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THAWING PERMAFROST
TEACHER GUIDE

Theme 2: Changing Landscapes
UNIT 4: Permafrost Thaw
High School

Introduction

Thank you for using this Raising Educational Achievement through Cultural Heritage Up (REACH Up) unit in your classroom! The lessons are designed to address the Alaska Science Standards and Grade Level Expectations, Alaska Cultural Standards and the Bering Strait School District Scope and Sequence goals. All of the activities focus on permafrost and related landscape changes from Alaska Native cultural, physical and earth science perspectives. This supplemental unit addresses the place-based question: How is permafrost thaw changing the landscape in our area and why are these changes important to our community?

The REACH Up Thawing Permafrost unit consists of three activities. Each activity will require a 45-minute class period; discussion could easily be extended into multiple class periods. You may also want to repeat sections of an activity during subsequent class meetings, such as reviewing the Permafrost Thaw video or having your students practice the vocabulary card games multiple times. If you are utilizing the entire Thawing Permafrost unit, you should introduce the activities in the order they are presented. However, if time is short, any of the activities could be presented independently.

The accompanying student guide is intended for use with multiple groups of students and you should not allow students to write in them. You can either have students record their work on a separate sheet of paper, or create copies of the corresponding worksheets that are included in this teacher's guide.

Whole Picture

In Alaska Native oral tradition, it is said that Raven made Earth's landforms and brought light and life to the world — including that of humans (Fienup-Riordan, 1994; Kawagley, 2006). This worldview provides an important clarification for understanding human roles and responsibilities in the world. Yup'ik creation stories, for example, tell how "the creative force [Ella] took the form of the Raven to make the world so that the Yupiaq will never think that they are above the creatures of the earth" (Kawagley, 2006, p. 17-18). According to this philosophy, people are on equal ground with the natural world, and in fact, have a responsibility to maintain ecosystem balances by demonstrating respect for all parts of the environment. This emphasis on the interconnectedness of all parts of the ecosystem, including the role and impact of humans within it, is echoed by climate scientists studying the impacts and driving forces behind climate change the Arctic (Richter-Menge, Overland & Mathis, 2016).

Nevertheless, the ecosystem balance has been disturbed, as is demonstrated by the unprecedented changes happening in the Arctic, including flooding, permafrost thaw, severe coastal erosion, thin and melting sea ice, ferocious wildfires, and changes to seasonal timing and range of plants and animals. Scientists and Alaska Native cultural knowledge bearers agree that many of the climate changes are the result of human activities, though the reasons cited for these changes sometimes differ between the two groups.

Scientists explain that "human activities—especially the burning of fossil fuels since the start of the Industrial Revolution—have increased atmospheric CO2 concentrations by about 40%, with more than half the increase occurring since 1970" (Royal Society and USNAS, 2014, p. 2). Carbon dioxide (CO2) is one of the greenhouse gasses that traps and absorbs heat high in the atmosphere. In turn, this contributes to the overall global temperature rise. By comparing observations with models, and "fingerprinting the detailed patterns of climate change caused by different human and natural influences," in connection with a deep understanding of physics, scientists know that the dramatic recent changes we have seen in the climate are human-caused (Royal Society and USNAS, 2014, p. 5).

Alaska Native people also link the changes currently happening in the climate to human action and interaction. This understanding is based in a worldview which links the human world with the natural and spiritual worlds. In Yup'ik tradition, Ellam Yua, the person of the universe, is always watching, and will reprimand people who do not follow strict rules for maintaining balance in the world (Fienup-Riordan and Rearden, 2012).

Culture bearers point to the fact that people aren't following the rules about how to act appropriately with the natural world as evidence of why the climate is changing so dramatically. For some, like Jeanette Aya from Savoonga, this translates directly into a respect (or disrespect) for Mother Nature: "Respect Mother Nature. We respect all the abundance that she gives to us. Just like if you don't respect your mother, she slaps you on the side of the head or something! Well it's the same thing with Mother Nature. If you don't respect what she gives to you, the signs that she gives to you, like the weather, the water currents, or whatever, something bad's gonna happen" (Aya, 2011). George Noongwook of Savoonga puts it this way: "We cannot change nature, our past, and other people for that matter, but we can control our own thoughts and actions and participate in global efforts to cope with these global climate changes. That I think is the most empowering thing we can do as individuals" (Krupnik and Jolly, 2002, p. 189).

Whether one agrees strictly with scientists who blame human use of fossil fuels, or Alaska Native oral tradition that cites inappropriate behaviors between people and the natural world, or some combination of the two, one thing is clear: "Climate change is already here … Everything that is impacted from another outside source it impacts us too. It's just like if somebody threw a rock into a pond, the ripples expand and expand, and it hits everybody" (Aya, 2011).

References

Aya, Jeanette L. (2011). *2011: Message to the World. Stories About Adaptation and Subsistence: Native Voices from the Frontlines of Climate Change.* Aksik. Accessed from: http://aksik.org/village/savoonga.

