relationships among organic mass of populations at different trophic levels in a simulated meadow ecosystem (the organic matter pyramid).

Resources You Provide

- Computers with internet access (1 per pair of students)

Resources Provided

- The Meadow Simulation (https://carbontime.bscs.org/sites/default/files/simulations/eco-simulation/index.html)
- 2.2 Meadow Simulation PPT
- 2.2 Meadow Simulation Worksheet (1 per student)
- 2.2 Assessing Meadow Simulation Worksheet

Setup

Set up a computer for each pair of students to work at as well as a projector to display the 2.2 Meadow Simulation PPT. Print a copy of the 2.2 The Meadow Simulation Worksheet for each student.

Directions

1. Use the instructional model to show students where they are in the course of the unit. Show Slide 2 of the 2.2 Meadow Simulation PPT.
2. Introduce the activity. Use Slides 3-5 to review the features of the online Meadow Simulation.
3. Students complete trials 1 & 2 on the Meadow Simulation Worksheet. Give each student a copy of the 2.2 Meadow Simulation Worksheet. Students should work in pairs at a computer. Use Slide 6 to give the following directions: • With a partner, complete trials 1 & 2 (questions 1 – 5) on the Meadow Simulation Worksheet. • Tell students: "Be ready to explain your results and your answers to the class. Do not go on until we have discussed our results as a class."
4. Discuss the results of trial 1 as a class. Use Slide 7 and 8 to discuss the results of trial 1. • Use Slide 7 to show the results of trial 1 (initial mass = 500 for foxes, rabbits, and grasses). Ask students: *What happened when we started with populations of equal mass?* Listen for students' responses to recognize that the fox population quickly declined, the rabbit population initially declined but then returned to somewhat higher levels, and the grass population increased and then leveled off (the line graph captures this information, but students also saw it happening on real time through the "camera" image of the organisms).

- Ask students: *What are the relationships between the four different representations (line graph, organic mass diagram, table, picture)?* Make sure that they realize that all four representations are different ways to represent the amount of organic matter in each of the three populations. The "camera" shows the populations in "real-time," the line graph shows the mass of each population at each time point, and the organic matter diagram and table show the mass of each population at selected time points. Help students connect the more concrete representation of the organisms through the camera viewer with the more abstract representations (especially the line graph and the organic matter diagram).
- Note to teachers: you may know the organic matter diagram as the "biomass pyramid" or "organic matter pyramid." In the next activity students will identify this pattern, so try to refrain from calling it a pyramid at this point. Subsequent lessons will help students to develop an explanation for the organic matter pyramid.
- Use Slide 8 to show the initial and final organic mass diagrams. Ask students: *How do we explain the changes in the organic mass diagram*? Listen for them to explain that rabbits eat grasses and foxes eat rabbits. Probe their ideas by asking *When a rabbit eats 10 pounds of grass do all 10 pounds end up as rabbit organic matter? Where does the rest go?* Listen to see if students remember that some of the mass of food that rabbits eat is lost as carbon dioxide and water through the process of cellular respiration. A full explanation of the organic matter diagram will be the focus of lesson 3.

5. **Discuss the results of trial 2 as a class.**

Use Slides 9 and 10 to discuss the results of trial 2.

- Use Slide 9 to show the results of trial 2 (initial mass = 1000 for foxes, 500 for rabbits, and 100 for grasses). Ask students: *What happened when we started with the greatest mass in the carnivore population, less in the herbivores, and the least mass in the producer population?* Listen for students' responses to recognize that the foxes quickly ate all of the rabbits, so both populations died out leaving only grasses.
- Use Slide 10 to ask, "*How do we explain the changes in the organic matter diagram?"* Listen for students to explain that only grasses remained and there were no herbivores, so the grass population increased.

6. Students use simulation to determine the maximum fox mass the meadow can support.

Use Slide 11 to explain the challenge and how they should record their data on the worksheet. Students will use this data to complete the Evidence-Based Arguments Tool in Activity 2.3.

7. Have students complete an exit ticket.

Show Slide 12 of the 2.2 Meadow Simulation PPT.

- Conclusions: What patterns did you find in the organic mass of the grass, rabbit, and fox populations?
- Predictions: Why is the fox population always small after 100 years?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you

prepare for the next activity. Student answers to the predictions question can be used as a lead into the next activity.

Assessment

Use 2.2 Assessing Meadow Simulation Worksheet to get a sense of students' initial ideas and explanations about patterns in organic matter in ecosystems. At this point, students should not be penalized for incorrect ideas, and they should not be given the "correct" answers. During this activity, pay particular attention to the explanations that students have for why it takes so much plant mass to support so few foxes. This will be important in the next lesson.

Differentiation & Extending the Learning

Differentiation

- Allow students to use personal devices to engage with the online Meadow Simulation independently
- Have students work independently through the online Meadow Simulation before getting together and discussing with a partner

Modifications

Extending the Learning

Ask students how the simulation would change with different ecosystems. Would the general pattern still apply, or would it change drastically?

