UTAH OFFICE OF
ENERGY DEVELOPMENT

Hands-On Permeation

Grade/Subject: Earth & Space Science

Strand/Standard ESS.4.2 Use computational thinking to explain the relationships between the sustainability of natural resources and biodiversity within Earth systems. Emphasize the importance of responsible stewardship of Earth's resources. Examples of factors related to sustainability could include costs of resource extraction, per-capita consumption, waste management, agricultural efficiency, or levels of conservation. Examples of natural resources could include minerals, water, or energy resources. (ESS3.A)

Lesson Performance Expectations:
Students will:

- Obtain information about oil extraction in Utah by performing investigations about porosity and fracking.
- Explore how the porosity of rocks affects the flow rate of oil and how porosity could be increased through the fracking process, allowing more oil to be extracted.
- Obtain information about how the fracking process could affect Utah's society, environment, and economy.
- Propose a solution to mitigate the impacts of the fracking process while still using fracking as a way to recover oil.

Materials:
Supplies for the permeation lab, each group of 4 needs.

- Sand and gravel of various sizes (About 1 cup for each group. Amount may vary depending on how the groups plan their experiment.)
- Powdered Clay (Powdered bentonite clay can be found at IFA or online) (About 1 cup per group)
- Ring stands - 1 per group
- Funnels (can use the tops of used water bottles) - 1 per group
- Screen to cover the end of the funnel, about 4" square - 1 screen per group
- Rubber bands to attach the screen to the funnel - 1 per group
- Beakers or graduated cylinders - 1 or 2 per group
- Measuring cup set - 1 set per group
- Scales - groups can share, 1 for every 2 groups
- Timers - 1 per group
- Small samples of various rocks such as marble, granite, limestone, sandstone, chalk, and shale - 1 of each per group but could vary depending on how each group plans their experiment
- Paper towels
- Water

Supplies for the fracking lab

- Gelatin - 1 tbsp. per cup and enough to make about 3 cups per group. Knox brand unflavored gelatin works well

- Straws, large enough to fit the tubing through it - 2 per group
- Tubing - 1 - 12” length per group, consider using enema tubing with holes along the end of the tube or punch your holes in the tubing with a small nail.
- Syringe - 1 per group
- Fracking Fluids with different properties: water/coke/oil/syrup/toothpaste/plaster of Paris - 1 cup per group, depending on which liquids the groups choose.

Time: (minutes/periods)
3 Class periods, 45 minutes each

Teacher Background Information:

- **What is porosity? What is permeability?**
  - Porosity is the amount of pore space in a rock.
  - Permeability is the ability of liquids to flow through the rock.
  - It is essential to consider both when determining how oil can be recovered from rock layers deep within the earth.

- **How does permeability affect oil recovery from the ground?**
  - The porosity of a rock determines how much oil the rock can hold.
  - Permeability determines how well the oil can flow through the rock, affecting how much the oil is recoverable.
  - For more information, visit here.

- **What is fracking, and how is it different from conventional oil drilling?**
  - In conventional oil wells, a vertical well shaft is dug to the oil-bearing rock. Oil is then pumped to the surface. In places where the permeability of the rock is insufficient to allow the oil to flow, Fracturing or “Fracking” of the rock may increase the permeability. That a fluid flows through solids is not an ordinary circumstance. If we put water in a glass, we do not expect it to seep through onto the counter. But in our everyday life, we do not often experience the types of pressures observed in drilling processes, and, given enough pressure, fluids can readily flow through apparent solids.

- **How does fracking affect permeability?**
  - Different rocks have different permeabilities. Some have low permeability, while other rock types, such as sandstone, are more permeable. With “fracking,” engineers can increase the permeability of impermeable rock formations by creating small cracks through which fluids may flow more efficiently instead of flowing through the solid rock. A necessary part of fracturing is understanding the existing permeabilities of the rocks you hope to drill through and the potential gains of fracturing those rocks.

