“Solutions-Oriented Learning” Storyline

MS- Forests: Carbon Sequestration

Storyline introduction and overview:

Students explore the phenomena of how a tree gets its mass. They are encouraged to think back to what they know about photosynthesis and explain what they know and what they wonder about the phenomena of a seed transforming into a large tree and having mass. Specifically, carbon is taken in from the atmosphere in the form of CO_2 and transformed into glucose to provide energy and ultimately building material (cellulose). In this storyline, **carbon sequestration** refers to the removal of **carbon** (**i**n the form of **carbon dioxide**) from the atmosphere through the process of photosynthesis. **Carbon storage** refers to the amount of **carbon** bound up in woody material above and below ground.

Carbon sequestration occurs in trees, other plants, the ocean, and soil. Not all plants sequester the same amount of carbon, for example, there’s a difference in the amount of carbon sequestered between young and old trees, and between different species of trees. This has implications for working forests and old growth forests. Using information from this storyline, students will draw conclusions about the value of managing forests to benefit human needs and natural needs.

Forests NGSS Learning Progression: The middle school storyline is part of a larger learning progression that includes students mastering standards pre-K to 12th grade. Take a look at how the middle school performance expectations fit in a continuum of learning for your students.

Placemaking:	Anchoring phenomena:	Drawdown:
Humans have a relationship with trees. Students will describe the ways they interact with trees (e.g. sit under them for shade, play hide and seek, use for lumber, gum rubber, burn for warmth, fireplaces for ambience, etc.). Students will determine which relationships sequester carbon, which release it, and which do neither.	Display a piece of wood (ideally several types of wood (e.g. a piece of firewood, a fallen branch, a piece of dimensional lumber, a piece of plywood, etc.) and ask “where does the mass of a tree come from?”	Temperate Forests Afforestation (depending on the site) Forest Restoration Indigenous People's Land Management
Indigenous and other relevant cultural connections: ● Worldview of trees as living beings with whom humans have a relationship versus trees as “resources” for human use. ● Giving respect to the sovereignty of living beings	**NGSS PEs (progress towards):** MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services. MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	

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Estimated time required to implement this storyline: 2 to 3 weeks

NGSS PEs:

MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Science & Engineering Practice (SEP)	Disciplinary Core Idea (DCI)	Cross Cutting Concept (CCC)
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students’ own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	**For MS-LS1-6** **LS1.C: Organization for Matter and Energy Flow in Organisms** Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.	**Energy and Matter** Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
Engaging in Argument from Evidence Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-LS2-5)	**For MS-LS2-5** **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of its health. (MS-LS2-5) **LS4.D: Biodiversity and Humans** Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. *(secondary to MS-LS2-5)* **ETS1.B: Developing Possible Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. *(secondary to MS-LS2-5)*	**Stability and Change** Small changes in one part of a system might cause large changes in another part. (MS-LS2-5) **Science Addresses Questions About the Natural and Material World** Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS2-5)

Learning Sessions

Learning	Materials List:

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Session:	
2 4 5	Wood samples (firewood, tree branch, etc.) A class set of tape measure, protractors, straws, string (learning session 4) Tree cookies (optional)

1.	**Grounding Native Ways of Knowing:**	
	• Worldview of trees as living beings with whom humans have a relationship versus trees as “resources” for human use. • Giving respect to the sovereignty of living beings	

2.	**Examine phenomena: Trees gain mass.**	Estimated time: 45-minutes
	Teacher prep: View MIT Video (MIT video), gather wood samples (firewood, tree branch, etc.), print/prepare student science notebook page. Activity: Gather students, and pass a chunk of wood around. Students brainstorm - what gives it its mass/heft? *Expected answers: soil, minerals, water, sun/light, CARBON.* Prompt students to fill out the first four boxes on the science notebook page to capture their thoughts and ideas on the question, “What gives a tree its mass?” Then, as a group, examine phenomena and connect back to prior knowledge on photosynthesis. *Ask students to remember the inputs and outputs of photosynthesis: CO_2 + water and the addition of sunlight produces glucose + oxygen; Ask - of the things here, what could give mass? Carbon.* Share the claim: The mass of a tree is primarily made up of carbon that the plant pulled from CO2 in the air around us. Prompt students to revisit science notebook page and revise their explanation, if they have new ideas. Celebrate this growth & change from the earlier understanding, and encourage students to not erase/rewrite their ‘original thoughts.’	

