UTAH OFFICE OF
ENERGY DEVELOPMENT

Transporting Liquid Oil

Grade/Subject: 6th Science

Strand/Standard 6.2.4 Design *an object, tool, or process* that minimizes or maximizes heat energy transfer. *Identify criteria and constraints, develop a prototype for iterative testing, and propose modifications for optimizing the* ***design solution.*** Emphasize demonstrating how the structure of differing materials allows them to function as either conductors or insulators. (PS3.A, PS3.B, ETS1.A, ETS1.B, ETS1.C)

Lesson Performance Expectations: Students will conduct an investigation to determine which insulators work best and compare materials. Students will design insulation that allows Utah's waxy crude oil to remain as a liquid during transport.

Materials:

- Paraffin wax
- Crock-Pot
- Crock-Pot Liner
- Paper Cup (for hot liquids) a plastic cup may melt
- Digital meat thermometers (one per group)
- Various materials for students to choose to build their insulators: felt, foam, newspaper, packing peanuts, bubble wrap, etc.

Time: 2 - 60-minute periods

Teacher Background Information:

- Heat moves in predictable ways, flowing from warmer objects to cooler ones until both reach the same temperature.
- Thermal insulation is composed of materials that do not conduct heat well. The material in an insulator is less dense than that of a conductor. The denser the material is (the closer together its atoms are), the easier it is to transfer energy from one atom to the next as the atoms bump into each other. OED Energy Efficiency Video (4:40 min)
- To slow heat transfer by conduction, insulators are put between materials that may transfer heat to one another.
- The concept of phase change is demonstrated when some of Utah's petroleum is extracted from underground to make gasoline to fuel our cars, as well as produce many other products that we use daily.
- Oil can be found in many parts of Utah. In locations like the Uinta Basin (Duchesne, Uintah, Grand, Carbon counties) and Paradox Basin (San Juan County), petroleum is not the liquid oily substance that we typically think of. Instead of being a black liquid, it is a waxy substance called waxy crude that hardens when it loses heat and its

temperature decreases. When it is below the earth's surface, this oil is hot enough to remain a liquid, as soon as it reaches the surface it begins to cool. If it is not kept warm using some kind of insulator, it will harden like wax.

- Waxy crude is found in two colors: yellow and black. The color difference is attributed to the type of organic material that it is derived from, along with the maturity of the crude. The yellow wax was formed during the period when Utah was covered by freshwater, whereas the black wax was formed when parts of Utah were covered by saltwater.
- While waxy crude oil is another resource to add to Utah's fossil fuel portfolio, transporting it before it hardens remains a challenge. Engineers found a way to keep the waxy crude below its freezing point while it is transported to the refineries through insulated containers.

Student Background Knowledge:

- Students understand that heat can be transferred through radiation, convection, and conduction.
- Students know the difference between insulators and conductors.
- Students know the Engineering Design Process.

Teacher Step by Step: A 3-d lesson should insist students do the thinking. Provide time and space for the students to experience the phenomenon and ask questions. The student sheet provided below provides guidance but is only an example of how students might respond.

This is a two-part lesson The first lesson is optional but is a good lead-in to types of insulators and what makes a good insulator. This may be taught a different way and the second lesson is not dependent on this initial lesson.

Lesson 1 -

1. **Introduce *Phenomenon:***
    a. Have students write questions about the phenomenon on their student sheet.
    b. Discuss student questions and guide them to the focus question: *How can we keep crude oil from solidifying*?

2. **Design a Solution**
    a. Students will design an object that will prevent heat from leaving paraffin wax.
    b. Review the Engineering Design Process.
        i. *Ask:* How can we keep heat from transferring out of the wax?
            1. Discuss Criteria and Constraints of the Design:
                a. Criteria - Create an insulator for a cup that prevents heat from leaving the wax.
                b. Constraints - 1) made from the materials provided, 2)reusable, 3)convenient
        ii. *Research:* Students will take initial temperature readings of the wax. Record on Student Sheet
        iii. Tell students that the wax needs to stay above 99 degrees in order to remain liquid.
        iv. *Imagine:* Using the information they obtained about insulators and the materials provided, students will sketch how they will insulate their cups.
        v. *Plan:* Students will be put into groups of 3 and discuss their ideas and decide on a final idea for their design.
        vi. *Create:* Students will create their insulators according to their plans.
        vii. *Test*: Students will test their insulator by recording the temperature of the wax at 1-minute intervals.
        viii. *Improve:* Students will make improvements to their design and test their results again.