Fienup-Riordan, Ann. (1994). *Boundaries and Passages: Rule and Ritual in Yup'ik Eskimo Oral Tradition*. Norman and London, University of Oklahoma Press.

Fienup-Riordan, Ann, and Alice Rearden. (2012) *Ellavut: Our Yup'ik World and Weather. Continuity and change on the Bearing Sea Coast*. Seattle and London: University of Washington Press.

Kawagley, Angayuqaq Oscar. (2006). *A Yupiaq Worldview: A Pathway to Ecology and Spirit*. Long Grove: Waveland Press.

Krupnik, Igor, and Daynna Jolly. (2002). *The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change*. Arctic Research Consortium of the United States and Smithsonian Institution Presses.

Royal Society and the US National Academy of Sciences [USNAS]. (2014). *Climate Change Evidence and Causes*. Accessed from: http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf

Unit Vocabulary

Science Terms to Define	
Climate	the long-term average weather conditions that occur in a particular region[1]
Permafrost	soil that has remained frozen year-round for at least two years
landslide	rapid, downhill movement of soil, loose rocks, and boulders
Active layer	the layer of soil that freezes and thaws annually -- In cold regions, this layer lies on top of permafrost

Terms for Incorporating Local Indigenous Language				
English	**Iñupiaq**	**Yup'ik**	**Siberian Yupik**	**Local Translation**
Permafrost	attani	napat ngeliit	kumlaneq	
Ice	siku	ciku	siku	
Lake	narvak	nunvaq	naayvaq	
Ground	nuna	cailkag	nuna	

[1]2009 Pearson/Prentice Hall Life Science Textbook definitions:

climate = the typical weather pattern in an area over a long period of time

permafrost = soil that is frozen all year

2009 Pearson/Prentice Hall Earth Science Textbook definitions:

climate = the average, year-after-year conditions of temperature, precipitation, winds, and clouds in an area

permafrost = permanently frozen soil found in the tundra climate region

Activity HS.4.1: Ask an Expert

Overview

In this activity, students will interview an Elder or cultural knowledge bearer.

Objectives

On successful completion of the lesson, students will be able to:

- demonstrate effective interviewing techniques
- interpret qualitative data from interviews
- describe how thawing permafrost is changing the local landscape

Alaska Standards

Alaska Science Standards / Grade Level Expectations

SA1: The student demonstrates an understanding of the processes of science by

[9] SA1.2 hypothesizing, designing a controlled experiment, making qualitative and quantitative observations, interpreting data, and using this information to communicate conclusions

[10] SA1.2 reviewing pertinent literature, hypothesizing, making qualitative and quantitative observations, controlling experimental variables, analyzing data statistically (i.e., mean, median, mode), and using this information to draw conclusions, compare results to others, suggest further experimentation, and apply student's conclusions to other problems.

[11] SA1.2 recognizing and analyzing multiple explanations and models, using this information to revise students' own explanation or model if necessary

Alaska Cultural Standards

[B] Culturally-knowledgeable students are able to build on the knowledge and skills of the local cultural community as a foundation from which to achieve personal and academic success throughout life. Students who meet this cultural standard are able to:

[B2] make effective use of the knowledge, skills, and ways of knowing from their own cultural traditions to learn about the larger world in which they live.

[D] Culturally-knowledgeable students are able to engage effectively in learning activities that are based on traditional ways of knowing and learning. Students who meet this cultural standard are able to:

[D.4] gather oral and written history information from the local community and provide an appropriate interpretation of its cultural meaning and significance.

[E] Culturally-knowledgeable students demonstrate an awareness and appreciation of the relationships and processes of interaction of all elements in the world around them. Students who meet this cultural standard are able to:

[E.2] understand the ecology and geography of the bioregion they inhabit.

Bering Strait School District Scope & Sequence

10.2E. Understands basics of soil formation (topsoil, porosity, permeability, permafrost).

Materials

- *Thawing Permafrost* High School Student Guide
- Student Worksheet: *Ask an Expert about Thawing Permafrost*
- Internet access and projector

Activity Preparations

1. Identify adults within your school who have lived year-round in the community for many years. This might include teachers, administrators, secretaries, teacher aides, lunchroom/kitchen staff, recess duties, maintenance and custodial staff, etc. Ask these local knowledge bearers if they would be willing to speak with a group of your students about how vegetation in the area has changed, and how those changes have affected the community. Make sure that the volunteers you have identified will be available during the time that your class will be completing this activity.
2. Ask the volunteers if they speak an Alaska Native Language, and if so, which language(s) and dialect(s) they are familiar with. If applicable, have them translate the written words on the student worksheet, so you have an answer key. Also, ask them to teach you the pronunciation of the terms.