3.	**Pre Assessment**	
	MS-Forest: Carbon Sequestration Pre-Assessment **MS-Forest: Carbon Sequestration Assessment Rubric**	

MS- Forests: Carbon Sequestration

4.	**Guiding question: How much carbon do different trees sequester?**	Estimated time: Two to Three 45-minute periods
	Teacher prep: Find trees on campus (young and old, different species) within walking distance of your classroom; gather tape measures 1. Students measure tree circumferences. a. Review definition of circumference. b. Measure the circumference of the trees from a standard height, about 4.5 feet off the ground. Each student should use a tape measure to figure out where 4.5 feet is on their body, and use that as their reference. c. Students record: general info - date, time, location, weather; and for each tree - tree species, tree circumference at 4.5 feet, tree diameter , other observations d. Calculate carbon sequestered in that tree National Tree Benefit Calculator. 2. Group students to share data to compare and contrast older and younger (larger/smaller) trees, and different species of trees. Graph data and make inferences about diameter of trees and amount of carbon sequestered. *Expected answers: a tree with a larger diameter is sequestering more carbon, smaller trees are younger or grew in less than ideal conditions.*	

5.	**Guiding question: What do tree cookies tell us about tree growth?**	Estimated time: 45 minutes
	Teacher prep: Gather tree cookies (if unavailable, print ‘tree cookie’ image from one of the two sources in ‘activity section’ just below) 1. Distribute mature tree cookies (see diagrams from NASA and TELUS World of Science for reference) to students. Students create a diagram and identify the oldest part of the tree and the youngest part of the tree (inner ring is oldest, outer ring is newest). Students describe differences in tree ring spacing from early years and later years and describe what might account for these differences. *Expected answers:* *Some rings are wider than others, the color changes; growing conditions (rain, sun, temperature) might be responsible for more tree growth at different phases in tree life cycle.* 2. Students go back and look at data from session 3. Does the tree cookie help to confirm	

	or add to their understanding of what they found in the data analysis of tree diameter and carbon sequestration? What additional information do students need/want to know? 3. View Tree Rings: How Tree Rings Reveal Extreme Weather Conditions. Allow students time to capture their thinking and questions in their science notebooks.

6.	**Guiding question: Photosynthesis requires CO_2. Where does that CO_2 come from and how has its presence in our atmosphere changed over time?**	Estimated time: 45-minutes
	Teacher prep: View graphs (still image and video) from the links below in preparation to lead discussion. 1. Lead class discussion: What are the main contributors of atmospheric CO_2? (use Padlet, Poll Everywhere quiz, Kahoot, etc. to collect responses, and perhaps formative assessment info). *Expected answers: animal respiration, “pollution” from cars and factories.* 2. Review class answers and have students categorize the contributors (e.g. human-caused, naturally occurring). Show the Global Monitoring Laboratory video and Climate Change: Atmospheric Carbon Dioxide graph). Students describe how atmospheric CO_2 levels have changed over time and indicate what from their previous list has contributed the most to that change? *What happened historically when the levels rose the most?* *Expected answers: Humans breathing, pollution, industry, natural variation. The industrial revolution marked when CO_2 levels increased the most.*	

7.	**Guiding question: What is the greenhouse effect and why is global warming a problem?**	Estimated time: 45-minutes
	Teacher prep: view videos. 1. Brainstorm consequences of global warming (Use Padlet, write on board, etc.). *Expected answers: melting ice, changing sea levels, biodiversity loss, more frequent and extreme weather events, drought, floods, fires, change in the range of disease carrying insects, agricultural shifts, health consequences (heat stroke, asthma, pollen), ocean acidification.* 2. Show the video The Greenhouse Effect (US EPA). Alternate/additional videos include: • Our Climate Our Future video series (specifically chapter 4 - teacher needs to make free account to view). 3. After viewing the video, return to the original brainstormed list, and add additional global warming consequences. Optional activities: Teachers can have students examine temperature and atmospheric CO_2 over time graphs. Have them describe the relationship between temperature and CO_2 as indicated by the graph. And/or, lead students through one of the many “greenhouse effect labs” available online to view this in a hands-on way.	