Student Background Knowledge:

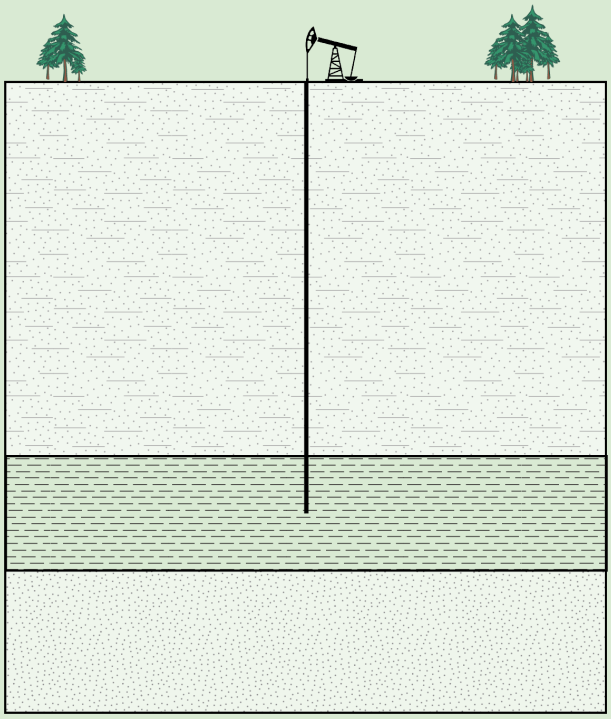
- What are sedimentary rocks, and how are they formed?
  - Information on sedimentary rocks.
- What kinds of resources can be recovered from sedimentary rocks?
  - Information on resources obtained from sedimentary rocks.
- What is petroleum, and what do we use it for?
  - Information on oil utilization.

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.

Hands-On Permeation

1. Phenomenon: Trapped!

Present the following to the students. On their student sheet, they will record three observations.



In eastern Utah, a well was dug to explore the possibility of oil production. At 5000 feet below the surface, the well hit a layer of oil-bearing shale. Over the years, the well was very productive, producing hundreds of thousands of barrels of oil. Today the well is idle. Although the well is no longer in production, geologists estimate that trillions of more barrels of oil are still waiting to be recovered from this shale layer.

After the students have recorded their observations, ask them to develop a possible explanation for why the oil in the well is not recoverable. Then they will record three questions they have about the phenomenon.

2. **Exploring Permeation**

By doing the following lab, the students will learn why gas and liquids such as water and oil can flow through certain rock types more efficiently than through others. Let the students design their experiment as much as possible. It's ok if each group does a slightly different version of the experiment.

Present the following research question to the students: **How does grain size affect how quickly a liquid can move through rock?** Tell the students what materials you have available and ask them to individually propose a way to test this. They will compare their proposals with their groups and agree on one method the group will use. You can also have the students brainstorm ways to test this as a class and design the experiment together.

Suggested materials (ring stands, funnels, rock and sand of various grain sizes, powdered clay (be sure to include this one!), small samples of various types of rock, beakers and graduated cylinders, scales, timers, etc.)
If groups are struggling to develop a way to test this, point out some of the available materials and ask if there is a way they could use that object. How could you use a scale to find this information? How could you use a timer? Possible ways this test could be run:

1. Students put a set amount of sand or rock in the funnel. Place a beaker below the funnel and time how long it takes for a given amount of water to filter through the material.
2. Instead of timing how long it takes a set amount of liquid to permeate, measure how much water filtered through in a given amount of time.
3. Each group finds the dry mass of rocks of several types. Students will submerge the rocks in the water for a set time. Then they will remove the rocks, sponge off excess water, and record the rock's final weight. Students can then calculate how much water was absorbed by the rock. Students can also color the water with food coloring. After soaking up the water, they will break open the rocks and measure the distance the water has penetrated the rock.

Help the students refine their experiment as they are designing it. You may want to do this by having them check off their proposal with you before running their tests. For example, “You have decided to use sand. Have you considered how much sand you will need? Will you use the same amount of material for each test?”

After the experiments are complete, discuss the results as a class. How did grain size affect how well the liquid traveled through the different materials? Ask the students how this might help to explain the phenomenon.