Activity Procedure

1. Distribute the Thawing Permafrost student guide and ask students to work with a partner to read pages 1-5.
2. Show the video *Permafrost Thaw*, available at www.k12reach.org/videos.php. Videos are located under the Multimedia tab. Allow time for students to share comments and ask questions.
3. Explain that students will interview a few community members about local permafrost. Separate students into small groups according to how many knowledge bearers are available to share information with your class. Explain if the appointed interviewees speak an Alaska Native Language, so students know whether or not they should pursue that portion of the interview.

4. Review expectations for student behavior while conducting the interview, including introductions and thanking the interviewee at the end of the interview. Discuss suggestions for effective interviewing techniques, such as allowing ample time for the interviewee to answer, and asking follow-up questions.
5. Distribute one Student Worksheet: Ask an Expert about Thawing Permafrost to each group and assign each group one local knowledge bearer to interview. Provide 15-20 minutes for students to locate and interview the knowledge bearer.
6. Reconvene in the classroom and ask groups to share their findings. How has the local vegetation changed? What impacts might the changes have on local lifestyles? If your students learned local indigenous words for the vocabulary terms, compare their translations with the translations found on page 5.

Student Worksheet: Ask an Expert about Permafrost Thaw

Names of Group Members _____

_____

Interview a long-term community member to learn more about lakes and ponds in your area. Take notes about what you learn.

Who did you interview? _____

Ask:

How do people in our community use nearby lakes and ponds?

Are nearby lakes and ponds changing? If so, how?

How are current changes to lakes and ponds impacting our community? If the lakes and ponds have not changed, how might future loss of lakes due to permafrost thaw impact our community?

For Alaska Native Language Speakers

What language(s) do you speak? _____

What dialect(s)?_____

Could you please translate the following words?

Permafrost _____

Ice _____

Lake _____

Ground _____

Activity HS.4.2: Permafrost Vocabulary

Overview

What terminology do we need to know to discuss permafrost? In this activity, students will learn key permafrost terminology in English and their local Alaska Native language by playing vocabulary games with peers.

Background Information

Based on the Visual Iñupiaq Vocabulary Acquisition (VIVA) Program of the North Slope Borough School District, the vocabulary cards provided for this activity have Alaska Native Language and English terms and an associated image. The games suggested are meant to promote fluency through repeated practice. Other vocabulary cards can be easily integrated into the games. This will extend potential length of the games and add a greater challenge. By working with the words through different games, students can develop greater fluency with the vocabulary.

Objectives

On successful completion of this lesson, students will be able to:

- read and speak indigenous terms related to climate, landscape and ecosystems
- illustrate and define terms related to permafrost and landscape changes in their region

Alaska Cultural Standards

[B] Culturally-knowledgeable students are able to build on the knowledge and skills of the local cultural community as a foundation from which to achieve personal and academic success throughout life. Students who meet this cultural standard are able to:

[B.2] make effective use of the knowledge, skills, and ways of knowing from their own cultural traditions to learn about the larger world in which they live.

[E] Culturally-knowledgeable students demonstrate an awareness and appreciation of the relationships and processes of interaction of all elements in the world around them. Students who meet this cultural standard are able to:

[E.2] understand the ecology and geography of the bioregion they inhabit.

Bering Strait School District Scope & Sequence:

10.2E. Understands basics of soil formation (topsoil, porosity, permeability, permafrost).

Materials

- Vocabulary card sets (1 per group of 4-6 students)
- Word Games Instruction Sheet (1 per group of students)
- Student Worksheet: Permafrost Vocabulary
- REACH Up High School Student Guide: Thawing Permafrost
- Dry Erase Markers (1 per group)
- Timers (optional)

Additional Resources

2009 Pearson / Prentice Hall

Earth Science Textbook Chapter 8-9

Activity Preparations

1. If your students completed Activity HS.4.1 Ask an Expert, refer to their completed worksheets for the terms you will have them use for the vocabulary word card games.
2. If your students did not conduct interviews with Native language speakers, consult with a local knowledge bearer or language expert to determine which language/dialect translation provided on page 6 of the Student Guide would be most appropriate for your students to practice. The following chart is provided for reference.

Alaska Native Languages in the Bering Strait Region				
Language	**Dialect Group**	**Dialect**	**Subdialect**	**Community**
Iñupiaq	Seward Peninsula Inupiaq	Bering Strait		Brevig Mission
			Diomede	Little Diomede
				Shishmaref
			Wales (Kinikmiu)	Wales
		Qawariaq	Teller	Teller
				Unalakleet
				Shaktoolik
			Fish River	Golovin*
				White Mountain
	Northern Alaskan Iñupiaq	Malimiut		Koyuk
Siberian Yupik		St. Lawrence Island Yupik		Gambell
				Savoonga
Yup'ik		Norton Sound (Unaliq-Pastuliq)	Unaliq	Elim
				Golovin*
				St. Michael
		General Central Yup'ik	Nelson Island and Stebbins	Stebbins

* It is very common for more than one language / dialect, or a combination of dialects, to be spoken in a community. It should also be noted that Inupiaq-Yup'ik bilingualism was common throughout the 1900s in the Norton Sound villages of White Mountain, Golovin, Elim, and Unalakleet. Golovin is listed twice on our chart because specific subdialects were cited in the research found on the Alaska Native Language Center website: http://www.uaf.edu/anlc/languages/.

