“The Frozen Ground Beneath Our Feet: Why Permafrost Matters”

Stephanie Dolan, Science Teacher
Portland, Maine

Developed as part of the Arctic LTER RET program, Summer 2024

Teacher: Stephanie Dolan	**Unit: Earth Science – Dynamic Earth**
Grade/Course: 7th grade General Science	**Lesson Title:** "The Frozen Ground Beneath Our Feet: Why Permafrost Matters"

NGSS Performance Expectation:
MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

NGSS Standards:

- 1. MS-ESS2-1 – Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
- 3. MS-ESS3-5 – Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
- 3. MS-ESS3-5 – Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Real World Phenomenon Addressed in the Lesson:

Rapid warming in Arctic regions is causing **permafrost to thaw**, releasing greenhouse gases, destabilizing ground, and impacting ecosystems and human communities. Students will investigate how changes in Earth's temperature can alter frozen ground systems and create global ripple effects.
Link to article: https://www.epa.gov/climate-indicators/climate-change-indicators-permafrost#:~

3 Dimensions of Science

Science & Engineering Practice(s) Used:

1. *Developing and Using Models*

Students build a physical model of permafrost using soil, ice, and heat sources to simulate warming and observe system changes.

2. *Analyzing and Interpreting Data*
Students collect and interpret temperature changes, soil conditions, and ecosystem observations from their models.

3. *Constructing Explanations*
Students construct explanations based on evidence from their model to describe how warming affects permafrost, carbon storage, ecosystems, and infrastructure.

4. *Engaging in Argument from Evidence*
Groups use data and research evidence to support claims about permafrost impacts (carbon cycle, community effects, infrastructure, climate change).

Crosscutting Concept(s) Used:

1. *Cause and Effect:* Students identify how increased temperatures (cause) lead to permafrost thaw and related impacts (effects) such as ground instability, carbon release, and ecosystem changes.

2. *Stability and Change:* Students examine how a once-stable frozen system becomes unstable due to warming, leading to long-term environmental and societal changes.

3. *Systems and System Models:* Students use models to represent how components of the Arctic system—soil, ice, vegetation, atmosphere—interact and respond to temperature changes.

4. *Energy and Matter:* Students explore how energy flow (warming) affects matter cycling, such as the release of carbon dioxide and methane from thawing permafrost.

Disciplinary Core Idea(s)

ESS2.A: Earth's Materials and Systems
- Permafrost is part of the geosphere and interacts with the atmosphere, biosphere, and hydrosphere. Changes in one part of the system can affect the others.

ESS2.C: The Roles of Water in Earth's Surface Processes
- Frozen water in soil stabilizes landscapes. Thawing alters landforms, soil structure, and ecosystem habitats.

ESS3.D: Global Climate Change
- Human activities affect climate systems. Warming temperatures can destabilize permafrost, releasing greenhouse gases that further influence Earth's climate.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- Thawing permafrost releases stored carbon, altering carbon cycles and impacting ecosystems.

Background Information

Prior Student Knowledge:

States of matter and temperature effects: Ice melts when heated; soil can hold water and nutrients.

Earth's surface materials: Soil, rock, and organic matter are parts of ecosystems.

Climate vs. weather: Long-term climate trends differ from daily weather changes.

Ecosystem basics: Plants and animals rely on stable environmental conditions for survival.

Energy flow in Earth systems: Heat energy affects physical and biological processes (e.g., plant growth, soil conditions).

Possible Preconceptions/Misconceptions:

Permafrost is just snow or ice.

- ➔ Many students think frozen ground is only ice or snow, not realizing it includes soil, rock, and organic material.

Permafrost exists only in Antarctica.

- ➔ Students may not know that it is widespread in Arctic and subarctic regions, as well as high mountain areas.

Melting permafrost is only a local problem.

- ➔ Students might not understand the global impact of carbon release on climate change.

Climate change effects are immediate.

- ➔ Students may expect permafrost thaw to cause instant flooding or dramatic events, rather than gradual ecological and infrastructural changes.

Weather and climate are the same.

- ➔ Students may confuse short-term weather events with long-term climate trends affecting permafrost.

Permafrost thaw only affects the ground.