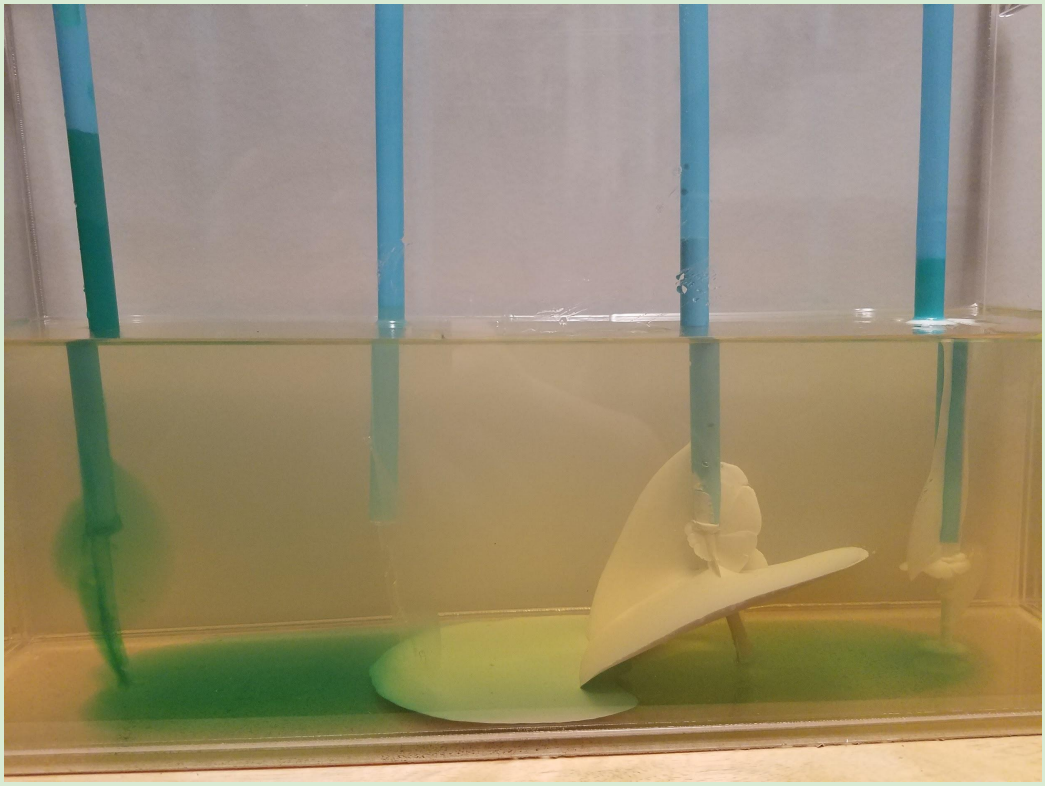
3. **Increasing Permeability of Rocks**
Show the students this cross-section of the rocks found beneath the Uinta Basin in eastern Utah. Explain that the Green River formation is an oil-bearing formation composed of shale and mudstones that are very fine-grained. Discuss how this might affect our ability to extract oil from the rock. A conventional vertical well can only retrieve about half of the available oil. What can we do to get more oil out of the rock layer without increasing our footprint on the surface? Explain that a process called rock fracturing or Fracking has been used in recent years. Provide the students with articles or videos about the fracking process, or allow the students to use the internet to research to answer the questions on their student sheet. What is fracking? When is it used? What are the parts of a fracking well? Discuss their results as a class.

Fracking experiment: The students will design and conduct an experiment to explore the properties of fluids used for fracking.

A. Prepare containers of gelatin the night before the experiment. One tablespoon of gelatin to one cup of water works well (using Knox unflavored gelatin). You may use empty clear water bottles for this.
B. Each student group will select a liquid to use as a fracking fluid. You may provide some they can choose from or have them bring other fluids they want to try.
C. Before experimenting, each student will predict how they think their fluid will affect the gelatin when injected under pressure.

D. “Drill the well” by inserting a straw into the gelatin. Place your thumb over the straw and carefully remove the straw and the plug of gelatin inside the straw. Reinsert the straw into the hole in the gelatin.
E. If your tubing does not have holes, punch a few holes along the last 1 to 1 ½ inches of the tubing using a small nail.
F. Attach the tubing to the syringe and fill the syringe with 25-50 ml of your chosen fracking fluid.
G. Insert the tubing through the straw in the gelatin and continue until it has pushed a few centimeters into the gelatin below the bottom of the straw.
H. Carefully inject the fluid through the tubing and into the gelatin.
I. Turn the container to look at the fractures made from all angles. Draw the results on the student sheet.
J. Students will compare their results with the results of other groups.

As the class discusses which fluids they think worked best. Why were these fluids best? What are the good properties of a fracking fluid? (Sandy textures help hold the fractures open, the oil helps the material flow through the rock easier, etc.) The image below shows some results of this test. Left to right; water with food coloring, canola oil, plaster, toothpaste.



4. The students will now obtain information on the possible effects of fracking on Utah's social, environmental, and economic factors. They will develop a research question about this topic, use the internet to obtain information, and propose a possible solution to the effects.