Activity 2.3: Evidence-Based Arguments for the Meadow Simulation (40 min)

Overview and Preparation

Target Student Performance

Students develop arguments from evidence about possible patterns in relationships among mass of populations at different trophic levels in a simulated meadow ecosystem (the organic matter pyramid).

Resources You Provide

- (From previous activity) 2.2 Meadow Simulation Worksheet

Resources Provided

- 2.3 Evidence-Based Arguments for the Meadow Simulation PPT
- 2.3 Evidence-Based Arguments Tool for the Meadow Simulation (1 per student)
- 2.3 Assessing the Evidence-Based Arguments Tool for the Meadow Simulation

Setup

Prepare a computer and a projector to display the PPT and one copy of 2.3 Evidence-Based Arguments Tool for the Meadow Simulation for each student.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 2.3 Evidence-Based Arguments for the Meadow Simulation PPT.

2. Students complete the Evidence-Based Arguments Tool.

Ask students to take out their completed 2.2 Meadow Simulation Worksheet.

- Display Slide 3. Pass out one copy of 2.3 Evidence-Based Arguments Tool for the Meadow Simulation to each student. Review the Tool directions. Instruct students to use their data from the 2.2 Meadow Simulation Worksheet as well as what they learned from class discussion to complete the tool.
- Give students about 5-10 minutes to complete the process tool.

3. Have students compare and revise arguments in pairs.

Display Slide 4 of the 2.3 Evidence-Based Arguments for the Meadow Simulation PPT. Divide students into pairs.

- Have each pair compare their evidence, conclusions, and unanswered questions for the questions on the Evidence-based Arguments Tool.
- Have partners discuss how their ideas are alike and different. Have students change or add to their responses, based on partner input.
- As students are sharing, circulate through the groups. Ask students about the patterns they observed.
- Pay attention to patterns in students' ideas. You will want to begin moving towards class consensus in this activity.
- Partner work should take about 10 minutes.

4. Have a class discussion of the Question 1 on the Evidence-Based Arguments Tool; move toward class consensus.

This is the consensus-seeking discussion part of the Discourse Routine for the Evidence-Based Arguments Tool.

Display Slide 5 of the 2.3 Evidence-Based Arguments for the Meadow Simulation PPT.

- Have students/pairs share their evidence and conclusions for the first row. Keep a class record, using the PPT slides or board. Ask students to update their answers using a different colored writing utensil. Discussions should move toward class consensus.
- Have students share unanswered questions. Discussions should move toward class consensus. Use the 2.3 Assessing the Evidence-Based Arguments Tool for Meadow Simulation to guide your goals for consensus. At this point in this unit you will begin to guide the path of inquiry toward tracing matter and energy in ecosystems.
- Class discussion should take about 10 minutes.

5. Have a class discussion of the Questions 2 and 3 on the Evidence-based Arguments Tool; move toward class consensus.

Display Slides 6 and 7 of the 2.3 Evidence-Based Arguments about the Meadow Simulation PPT.

- Class discussion may take another 10 minutes.

6. Review the conclusions from the investigation.

Use Slides 8 and 9 to review the two main conclusions that students should have on their Evidence-Based Arguments Tool:

1. The organic matter diagram that represents the maximum mass of all three populations after 100 years resembles a pyramid (this diagram is also called the organic matter pyramid). Ask students to share their ideas about why so much grass is necessary to support so few foxes. They will learn more about this in Lesson 3.
2. There are three possible final mass diagrams that could occur in the meadow ecosystem (the organic matter pyramid with all three populations, rabbits and grasses only, and grasses only). Students can share ideas about how the foxes and rabbits could all die (if the rabbit population dipped so low that the foxes died out, but there were still a few rabbits left to reproduce and repopulate the meadow).

7. Conclude the discussion of the meadow ecosystem and identify unanswered questions for future lessons.

Use Slide 10 to emphasize that the organic matter pyramid is an important pattern in ecosystems, but that we have not yet explained what causes this pattern. That will be the focus of Lesson 3.

Assessment

Remember that at this point in the Unit it is okay for students to have many unanswered questions and incorrect ideas. It is important that they are able to describe the organic matter pyramid as a pattern in ecosystems, but they should not be expected to fully explain it at this point. Use the 2.3 Assessing the Evidence-Based Arguments Tool for Ecosystems to get a sense for where students are in their ability to identify the main pattern in this unit: the organic matter pyramid.

Differentiation & Extending the Learning

Differentiation

- Strategic grouping with strong speakers
- Provide sentence stems for discussion and filling in the Evidence-Based Arguments Tool
- Refer to previous Evidence-Based Arguments Tools from past *Carbon TIME* Units, if applicable
- Compare the Evidence-Based Arguments Tool to the Predictions and Planning Tool. Have students verbalize similarities and differences in groups before sharing with the class.
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Modifications

Extending the Learning

- Have students make predictions about how the results of the investigation would change if they used different ecosystems.

Activity 2.4: Organic Carbon Pools in Other Ecosystems (40 min)

Overview and Preparation

Target Student Performance

Students describe patterns in relationships among mass of populations at different trophic levels in other ecosystems (the organic matter pyramid).