3. Keep in mind that different individuals may translate certain terms differently. For example, some languages may not have a separate term for "shrub" and "willow". Or, distinct terms may exist, but the individual speaker does not know the term for "willow", and uses the term for "shrub" in both instances. It's fine to have different student groups working with various translations, or you can choose a set list of words for your whole class to practice. Highlight the diversity and do not attempt to offer an authoritative translation; the goal is to practice an Alaska Native language while discussing climate

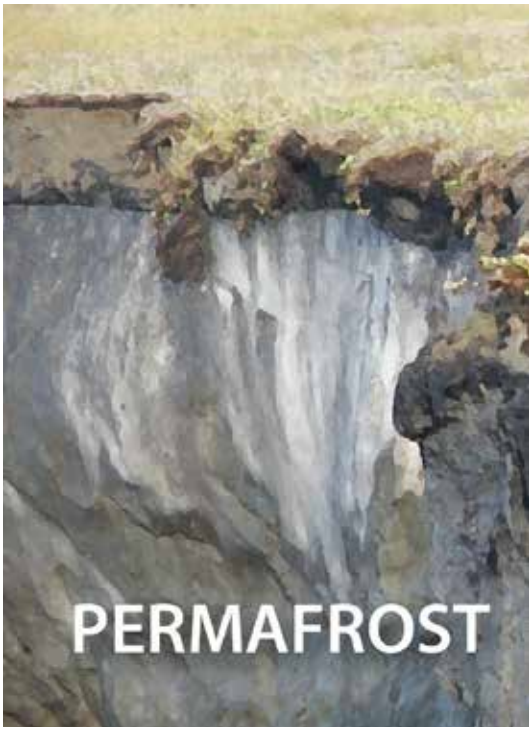
change topics.

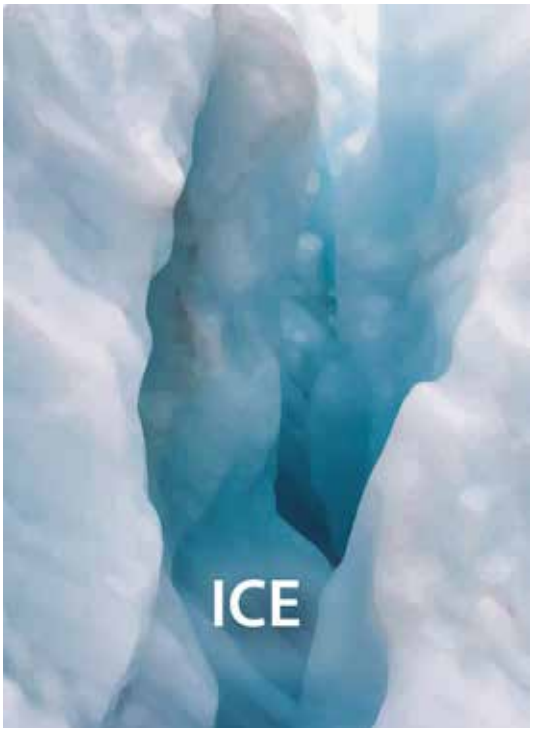
4. If using the Vocabulary Cards provided by REACH Up, label a sample set of cards with local indigenous words using a dry erase marker. If needed, create your own sets of the vocabulary cards from the template provided.
5. Make copies of the Word Games Instruction Sheet (one per group) and the Thawing Permafrost worksheet (one per student).

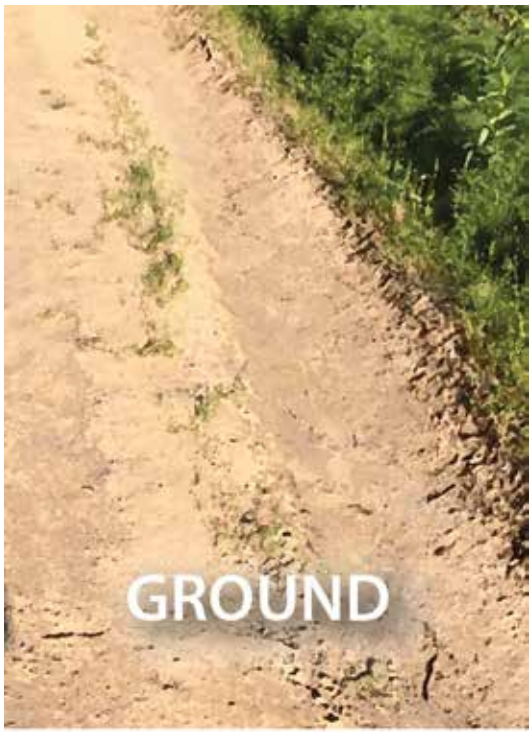
Activity Procedure:

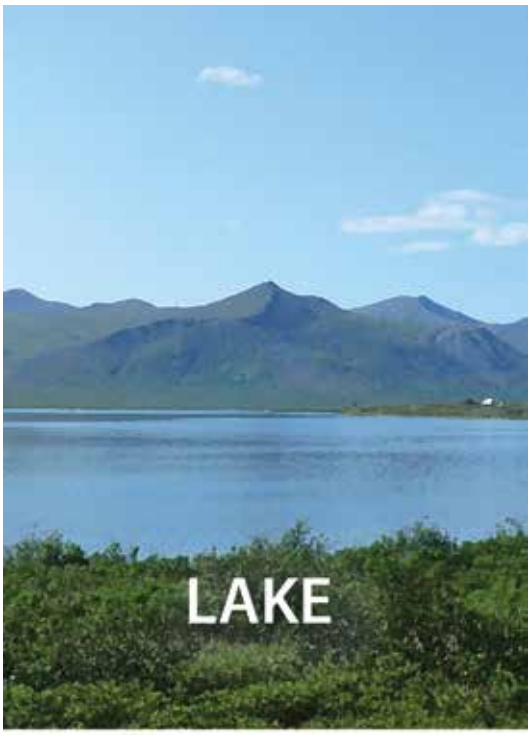
1. Distribute the Thawing Permafrost Student Guide and review pages 1-6.
2. Show students the vocabulary cards. Hold up each card. Discuss what each card depicts. How do these terms relate to vegetation in their region?
3. Say the English and local Alaska Native Language word for the illustration depicted on the card. Ask students to repeat the words. Repeat this once or twice, then ask students to call out the correct words as you hold up each card.
4. Divide the class into four groups.
5. Provide each group with the Word Games Instruction sheet, a set of Vocabulary Cards, dry erase marker, and a timer (optional).
6. Instruct students to label their cards with the local indigenous words. Groups can select one student from the group for this task, or take turns.
7. Direct students' attention to the Word Games Instruction sheet. Students can commit to one game for a period of time or mix and match.
8. Encourage students to play the vocabulary games and practice the vocabulary words during free time throughout the duration of the Thawing Permafrost unit. If possible, schedule 10-15 minutes twice per week to practice the vocabulary terms.
9. Write the following terms on the board: climate, permafrost, active layer, and landslide. Ask students to share definitions for these terms. Refer back to the Thawing Permafrost Student Guide or to the science textbook as necessary.
10. Distribute the Thawing Permafrost Vocabulary Worksheet and ask students to complete it.

Vocabulary Cards









Vocabulary Cards

Local indigenous word

Local indigenous word

Local indigenous word

Local indigenous word

Student Information Sheet: Word Games Instructions

VOCABULARY SWAP

1. Distribute one card to each person.
2. Practice the word on your card, then find a classmate. Teach them the word on your card and learn the word on their card. Trade cards.
3. Find another classmate and repeat.

FIND THE CARD

1. Divide into small groups. Each group will need a set of vocabulary cards. Spread the cards in front of you so that everyone in your group can see the pictures.
2. Listen as your teacher says a word aloud from one of the cards.
3. Work with your group to find and hold up the correct card.

VOCABULARY SLAP

1. Select one student to serve as the "caller" for this game. That student should make a list of the vocabulary words on a separate sheet of paper. The words can be found on the back of the cards.
2. Place the cards in a circle, picture-side-up, in the middle of the playing area.
3. The caller should call out a word from their list. Everyone else should quickly place their hand on the picture that they believe represents that word.
4. Turn over the card or cards that students selected to see who chose correctly. Each student who placed his or her hand on the correct card earns a point.
5. Put the card(s) back in the circle and play again.
6. Play for a designated period of time. At the end of the time, the person with the most points wins.

TEAMWORK

1. Divide your group into two teams. Each team will need a pencil and paper.
2. Shuffle the vocabulary cards and stack them picture-side up in the middle of the table.
3. Work with your team to write down the local Alaska Native Language term and English words for the picture on the card.
4. After both teams have written answers for the top card, turn the card over to check. Teams get 1 point for each correct Alaska Native Language word.
5. Repeat until all cards are gone. The team with the most points wins.

Student Worksheet: Permafrost Thaw Vocabulary

Name _____

1) Draw a line connecting each definition to the term that it represents.

Active layer	The long-term average weather conditions that occur in a particular region
Climate	Soil that has remained frozen year-round for at least two years
Landslide	Rapid, downhill movement of soil, loose rocks, and boulders
Permafrost	The layer of soil that freezes and thaws annually. In cold regions, this layer lies on top of permafrost.