5. Returning to the Phenomenon. Hold a class discussion about the phenomenon. Include why it is impossible to extract all of the oil from the rock using conventional oil drilling methods and what we can do to solve that problem. Answer any other questions the students still have. They will record their explanation on their student sheet.

6. Ask students to write a research question about the effects fracking can have on Utah's social, environmental, or economic systems. Ask them to use the internet to obtain information to answer this question. They should propose a solution that will mitigate the effects of any problems with fracking found in the research.

Assessment of Student Learning.
Title: Hands-On Permeation - Assessment
1. Students will create a poster, video, or brochure about fracking. The project should include what fracking is, its purpose, possible impacts/effects on Utah's society, environment, or economy, and a proposal to mitigate any adverse effects of fracking.

Standardized Test Preparation:

Hands-On Permeation

1. How does rock porosity affect the natural storage of oil and gas underground?
    a. Porous rock allows oil and gas to move slowly through it.
    b. Porous rock stores oil and gas in spaces between rock particles.*
    c. Porous rock becomes a gas or liquid when they are present.
    d. Porous rock is denser than oil or gas and sinks when they are present.

2. How does rock permeability affect the natural storage of oil and gas underground?
    a. Permeable rock allows oil and gas to move slowly through it.*
    b. Permeable rock stores oil and gas in spaces between rock particles.
    c. Permeable rock becomes part of the gas or oil when they are present.
    d. Permeable rock is less dense than oil or gas and rises when they are present.

3. How does "fracking" affect the permeability of rock?
    a. It shakes the earth to create cracks in the rock.
    b. It pumps the oil or gas out and fills the hole with other fluids.
    c. It adds oil or gas to the well, which attracts those fluids to rise.
    d. It adds liquids under pressure to crack the oil-bearing rock.*

4. How has fracking impacted the oil and gas industry?
    a. It has made oil and gas less valuable.
    b. It has created a less controversial way to recover oil.
    c. It has created more oil and gas in the ground to recover.
    d. It has allowed the recovery of oil and gas that was previously too difficult.*

Extension of lesson and Career Connections:
Have students investigate careers in the oil industry. Select one, explain what this person does, the average salary for the profession, the training required, etc. O*NET OnLine (onetonline.org)

Hands-On Permeation

Name_____

Phenomenon: Trapped!

After experiencing the phenomenon, record three observations about what occurred.	
Draw or explain what you think is causing this phenomenon.	
Ask three questions about what is causing the phenomenon.	

Permeation Experiment

Research Question	How does grain size affect how quickly a liquid can move through rock?
Hypothesis	
Independent Variable	
Dependent Variable	
Control Test	
Supplies	
Procedures	

Data	
Analysis Summarize the results of your experiment. Use graphs or drawings to illustrate your analysis.	
Conclusion Write a statement that explains why liquids move through some rock types faster than others. Use data from your experiment to support your statement.	

Exploring the phenomenon

How do the results of your experiment help explain what was happening in the phenomenon?
What questions do we still need to answer?

Increasing permeability of rock - Fracking

Use the resources you have been provided to obtain information about the fracking process.

What is fracking?	
How is fracking different from conventional oil drilling?	
Describe why the fracking process is used.	

In the space below, describe what steps are involved in drilling a well and fracturing the rock to release more oil and gas.	In the space below, draw a fracking well. Include the following parts: drill hole, steel casing, concrete sleeve, oil-bearing rock layer. Label each part and include a description of the function of each part.

Fracking Experiment

Research Question	What properties of fluids are useful for fracking?	
Fluid used:		
Explain what properties this fluid has that will make it useful for fracking.		
Prediction: Draw what you think will happen when you inject the fluid into the rock (gelatin).	Front view	Side view
Draw what happened.	Front View	Side View

What part of a fracking well does the straw represent?	
What part of the well does the tubing represent?	
Compare your results with the results obtained by groups who used a different fluid.	

Fracking: Mitigating the Effects

Research Question: Write a research question about the effects fracking can have on social, environmental, or economic factors in Utah.	
Obtain information: Use the internet to obtain information to answer this question. Record what you find here.	
Propose a solution Use the internet to help you propose a solution that will mitigate the effects of any problems with fracking that you found in your research.	

Explaining the Phenomenon: Trapped!

Using what you have learned, explain the phenomenon. Include the answers to the questions you asked at the beginning of this unit.