Resources Provided

- 2.4 Organic Carbon Pools in Other Ecosystems PPT

Recurring Resources

- (Optional) Big Idea Probe: Wolves and Deer (1 per student)
- (Optional) Assessing Big Idea Probe: Wolves and Deer
- Learning Tracking Tool for Ecosystems (1 per student)
- Assessing the Learning Tracking Tool for Ecosystems

Setup

Prepare a computer and projector to display the PPT. Print 1 copy of Big Idea Probe: Wolves and Deer for each student (optional).

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show Slide 2 of the 2.4 Organic Carbon Pools in Other Ecosystems PPT.

2. Discuss carbon pool sizes in different ecosystems.

Use 2.4 Organic Carbon Pools in Other Ecosystems PPT to compare the Meadow Simulation to different ecosystems.

- Remind students that the Meadow Simulation was a simulation of one specific ecosystem: a meadow. Show students the organic matter pyramid on Slide 3 and discuss how it represents the patterns observed in the simulation.

3. Have students predict which ecosystems have the largest organic carbon pools.

Use Slide 4 to introduce four different types of ecosystems. Have students consider two ecosystems at a time—prairie vs. desert and cornfield vs. forest—during Slides 5-13. Students should write down a prediction on a piece of paper. Ask: *Which ecosystem will have the most organic carbon?* They could also predict which pool they think will be the largest.

Many students will make reasonable predictions about the amount of living organic matter, but we expect that many students will be surprised when they see that in most terrestrial ecosystems the largest organic carbon pool is soil carbon.

Accommodation: Have students share their predictions to the class for the question "Which ecosystem will have the most organic carbon?" As students share their predictions, write down these predictions on a sheet of paper or the board.

4. Compare four different ecosystems.

Use Slide 14 to prompt students to write down as many observations as they can about how the four ecosystems are alike and different.

- The main thing they should notice is that the relative sizes of ecosystem pools is the same across ecosystems: the largest pool is the soil organic carbon, followed by producers, then herbivores, then carnivores.
- They may also notice that soil organic carbon is the largest pool in the prairie, but the forest has the most organic carbon in producers. You may use this opportunity to talk about how pool sizes are different because of the history of the site (lots of grasses growing and dying increase the soil organic carbon pool) and the size of the organisms that live there (trees versus corn).
- They should also notice that the total organic carbon differs across ecosystems.
- They may also notice that human management produces a somewhat different pattern for the corn field. Humans use fences, hunting, and pesticides to kill or keep out most herbivores (since we want to use the corn for ourselves), so the herbivore and carnivore populations are much smaller than for natural ecosystems.

Use Slide 15 to introduce the ideas differ in the total organic carbon that they can support Students will be explore this idea more deeply more in Lesson 4. Ecologists answer the last question (about why different ecosystems have different amounts of total organic carbon) by identifying *limiting factors,* including:

  - Water (the primary limiting factor for deserts)
  - Temperature (the primary limiting factor in Arctic and alpine ecosystems)
  - Nutrient availability (the primary limiting factor in rain forests)

This is a good time elicit students' ideas and questions about what limits organic carbon in different ecosystems. You do not need to teach about limiting factors at this point.

Accommodation: For the information on the final slide, as a class create organic matter pyramids or other bar graphs to show the size of the pools as visuals. Have students describe the organic matter pools in the four ecosystems (desert, forest, corn field, and prairie) including the herbivores, producers, and carnivores that live in each ecosystem.

5. (Optional) Have students complete the Big Idea Probe: Wolves and Deer for the second time.

If you decided to use the Big Idea Probe: Wolves and Deer, have students complete it and share their ideas for a second time. See Assessing the Big Idea Probe: Wolves and Deer and Using Big Idea Probes for suggestions about how to use the Big Idea Probe.

6. Have a discussion to complete the Learning Tracking Tool for this activity.

Show Slide 16 of the 2.4 Questions about Ecosystems PPT.

- Pass out a Learning Tracking Tool for Ecosystems to each student.
- Have students write the activity chunk name in the first column, "The Meadow Simulation."
- Have a class discussion about what students did during the activity chunk. When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students figured out during the activity chunk that will help them in answering the unit driving question. When you come to consensus as a class, have students record the answer in the third column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the fourth column of the tool.
- Have students keep their Learning Tracking Tool for Ecosystems for future activities.

- Example Learning Tracking Tool

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Patterns in Organic Matter in Ecosystems Investigator	Use the Meadow Simulation to investigate an ecosystem. Use the Predictions and Planning Tool and the Evidence-Based Arguments Tool to describe patterns.	Most terrestrial ecosystems have an *organic matter pyramid:* Producers organic matter > herbivore organic matter > carnivore organic matter.	What causes the organic matter pyramid?

Assessment

During this activity, check to see if students can identify the differences in organic carbon in the ecosystems.

Differentiation & Extending the Learning

Differentiation

- Divide students up into strategic groups so that they have different ecosystems to compare. Allow them to share their ideas with the class.

Modifications