- ➔ Students may overlook secondary effects, such as greenhouse gas release, changes in ecosystems, and impacts on human communities and infrastructure.

Content Information for Teacher:

Definitions:

Permafrost is ground (soil, rock, and organic material) that remains frozen for two or more consecutive years. It often contains ice lenses that help stabilize the ground.

Where It Occurs

- Arctic and subarctic regions (Alaska, Canada, Russia, Greenland)
- High-altitude mountain regions

Types of Permafrost

- Continuous: Found throughout the landscape, mostly in the far north.
- Discontinuous: Patchy permafrost separated by unfrozen ground.
- Sporadic: Small, isolated patches of frozen ground.

Importance

- Carbon Storage: Contains massive amounts of organic carbon—twice as much as in the atmosphere.
- Ecosystem Stability: Supports tundra vegetation and wildlife.
- Human Infrastructure: Provides stable ground for roads, pipelines, and buildings in northern regions.

Why It's Changing

- Global temperatures are rising, with Arctic regions warming 2–4× faster than the global average.
- Thawing occurs when ground temperatures rise above 0°C (32°F).

Consequences of Thawing

- Environmental: Release of CO_2 and methane, altered plant growth, changing wildlife habitats, erosion, and formation of thermokarst (uneven ground).
- Human: Damage to infrastructure, destabilized buildings, roads, and pipelines.
- Global Climate: Thawing accelerates climate change due to greenhouse gas release.

Scientific Study Methods

- Temperature Monitoring: Thermistors, boreholes, and data loggers measure ground temperature over time.

- Satellite Observations: Detect surface changes and thaw patterns.
- Carbon Flux Measurements: Estimate greenhouse gas emissions from thawing permafrost.

Arctic Sinkholes I Full Documentary I NOVA I PBS

5E	Evidence of Use/Student Activity
Engagement ● Capture attention ● Activate prior knowledge ● Connects to the real world phenomenon	● Activity: Start with a thought-provoking video about permafrost, showcasing its role in the climate system, habitats it supports, and recent impacts of climate change. What happens when the permafrost thaws? | BBC Ideas What happens when the Arctic permafrost melts? - Brendan Rogers and Jessi… Permafrost - what is it? Thawing Permafrost | Changing Planet ● Discussion Questions: ○ What is permafrost, and where is it found? ○ Why is permafrost important to the environment? ○ What might happen if permafrost melts? https://neo.gsfc.nasa.gov/view.php?datasetId=PermafrostNSIDC https://river-runner-global.samlearner.com/
Exploration ● Test ideas and develop knowledge using explorations, investigations, experiments ● For NGSS, provide an initial activity/lab that allows for investigation of real world phenomenon	● Hands-On Activity: Create a model to simulate permafrost and its interactions with temperature changes. ○ Materials: Clear plastic containers, soil, ice (representing permafrost), thermometers, hair dryers of heating pads, and small plants or seeds (to represent vegetation). ○ Prior to starting, have students write a hypothesis on how they predict their vegetation will change over time when exposed to the heat versus no heat. ○ Procedure: 1. Layer soil at the bottom of the container and place ice on top, simulating permafrost. 2. Add small plants or seeds on top of the ice. 3. Use thermometers to monitor the temperature in the container.

	4. Place some containers under bright lights or a hair dryer to simulate warming(from above) and observe changes over time. 5. Students should record observations (qualitative and quantitative–temperature every minute) ● Guiding Questions: ○ How does the presence of ice affect soil temperature and plant growth? ○ What changes do you observe in the simulated ecosystem as temperatures increase?
Explanation ● Analyze data/information and construct explanations ● Communicate understandings orally and in writing ● Describe possible solutions	● Class Discussion: Have students share their observations from the exploration activity. ● Concept Introduction: Introduce key concepts related to permafrost, including: ○ Definition and formation ○ Types of permafrost (continuous, discontinuous, sporadic) ○ Impact on carbon storage and greenhouse gases ○ Effects of thawing on ecosystems and human infrastructure ● Resource Materials: Handouts summarizing the key concepts discussed. https://permafrost.gi.alaska.edu/site/tl1 https://www.permafrost.org/what-is-permafrost/ https://science.nasa.gov/kids/earth/ https://education.nationalgeographic.org/resource/permafrost/
Extension ● Modify/refine procedures, prototypes, models, solutions, arguments, essays, etc. ● Apply or practice in a new setting	● Group Project: Assign students to groups to research one of the following topics: ○ The role of permafrost in the carbon cycle. ○ The impact of permafrost thaw on indigenous communities. ○ Case studies of infrastructure damage due to melting permafrost. ○ Future predictions for permafrost regions under climate change scenarios. ● Presentation: Groups will create a visual presentation (poster, slideshow) to share their findings with the class.