2) Complete the chart by writing the local Alaska Native Language terminology and illustrating the missing terms.

My Community:_____

English Word	*Local Alaska Native Lanuage Word*	*Illustration*
Ground		
Ice		
Lake		
Permafrost		

Answer Key: Permafrost Thaw Vocabulary

1)

Active layer		The long-term average weather conditions that occur in a particular region
Climate		Soil that has remained frozen year-round for at least two years
Landslide		Rapid, downhill movement of soil, loose rocks, and boulders
Permafrost		The layer of soil that freezes and thaws annually. In cold regions, this layer lies on top of permafrost.

2)

My Community:_____

English Word	*Local Alaska Native Lanuage Word*	*Illustration*
Ground	Answers will vary depending on language and dialect spoken in this community	Sketch should illustrate word at left
Ice	Answers will vary depending on language and dialect spoken in this community	Sketch should illustrate word at left
Lake	Answers will vary depending on language and dialect spoken in this community	Sketch should illustrate word at left
Permafrost	Answers will vary depending on language and dialect spoken in this community	Sketch should illustrate word at left

Activity HS.4.3 Engineering for Permafrost

Overview

In this lesson, students test foundation models to determine which holds up best when permafrost thaws.

Objectives

On successful completion of this lesson, students will be able to:

- describe the impacts that thawing permafrost can have on structures
- identify which type of modeled foundation is best for building on permafrost
- explain the energy transfer that occurs as permafrost thaws

Next Generation Science Standards

Standards by Disciplinary Core Ideas: Energy, Engineering Design

Standards by Topic: Energy, Engineering Design

Performance Expectations

The activity is just one step toward reaching the performance expectations listed below:

HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Dimention:

Science & Engineering Practices

Constructing Explanations and Designing Solutions

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-4)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4)

Crosscutting Concepts

Energy and Matter

Alaska Standards

Alaska Science Standards/Grade Level Expectations

SA1: The student demonstrates an understanding of the processes of science by:

[9]SA1.1 asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring and communicating.

[10] SA1.1 asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring and communicating.

[9]SA1.2 hypothesizing, designing a controlled experiment, making qualitative and quantitative observations, interpreting data, and using this information to communicate conclusions.

SB2: The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by:

[9] SB2.1 applying the concepts of heat transfer (i.e., conduction, convection, radiation) to Alaskan dwellings.

Alaska Math Standards

N-Q.2. Define appropriate quantities for the purpose of descriptive modeling.

Alaska Cultural Standards

[B] Culturally-knowledgeable students are able to build on the knowledge and skills of the local cultural community as a foundation from which to achieve personal and academic success throughout life. Students who meet this cultural standard are able to:

[B2] make effective use of the knowledge, skills, and ways of knowing from their own cultural traditions to learn about the larger world in which they live.

Bering Strait School District Scope & Sequence

10.2E Understands the basics of soil formation (topsoil, porosity, permeability, permafrost).

11.7A Understand energy as it appears in different forms and that it can be transferred from

one place to another and transformed from one form to another.

11.7B Differentiate between conduction, convection, and radiation energy transfers. (Applying the concepts of heat transfer to Alaskan dwellings.) (SB2.1)

11.7D Use scientific processes and inquiry to directly support concepts of energy thermodynamics. (SA)

11.7E Students develop an understanding of the dynamic relationships among scientific, cultural, social and personal perspectives.

Materials: (for 9 groups - 3 of each type of model)

- Plastic shoebox (9)
- Small metal bread pan (9)
- Rectangular Legos (12)
- Square Legos (4)
- Ice cubes
- Aquarium gravel
- Aluminum foil
- Bamboo Skewers (12)
- Rulers (9)
- Hot water
- Timers (9)
- 250 ml measuring cups (9)
- Colander (for drying gravel after activity)
- Tape
- Scissors

Additional Resources

2009 Pearson Prentice Hall

Permafrost:

- Earth Science Textbook Chapter 8-9, 18
- Life Science Textbook Chapter 22

Energy Transfer and Transformation:

- Earth Science Textbook: Chapter 11
- Physical Science Textbook: Chapter 15, 16

Activity Preparations

1. Decide whether you would like to divide this lesson into two class periods. If so, plan to read the student guide, discuss and build foundation models on Day 1. Plan to build the permafrost model and test the foundations on Day 2.
2. During the activity, students will have down time between taking measurements of their model. Make a plan for what you will have them do during this time: class discussion, reading, or another assignment, etc.
3. Freeze appropriate quantity of ice.
4. Heat water for model homes and simulated climate change.
5. Make copies of the Student Worksheet: Engineering for Permafrost.

