ENGINEERING ICE CELLARS

Overview:

In this lesson, students investigate traditional ice cellars and the problems posed by thawing permafrost. Classes conduct a hands-on demonstration to build an understanding of how convection can work to cool permafrost around cellars then design their own food storage system for their community.

Objectives:

The student will:

- describe a convection current in a model ice cellar;
- explain how thermal chimneys create a convection current and can cool an ice cellar; and
- design an ice cellar for their community.

Targeted Alaska Grade Level Expectations:

[9]SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.

[9]SA1.2 The student demonstrates an understanding of the processes of science by hypothesizing, designing a controlled experiment, making qualitative and quantitative observations, interpreting data, and using this information to communicate conclusions.

[10]SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[9]SA2.1 The student demonstrates an understanding of the attitudes and approaches to scientific inquiry by formulating conclusions that are logical and supported by evidence.

[9]SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by applying the concepts of heat transfer (i.e., conduction, convection, radiation) to Alaskan dwellings.

[10]SD3.1 The student demonstrates an understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by describing causes, effects, preventions, and mitigations of human impact on climate.

[9]SE1.1 The student demonstrates an understanding of how to integrate scientific knowledge and technology to address problems by recognizing that the value of any given technology may be different for different groups of people and at different points in time (e.g., different uses of snow machines in different regions of Alaska).

[10]SE1.1 The student demonstrates an understanding of how to integrate scientific knowledge and technology to address problems by identifying that progress in science and invention is highly interrelated to what else is happening in society.

[9]SE2.1 The student demonstrates an understanding that solving problems involves different ways of thinking by questioning, researching, modeling, simulating, and testing a solution to a problem.

[10]SE3.1 The student demonstrates an understanding of how scientific discoveries and technological innovations affect our lives and society by researching a current problem, identifying possible solutions, and evaluating the impact of each solution.

[9]SF1.1-SF3.1 The student demonstrates and understanding of the dynamic relationships among scientific, cultural, social, and personal perspectives by describing the scientific principles involved in a subsistence activity (e.g., hunting, fishing, gardening).

Whole Picture:

Alaska Native people have used ice cellars to store food for thousands of years. An ice cellar is an underground storage area dug into the permafrost. This traditional means of food storage is still in use in many Alaska Native communities today.

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Ice cellars are economical and provide ample space for storing subsistence foods, especially when compared with conventional electric freezers. However, above average annual temperatures and increased coastal erosion in recent decades have resulted in many reports of compromised cellars. Thawing permafrost, warmer soils and coastal erosion create infrastructure problems, flooding and temperatures beyond those optimal for safely storing food. The subsequent inability to store traditional foods is a significant health problem in Alaska Native villages because it decreases both the quality and quantity of healthy food available.

Alaska Native communities are working together with scientists to explore solutions to these problems. The best adaptive responses will be locally driven and culturally appropriate. Other important considerations include strategies that are economical and sustainable while also meeting public health guidelines for proper food storage.

Vocabulary:

convection—movement within a fluid resulting from warmer (and therefore less dense) materials rising and colder (denser) materials sinking resulting in heat transfer

thermal chimney—a passive cooling design that relies on a convection current; warm air rises through one chimney creating a current that draws cooler air down through a second chimney; the resulting convection current results in a net cooling of the air inside; thermal chimneys only work when the temperature outside is colder than the air inside.

Materials:

- 2 clear plastic soda/water bottles (approximately 1 pint or less, smallest diameter you can find)
- Razor knife
- Scissors
- 1 stick incense
- Matches
- Permanent marker
- Duct or masking tape
- Small candle
- Aluminum cake pan (shallow)
- Plastic container (approximately shoe box size, preferably heat resistant; available from restaurant supply companies)
- TEACHER INFORMATION SHEET: “Preserving Traditional Ice Cellars in Thawing Permafrost”
- STUDENT WORKSHEET: “Designing Ice Cellars”

Activity Preparation:

1. Construct the ice cellar model ahead of time. Do this with a small group of students if possible. Refer to the diagram on the student worksheet if necessary.
   a. The plastic container is the ice cellar.
   b. Use the razor knife to carefully cut the bottoms and tops off the soda/water bottles. These are the chimneys.
   c. Carefully cut the aluminum cake pan so that it is slightly larger than the plastic container. This is the top (roof) of the cellar.
   d. Use the marker to trace the chimneys onto the roof of the cellar, approximately one inch from the edge. Cut out these circles.
   e. Work the chimneys into the holes. They should fit snuggly. One should be oriented approximately halfway inside the cellar and halfway outside the cellar. This is the cold air intake. The other should be almost entirely out of the cellar, with its base about level with the roof. This is the warm air chimney.
   f. Place a small piece of tape on the bottom of the candle and secure it in the ice cellar It should be oriented underneath the warm air chimney.

2. The lesson includes a classroom demonstration. Students will need to record observations on their worksheets. Plan to conduct the demonstration in a location where students can easily observe the results, or conduct it a few times in locations around the classroom.
3. Consider the role of traditional ice cellars in your community. Do they exist? Are they used? If your students will be relatively unfamiliar with traditional ice cellars, consider watching the video on the UNITE US playlist. Visit the linked videos in the lesson description and click on "Living in a Frozen Land." Click on "Nature's Cold Storage" then "Video about ice cellar."

Activity Procedure:

1. Begin with a discussion about traditional ice cellars. Ask students to describe ice cellars they use or have seen.
2. Write the words "benefits" and "challenges" on the white board. Brainstorm and record lists of the benefits and challenges to using traditional ice cellars. Benefits include: ample storage space (especially for subsistence foods); inexpensive or even free to maintain; ecologically sustainable in that they do not require use of fossil fuels and so do not contribute to greenhouse gases; and maintaining/preserving cultural knowledge and traditions. Challenges include: sometimes difficult to construct; infrastructure problems; flooding and temperatures beyond those optimal for safely storing food (caused by thawing permafrost, warmer soils and coastal erosion create). Students may have additional ideas.
3. Explain today's lesson will merge scientific ideas and traditional knowledge by exploring ideas to help preserve traditional ice cellars. Pass out STUDENT WORKSHEET: "Designing Ice Cellars."
4. Review the design of a model ice cellar and how it relates to a real-world cellar. Actual ice cellars do not have a heat source (candle) inside. What real-world situation does this represent? (It represents winter when the air outside the cellar is much colder than the air inside the cellar.) Why are we using the incense? (The smoke makes the air visible and we can see what direction it moves.)
5. Ensure all students are in a place where they can see and then conduct the demonstration. Ask students what they predict will happen.
6. Conduct the demonstration and discuss the results. (Warm air is less dense so it rises up and out the chimney above the candle. Cooler air from outside the container rushes in through the other chimney to fill the space left by the rising warm air. This current is visible as the smoke is drawn into the chimney instead of rising up.) (NOTE: If a stick of incense is not available, simply use a crumpled piece of paper. Light the paper, then blow it out and hold the smoking paper next to the cold air intake.)
7. Explain this is called a convection current and discuss how this can help preserve a real-world ice cellar. Discuss other ways to preserve ice cellars. (See TEACHER INFORMATION SHEET: "Preserving Traditional Ice Cellars in Thawing Permafrost" for more information.
8. Allow time for students to complete STUDENT WORKSHEET: "Designing Ice Cellars" in class or as homework.
9. Allow time for students to share their ice cellar designs.

Ideas for Filming:

NOTE: Students will create a short film about permafrost for the final project associated with this UNITE US unit. Each lesson leading to the final project contains ideas about what students might film as they compile clips. Students are not limited to the list and are encouraged to use their imagination and creativity when filming.

Students can film the classroom demonstration and include narration to explain how this relates to ice cellars. Photos/scans of students' ice cellar designs could also be included in the movie. If possible, film a visit to an ice cellar in your community.