8.	**Guiding question: What role can forests, both working and old-growth, play in mitigating the effects of climate change?**	Estimated time: one to two 45-minute periods
	1. In order to change where we’re headed, what role can trees play to abate rising atmospheric CO_2 levels? Do working forests (defined as, “forests that are actively managed by people, for timber or other services like recreation”) have a place in that solution? 2. Ask, “What is our relationship with trees?” Prompt students to draw a picture of how they interacted with a tree this week. *Expected responses: paper, shade, wood products, fruit from a tree, recreation (climbing), etc.* Ecosystem services are ways that nature benefits humans. They can be divided into four	

categories including: production (e.g. food and water), regulating (e.g. climate and disease), supporting (e.g. nutrient cycles and oxygen production), and cultural (e.g. recreation and spiritual). Water purification, pollination, and waste management are other examples of ecosystem services.

Show Dr. Ganguly's graph [Global Warming Mitigating Role of Wood Products from Washington state's Private forests], Figure 4. Discuss the information in the graph. The Global Warming Mitigation on the y axis correlates to the net carbon storage potential. Negative values for a product have more carbon storage than emissions. Students can conclude that most wood products store more carbon than they emit from harvest to disposal.

Discussion: Does this mean that all forests should be working forests? No. Have students come up with reasons why non-working forests are valuable. What services do forests provide beyond carbon sequestration? Have them list all considerations when managing forests.

Expected answers:

- *Biodiversity*
- *Cultural value*
- *Shade/wind protection*
- *Carbon sequestration and nutrient cycling*
- *Effect on hydrology*
- *Tourism/recreation*
- *Food (fruit trees)*

Discuss/find examples of local forests that are managed in the ways listed above. Some of these uses involve the tree being cut down, others do not. When a tree is cut down, where does the carbon go? Look at your drawing, draw a model of where CO_2 is in your tree system.

Discuss the Indigenous perspective that trees are living beings and are not meant to be treated strictly as resources. Ask, how does this way of thinking about trees change the way we might interact with trees? If we respect trees as living beings, does that mean we cannot use trees to help us? Tribal communities have used trees for building materials, firewood, and more since time immemorial (for a very long time, long before European people colonized North America), but in a sustainable way that encouraged forest growth and health.

What happens to wood when trees are cut down? Which uses of wood sequester even after a tree is no longer growing? Have students create a T-chart that identifies situations where carbon is sequestered vs. released (e.g. framing of homes vs. burning firewood). Students can

	check their list against the “Sustainable Forestry Carbon Cycle” diagram. Students summarize learning over the course of this storyline by evaluating the claim, “Forests, working and non-working, are a climate change solution.” Use evidence to support your reasoning.

9.	**Possible next steps/off-ramps/actions:**	
	• Career connections: What kind of jobs work support healthy forests? Using the resources below, explore possible forest related careers with students: PEI Career Card: Assistant Forester PEI Career Card: Land Steward PEI Career Card: Senior Resource Information Forester PEI Career Card: Silviculture Forester Natural Inquirer: Forest and Plants Scientist Cards • Visit forests managed for different purposes - tribal/first foods, wood harvest, Christmas trees, etc. • Design a tree management plan for your school campus or community • Look at an existing community management plan and make recommendations for managing it for CO_2 sequestration • Research different endemic tree species to better understand different species’ sequestration rates	

10.	**Post Assessment:**	
	MS-Forests: Carbon Sequestration-Post Assessment **MS-Forests: Carbon Sequestration-Rubric**	

OER Tracker - MS Forests: Carbon Sequestration

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