Evaluation ● Self-assess understanding of concepts ● Demonstrate understanding of concepts through performance-based tasks ● Reflect and/or revise answers or solutions to a complex question, issue, challenge, or real world problem	● Assessment: Use a combination of formative and summative assessments: ○ Peer Review: Students evaluate each other's presentations using a rubric that assesses understanding, creativity, and clarity. ○ Reflection Journal: Students write a short reflection on what they learned about permafrost, its significance, and the implications of its melting. ○ Quiz: A short quiz on key terms and concepts covered in the lesson.
Lesson Closure ● Summarize the lesson ● Check for understanding via exit slip or exit ticket ● Preview the next lesson	

5E Model Framework

1. Engage (20 minutes)
    - Activity: Start with a thought-provoking video or slideshow about permafrost, showcasing its role in the climate system, habitats it supports, and recent impacts of climate change.
    - Discussion Questions:
        - What is permafrost, and where is it found?
        - Why is permafrost important to the environment?
        - What might happen if permafrost melts?
2. Explore (30 minutes)
    - Hands-On Activity: Create a model to simulate permafrost and its interactions with temperature changes.
        - Materials: Clear plastic containers, soil, ice (representing permafrost), thermometers, heating pads, and small plants or seeds (to represent vegetation).

    - Procedure:
        1. Layer soil at the bottom of the container and place ice on top, simulating permafrost.
        2. Add small plants or seeds on top of the ice.
        3. Use thermometers to monitor the temperature in the container.
        4. Place heating pads under some containers to simulate warming and observe changes over time.
- Guiding Questions:
    - How does the presence of ice affect soil temperature and plant growth?
    - What changes do you observe in the simulated ecosystem as temperatures increase?

3. Explain (20 minutes)
    - Class Discussion: Have students share their observations from the exploration activity.
    - Concept Introduction: Introduce key concepts related to permafrost, including:
        - Definition and formation
        - Types of permafrost (continuous, discontinuous, sporadic)
        - Impact on carbon storage and greenhouse gases
        - Effects of thawing on ecosystems and human infrastructure
    - Resource Materials: Handouts summarizing the key concepts discussed.
4. Elaborate (30 minutes)
    - Group Project: Assign students to groups to research one of the following topics:
        - The role of permafrost in the carbon cycle.
        - The impact of permafrost thaw on indigenous communities.
        - Case studies of infrastructure damage due to melting permafrost.
        - Future predictions for permafrost regions under climate change scenarios.
    - Presentation: Groups will create a visual presentation (poster, slideshow) to share their findings with the class.
5. Evaluate (20 minutes)
    - Assessment: Use a combination of formative and summative assessments:
        - Peer Review: Students evaluate each other's presentations using a rubric that assesses understanding, creativity, and clarity.
        - Reflection Journal: Students write a short reflection on what they learned about permafrost, its significance, and the implications of its melting.
        - Quiz: A short quiz on key terms and concepts covered in the lesson.

Materials Needed

- Video/slideshow equipment
- Clear plastic containers
- Soil

- Ice
- Thermometers
- Heating pads/ hair dryers
- Small plants or seeds
- Research materials (books, articles, internet access)
- Poster board, markers, or digital presentation tools

Differentiation Strategies

- For advanced students: Provide more complex research topics or data analysis tasks.
- For struggling students: Offer guided notes or graphic organizers to help them organize their thoughts.
- Visual/Auditory Learners: Incorporate videos, images, and soundbites related to permafrost and its ecosystems.

Extension Activities

- Conduct a field trip to a local science center or environmental organization focusing on climate change.
- Invite a guest speaker, such as a climate scientist or environmental activist, to discuss permafrost and climate change.