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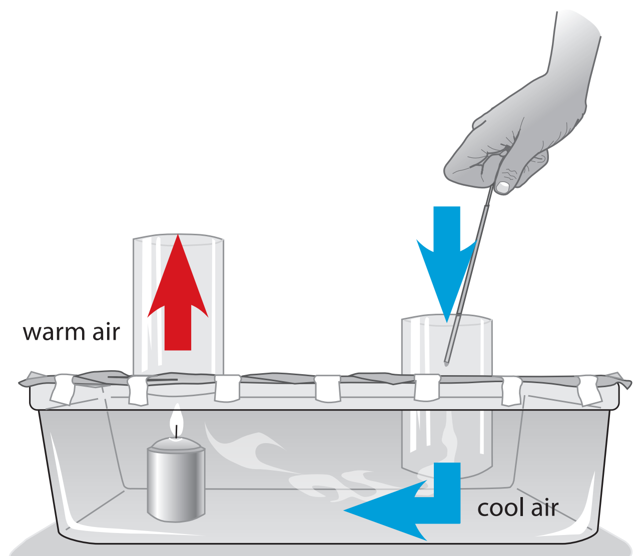
Extension Ideas:

1. Repeat the convection experiment with a hand warmer instead of a candle. Observe and discuss any differences.
2. If warming ice cellars are a problem in your community, organize an informational meeting where your students can share what they have learned with community members. Another option is to have your students write an informational handout or brochure to distribute/post around your community.
3. Take a trip to a local ice cellar if possible. Ask an Elder to visit with you and to share their knowledge about traditional ice cellars.
4. If you have access to a local ice cellar, work with students to design a method for studying its thermal resilience. Install a thermometer and a hygrometer (used to measure humidity), if possible. Track conditions in the cellar over the course of a year.
5. Explain convection can happen in any fluid—a liquid or a gas. Challenge your students to design a demonstration to show a convection current in a liquid such as water.

Answers:



1. See figure.
2. Thermal chimneys do not function in the summer months because the outside air is warmer than the air inside the cellar. Warm (less dense) air rises and cooler (denser) air sinks and so when it is colder in the cellar, the colder air will stay down in the cellar.
3. Significant cooling in winter can result in slower warming in summer and may help keep permafrost frozen (and cellars at or below recommended safe food storage temperatures).
4. Answers should include any two of the following: locating them far from the danger of coastal or streamside erosion, increasing the depth of cellars, adding a protected entrance, removing the insulating layer of snow in winter and installing thermosyphons to increase winter cooling.
5. Student essays and drawings may vary significantly, but should reflect an understanding of the information in the previous four questions.

PRESERVING TRADITIONAL ICE CELLARS IN THAWING PERMAFROST

There are many factors affecting the thermal resilience of a traditional ice cellar, including components of the original design. For example, depth is an important factor. Cellars located closer to the soil surface experience more significant warming in summer increasing the likelihood that the surrounding permafrost will thaw. A protected entrance can significantly affect the winter temperature of a cellar and subsequently the temperature of the surrounding permafrost. (Cellars with a structure over the entrance attain much colder temperatures in the winter months because the structure prevents the accumulation of an insulating layer of snow. Conversely such structures also shield the cellar from the cooling action of wind and therefore can sometimes result in a net warming in very windy areas.)

Retrofits: One potential solution to warming ice cellars is to make improvements to existing structures. Techniques include: building thermal chimneys to facilitate convective cooling in winter, installing surface insulation to protect permafrost from rising summer temperatures and installing thermosyphons like those used on the Trans Alaska Pipeline. A successful retrofit may include one or more of the following ideas:

> **Thermal chimneys** can be used to cool permafrost through convection. In order to cool an ice cellar, you need to install two chimneys. One chimney is installed so that it will allow warm, less dense air to rise and escape from the ceiling area of the cellar. A second chimney is installed that reaches almost to the floor of the cellar. As the warm air rises and escapes through the ceiling-level chimney, colder air rushes in through the floor-level chimney to fill the space. This air is then slowly heated and rises towards the ceiling. This creates a convection current that exchanges the colder outside air for the warmer air inside the cellar. The result is a net cooling of the cellar and the surrounding permafrost. Thermal chimneys do not function in the summer months when the outside air is warmer then the air inside the cellar. However, significant cooling in winter can result in slower warming and may help keep permafrost frozen (and cellars at or below recommended safe food storage temperatures) by significantly decreasing temperatures in winter.
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> **Snow removal** eliminates the insulative layer from the ground in winter. This will allow the active layer and permafrost to become colder over the course of the winter, therefore making it slower to warm and thaw in summer.
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> **Thermosyphons** are devices that can be used to cool permafrost through passive heat transfer. They consist of a sealed tube containing a fluid. The lower end of the tube is buried in the permafrost and the upper end is usually exposed in the air. Cold winter air temperatures surrounding the upper end cause the fluid to condense. Gravity then causes the denser liquid to flow to the lower end of the tube where it is warmed and evaporates. The vapor is less dense and so it rises to the upper (colder) end where the circulation begins again. In this way heat is transferred from the warmer permafrost to the colder air. Like thermal chimneys, thermosyphons do not function in the summer (because the air is warmer than the ground), but they help keep permafrost frozen longer by significantly decreasing its temperature in winter. A significant amount of energy is required for phase change (from a liquid to a vapor) and so considerable quantities of heat can be transported out of the ground through this process. Thermosyphons are installed around many buildings and roads in the far north (as well as along the Trans Alaska Pipeline) to help prevent thawing permafrost from destroying pavement and foundations.

An alternative to retrofitting old cellars is to design new cellars in optimal locations using both traditional knowledge and contemporary scientific strategies. Locations should be far from the threat of coastal or stream/lake side erosion, dug deep into the permafrost layer and include small entrance structures. An insulation layer can be added above the permafrost layer during the initial excavation. Thermal chimneys and/or thermosyphons can be added for additional winter cooling.

Other Options for Cold Storage: According to the U.S. Department of Agriculture, the optimal storage temperature for most frozen foods is from 0˚F to -10˚F. It is important to consider that although food may be frozen, this temperature may not be attainable in a traditional ice cellar. In these cases, communities may consider choosing one of the many efficient refrigerators or freezers that can be powered using alternative energy. Cold storage is most necessary in the summer and early fall when solar energy is abundant, making solar-powered refrigerators and freezers a viable option. However, storage of some subsistence foods (such as whales) requires significantly more space than conventional appliances can provide. In these circumstances communities will need to work together to explore creative solutions.

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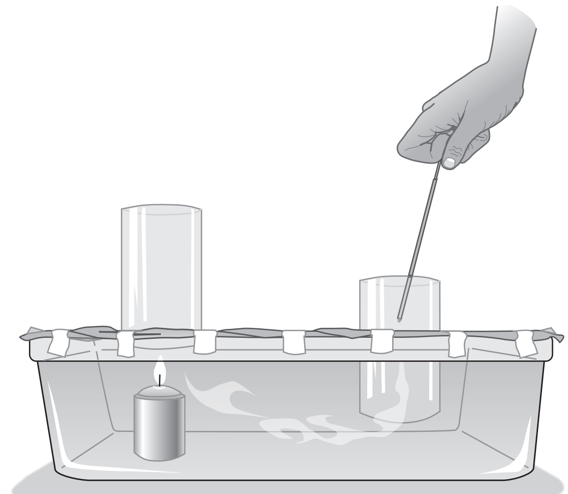
DESIGNING ICE CELLARS

Directions: Watch the teacher demonstration. Answer the following questions.



1. Use arrows to draw the path of air circulating through the ice cellar model. Label the path of the warm air and the cool air.

2. Based on this diagram, explain why thermal chimneys only circulate air in the winter (when the air is colder outside than inside the cellar).

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3. If thermal chimneys do not circulate air in the summer, how could they help keep ice cellars cooler in summer?

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4. Describe at least two other ways to preserve the use of traditional ice cellars for food storage.

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DESIGNING ICE CELLARS

5. Design an ice cellar for your community. Describe where it would be located and why. Describe how you would construct it and what features you would use to help ensure it wil keep food cold. Use the back of this page to make a sketch.