Background Information

Permafrost is soil that has remained frozen year round for at least two years. Most of Alaska is underlain by permafrost, much of which has been around for tens of thousands of years. Alaska's climate is warming. As average temperatures rise, permafrost begins to thaw. This has significant impacts on landscapes and ecosystems. It also presents special challenges related to building homes and other structures. Permafrost that includes ice takes up more space than thawed soil. If the permafrost beneath a structure thaws, the ground can sink, causing the structure to settle unevenly. Builders must be aware of not only climate-driven permafrost thaw, but also the thaw caused by heat from the structure radiating or conducting into the ground beneath the structure. The type of foundation used beneath a structure can help reduce the likelihood that heat loss from the structure will thaw the permafrost. It can also help to reduce the impact of naturally thawing permafrost on the structure.

Four common foundations used in the Bering Strait region include:

Post on Pad Foundation: Small concrete pads are constructed on prepared ground, with a post above each pad. The posts support the home, allowing cold air to circulate beneath. This type of foundation is easily adjusted, by adding blocking or adjusting posts as the structure settles.

Driven Pile Foundation: Metal or wood posts are driven deep into the ground. The floor of the home is framed to perch above the ground, resting on the posts. This allows cold air to circulate beneath the home.

Space Frame Foundation: Many small concrete pads built on prepared ground support a metal framework, distributing the weight of the home and allowing cold air to circulate beneath. If one of the pads sinks, the other bracings continue to support the structure until blocking or adjustments can be made in the sunken area.

Slab on Grade Foundation: A large concrete pad the same size as the footprint of the home is poured on prepared ground. The home is built on top of the slab. The pad conducts heat from the home down into the ground beneath the home.

Activity Procedure

1. Review pages 1-5 in the REACH Up Thawing Permafrost High School Student Guide.
2. Next read and discuss pages 6-7 together as a class.
3. Ask students: What is permafrost? Why must it be considered when building homes and structures in communities with permafrost? Discuss the different types of foundation found in your community. What type of foundation does your school have? How about the store or post office? What types of foundation do the homes in your community use? Why? How does the heat from a structure transfer the ground beneath the structure differently with different foundations? If the weather is suitable and time allows, go outside and look under the school at the foundation.
4. Explain that during this activity students will model three foundation types, then create a model of permafrost in their area and test the foundations on permafrost.
5. Place students in groups of 2-4 and assign each group a foundation type. Distribute Engineering for Permafrost worksheet and provide groups with the materials necessary to build their model foundation.
6. Before students begin building their foundation model, ask them to use what they have learned about permafrost and foundations to predict which of the three foundation models will be most and least effective in a permafrost area and why.
7. Ask students to build their foundation models and attach them to their bread pan "homes."
8. Provide ground model materials (plastic shoeboxes, ice, gravel, measuring cups, rulers, hot water, timers).
9. Ask students to use their worksheets to guide them in constructing their permafrost models. Provide assistance as needed.
10. Ask students to place their model houses with foundations into their permafrost models and measure the height of each end of the house (from the bottom of the container). Record measurements on the worksheet.
11. Oversee pouring hot water into the "houses." Ask students to use their timers to help them measure the height of the house every 5 minutes. Explain that the hot water simulates the heat inside the building. Discuss energy transfer (conduction and radiation) of the heat energy from the home to the ground.
12. After 4-5 measurements, simulate climate change! Ask students to pour hot water into the ground of their permafrost model. This will thaw the permafrost. Allow the permafrost 2-5 minutes to thaw and then measure the house one last time, recording the measurements on student worksheets.
13. Ask students to share their data and complete the discussion questions on their worksheets.

14. Discuss: Which type of foundation worked best before climate change? Why? How about after climate change? How is energy transfer related to how each type of foundation affected the permafrost before climate change? [*Answers will vary. For the last question, responses should indicate understanding that heat from the house conducts (slab on grade) or possibly radiates (other foundation types) into the ground beneath the house.*]

References

Cysewski, Margaret. (2016) "Middle School Lesson: Permafrost Foundation Model Design Project." Provided by author via email 2016.

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https://www3.epa.gov/climatechange/kids/impacts/signs/permafrost.html

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Student Worksheet: Engineering for Permafrost

Name _____

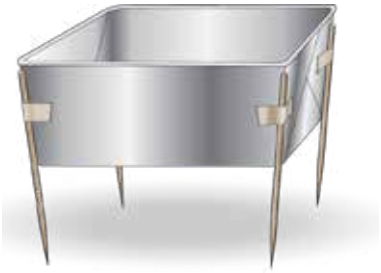
Introduction

How can we build lasting homes on permafrost? Plan from the bottom up!

The foundation of the home is key in determining how the building will impact and withstand permafrost thaw.

Model and test one of the following three foundation types to see how it holds up in permafrost conditions!