Assessment of Student Learning. Students will successfully fill out the Engineering Design Sheet and build an insulator for a cup to keep the wax above 99 degrees for 10 minutes.

Standardized Test Preparation: Transporting Liquid Oil

1. What is the challenge faced when transporting Utah's waxy crude oil?
    a. It hardens into a solid as it cools.*
    b. It turns into a different substance.
    c. It evaporates into a vapor.
    d. It is located too far from cities.

2. What is the criteria for a design to transport Utah's waxy crude oil?
    a. It must be the same color as when it started.
    b. It must be the same mass as when it started.
    c. It must be in the same phase as when it started.*
    d. It must not cost too much to transport.

3. What are constraints for a design to transport Utah's waxy crude oil? Choose all that apply.
    a. The design should not cost too much.*
    b. The design should use available materials.*
    c. The design should be able to use existing roads or tracks.*
    d. The design should be attractive and not distract drivers.

4. What should the design do?
    a. Prevents evaporation.
    b. Heats the crude oil.
    c. Prevents heat exchange.*
    d. Allows oil to solidify.

Extension of lesson:

- Visit the website of your local electricity or natural gas provider to learn more about the home energy audits or energy services that they might provide.
- Students will meet with someone that installs various types of insulation during the construction process of homes and buildings.

Career Connections: Potential careers related to this activity are Petroleum Engineer, Telecom. Field Technician, and Chemical Engineer

Transporting Liquid Oil

Name_____

The Problem: Utah Oil Wells Produce Black and Yellow Waxy Crude

Black and yellow wax are thick crude oils with a higher paraffinic content than most crude oils found in North America. These waxy crudes are viscous and have a high pour point, which means they become semi-solid at lower temperatures.

Waxy Crude Oil Before Hardening *Waxy Crude Oil After Hardening*

The process for refining waxy crudes presents some challenges. Although black wax is well suited for making gasoline, lubricants, and diesel fuel, refining must occur close to the source, because waxy crudes solidify quickly. Currently, black and yellow crudes must be heated in the field and transported in insulated trucks. Producers are interested in finding inexpensive ways to insulate the oil to keep it a liquid. https://deq.utah.gov/legacy/pollutants/p/petroleum/black-yellow-wax.htm

Write down three questions you have about this design problem.

1.

2.

3.

Testing Insulators

Type of Insulator: _____

Time	Temperature of Material #1	Temperature of Material #2
Starting		
30 seconds		
1:00		
1:30		
2:00		
2:30		
3:00		
3:30		
4:00		
4:30		
5:00		
10:00		

Create a line graph of the temperatures from your investigation. Be sure to include labels, have the dependent variable on the Y-axis, and evenly space out the integers on the axes.

After looking at the class data chart, write an explanation of the results. Include evidence from your investigation in your explanation.

After looking at examples of insulators. Write down some similarities and differences of common insulators.

Similarities	Differences

Oil Transportation Insulator

Names of group members: _____

Ask: How can we keep heat from transferring from the oil? Criteria: Constraints:	Research: Starting Temperature of oil
Imagine: Sketch an insulator you could design for the cup.	
Plan: After sharing your design with your group, draw a detailed design of your plan. Include labels and dimensions where necessary.	

Test:

Time	Temperature
1 minute	
2 minutes	
3 minutes	
4 minutes	
5 minutes	
6 minutes	
7 minutes	
8 minutes	
9 minutes	
10 minutes	

Improve: What were your results? How can you make your insulator more effective?

Get another design sheet and improve your insulator.

Based on your results, how quickly must Utah oil producers move the oil before it hardens?