1. Which type of foundation will you model? (Circle one and build it!)

Post and Pad	Slab on Grade	Driven Pile
		
You will need: • 1 bread pan (house) • 16 square building bricks (posts) • 4 rectangular building bricks (pads) • tape	You will need: • 1 bread pan (house) • 1 sheet aluminum foil (slab) • tape	You will need: • 1 bread pan (house) • 4 skewers (pilings) • tape

2. Make a hypothesis. Which type of foundation do you think will work best in a permafrost area? Why?

_____
_____
_____
_____

Which will be the least effective? Why?

_____
_____
_____
_____

3. Learn how to create a proportional model of permafrost for your community.

   Ice cubes = ground with permafrost

   Gravel = ground without permafrost

   You will use 1,000ml of "ground" for this activity. Look at the chart to learn how much of the ground has permafrost in your community. Hint: 100ml cup of "ground" equals 10%.

   What is the name of your community? _____

   How much gravel do you need? _____ ml

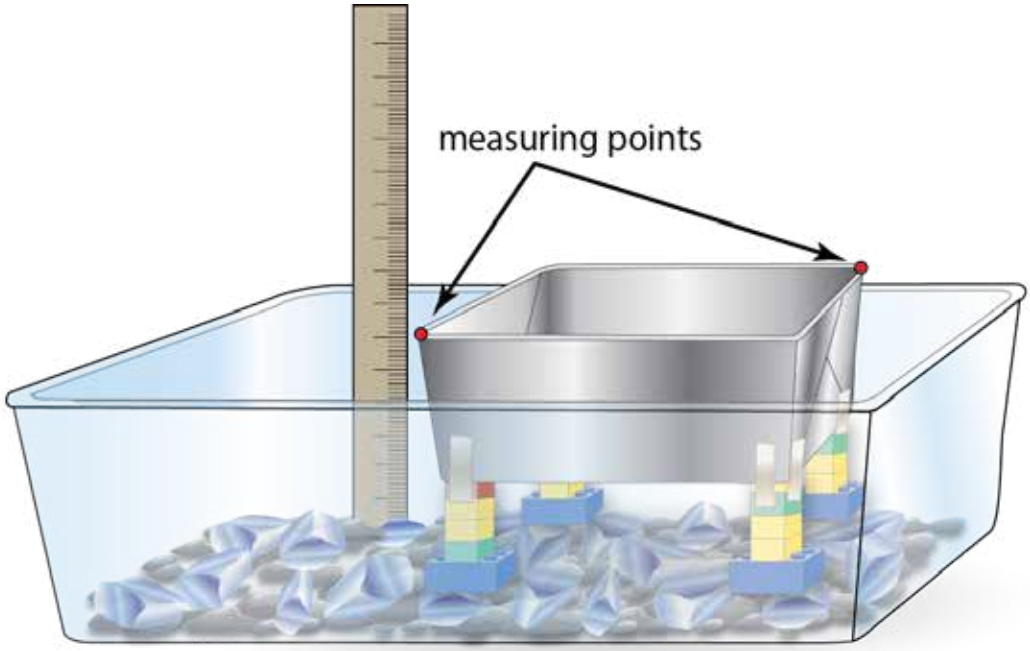
   How much ice do you need? _____ ml

Community	% of ground with permafrost
Brevig Mission	>90%
Diomede	>90%
Elim	50-90%
Gambell	50-90%
Golovin	50-90%
Koyuk	50-90%
Savoonga	50-90%
Shaktoolik	50-90%
Shishmaref	>90%
Stebbins	10-50%
St. Michael	10-50%
Teller	50-90%
Unalakleet	50-90%
Wales	>90%
White Mountain	10-50%

4. Prepare your ground model based on your calculations! Pour each cup of ground (ice or gravel) in a different area on the bottom of the plastic shoebox. Some areas will have permafrost, others may not. Make the surface of the ice and gravel level with your hands.

   You will need:

   - Plastic shoebox
   - Ice
   - Gravel
   - Measuring cup
   - Ruler
   - Hot water
   - Timer



5. Place your house model on your ground. If you have the Driven Pile model, be sure to press the pilings into the ground as far as you can. Post on Pad and Slab on Grade models should rest on top of the ground.
6. Use a ruler to measure the height of the house (from the bottom of the container) at each end. Record your measurements to the nearest millimeter in the following chart.

7. Pour hot water into your "house" (~200ml) and then repeat your measurements every 5 minutes. If the water in your house is cool after 15 minutes, add more hot water.

	Height of House Side 1	Height of House Side 2
Starting Measurement		
5 minutes		
10 minutes		
15 minutes		
20 minutes		

8. Induce climate change! Pour hot water into the ground. This will thaw the permafrost in your model.

	Height of House Side 1	Height of House Side 2
25 minutes		
30 minutes		

9. Did your house sink? _____ If so, how long before it sank? _____

10. Why do you think that your house responded to permafrost the way it did?

_____
_____
_____

11. Share your data with your classmates. Which type of foundation worked best? Why?

_____
_____
_____

12. How is energy transfer related to how each type of foundation affects the permafrost?

_____
_____
_____