Lesson Nine: Good to the Last Drop

Grade Level: 4th Grade

Time: Two 60-minute class periods

Essential Question: How can we be stewards of Wyoming's minerals and energy to benefit current and future generations?

Objective: Students will complete the engineering design process (refining a model for extracting oil from a rock formation) to understand the potential for technology to improve our ability to steward Wyoming's resources.

Purpose: Students learn that scientists and engineers go through a design process to improve upon existing technology or create new innovative solutions to problems that can improve our ability to steward Wyoming's resources.

Required Materials/Resources:

- Video: https://www.youtube.com/watch?v=kxBqKY36h7M *The Phases of Oil Recovery – So Far* (Source 4) Video Length: 2 minutes 40 seconds
- Video: https://www.youtube.com/watch?v=fiWsM8TPzI0 *The Environmental Partnership: Who We Are* (Source 1) *Video Length: 2 minutes 12 seconds*
- Oil Production text (one per student) (Sources 2, 3)
- Oil Recovery Design Challenge student worksheet (one per student)
- Supplies for Oil Recovery Model
    - Instruction sheet or video: https://youtu.be/V337sOZLt_4 *How to: Build an Oil Recovery Model* (Source 5) Video Length: 2 minutes 28 seconds

TEACHER NOTE: Instructions have been included to build your own oil reservoirs. If you would like to have one provided, please contact Wyoming Agriculture in the Classroom, and we will provide pre-built oil reservoir models for your classroom.

- Small disposable plastic containers (1-2 cup) with tight-fitting lid
- Plastic water bottles for injection reservoir and oil collection (one for the "extracted" oil, and one for water. Additional bottles may be needed for alternate design methods)
- Rocks or gravel (gravel that has been sifted or had the sand removed would work best)
- Vegetable Oil
- ¼ inch plastic tubing (two 30 cm pieces)
- Material to make a watertight seal (ex: Goop, silicone caulk, hot glue)
- Food coloring for the inlet water *optional
- Bucket or container for disposal of liquids
- Seal-able container for disposal of oil
- Metric measuring cup or graduated cylinder for liquids
- Water
- Additional materials and liquids of your choice use for design challenge (See steps 7-10)

TEACHER NOTE: The purpose of the lesson is for students to use the design process to improve an existing technology. Because of that and a desire to not have students spending their time trying to create a functional model, the teacher is providing them with a basic design structure from which to start.

Suggested Teacher Preparation:

- Preview video resources
- Before the lesson, make an oil recovery model following the attached instruction sheet or by watching: https://youtu.be/V337sOZLt_4
- Review the Oil Recovery Design Challenge Student worksheets in order to model/explain them for your students.
- Think about which supplies you can have available for your students to use in their design challenge.
- Gather appropriate supplies.

Standards:

Science: 4-PS3-4, 3-5-ETS1-1,3-5-ETS1-3 (Explicit)
3-5-ETS1-2 (Practiced/Encountered)

Social Studies: SS5.1.1, SS5.3.3,
SS5.4.2 (Practiced/Encountered)

CVE: CV5.3.1, CV5.3.2 (Explicit)
CV5.2.3 (Practiced/Encountered)

Vocabulary:

- **Constraint** - a limitation or restriction
- **Engineer** - a person who designs, builds, or maintains engines, machines, or public works
- **Extraction -** the action of taking out something, especially using effort or force
- **Oil field -** an area of land or seabed underlain by strata yielding petroleum, especially in amounts that justify commercial exploitation
- **Oil industry** - the global processes of exploration, extraction, refining, transporting (often by oil tankers and pipelines) and marketing of the products
- **Reservoir -** a natural or artificial place where water (or oil) is collected and stored for use
- **Residual oil -** oil found in low concentrations naturally or in oil fields following primary production

Instructional Procedure/Steps:

Part One:

1. Say**: "In past lessons, we talked about being a good steward of Wyoming mineral and energy resources. We have also learned about oil, an energy used throughout the world, and how it is found, extracted, transported, and refined within the state of Wyoming. Imagine what it means to Wyoming for the oil industry to be a good steward. Today, we are going to learn more about how the oil industry extracts this valuable resource from the ground, and one way they are good stewards, by using multiple techniques to recover as much oil as possible from a well."**

2. Play the video: *The Phases of Oil Recovery – So Far*. (Source 4)

3. Discuss with students how oil companies have used the engineering process. Why might it be a good idea for companies to try and continue using an older well instead of just digging new ones?
    - Possible answers could include: maximizing the production of the well, minimizing the number of wells needed as each well has an impact on the surface, more cost efficient.

TEACHER NOTE: Students may not independently come up with the idea of using CO_2. If they do not, the teacher might prompt their thinking by asking them to think back to the video about extraction and the tertiary method that was described.

Students may also need scaffolding to help think about how they might be able to put CO_2 into the system. The teacher can draw on their background knowledge of carbonated beverages. Some students may also be familiar with the bubbles produced from reactions such as effervescent tablets dissolving or Mentos and soda.

4. Pass out and read the Oil Production text. Say: **"Remember every energy resource has its benefits and its challenges. Discuss with a partner the challenges that the oil industry faces."** Have students identify the challenges with a partner. After a few minutes, have students share out. Say: **"When we get to the planning process, we will factor in these challenges to improve your oil extraction design."**

5. Show students the oil recovery model you created before the lesson. Fill the reservoir with just enough oil to cover the rocks. (Mark on the outside of the container the level of the oil so that it can be "reset" for future experiments.) Explain how this represents the oil trapped in a rock formation in the ground. Remind students that the layers of rock and soil covering the oil reservoir places the oil under pressure. To simulate the pressure oil is under in real life, our oil recovery model must be a sealed system to keep the oil under pressure. Discuss with students how the scaled model relates to a full-scale oil field.

6. Ask students to recall what they learned in the video about oil extraction. Tell them that this represents a well that has already gone through pumping/primary recovery. Say: "**There is still oil in the rock formation. What might be the next method of extraction?"** Students should bring up the secondary recovery method of water flooding. Demonstrate for the class the water flooding process. Pass out the Oil Recovery Design Challenge worksheets and have students complete the first portion with a brief description of the water flooding process. Measure the oil that was extracted, and have students record the amount, along with other observations of the results. (They should be able to note that there is still oil visible in the rock formation.)

Students should understand that the oil being extracted now is actually "leftover" or residual oil after the primary and secondary extraction processes. The analogy of a spatula and a cake mix might help students understand that the additional residue can be removed using another tool or process.

7. Say: **"Now we are going to be think about some additional oil recovery methods to help us complete an engineering design challenge. The purpose of this engineering challenge will be to recover as much oil as possible from our model, so our success criteria will be that we are able to recover more oil. Like the engineers in the oil industry, we will have a specific goal, but we will also have constraints."** If students are unfamiliar with the word "constraints" go over the definition together. Read the list of constraints and discuss why each one is in place.

8. Give students a few minutes to brainstorm ways that they might use the oil recovery model to extract more oil from the well. After they have had some time to work say: **"Let's see what kinds of ideas you generated."** As students share out ideas, record them on a document camera, chart paper, or smart board so they are visible to everyone. Student responses might include trying a different liquid, a larger amount of water, soapy water, carbonated water or soda, hot water, etc.

9. Say: "**Once engineers have generated some ideas, their next step is to compare multiple possible solutions and think about how well each is likely to meet the criteria and constraints of the problem. Let's look at our list. Are there any ideas that don't meet the constraints of the problem?**" Guide students in eliminating from the list any ideas that would require a whole new "well" to be built, that would require materials that are cost/time prohibitive or that you as the teacher are not able to acquire before part 2 of this lesson. Say: "**Now let's think about which possible solutions might be most likely to meet our success criteria, which is extracting as much of the oil as possible.**"

10. As a class, select 2 "enhanced methods" to try. Tell students that they will be running experiments with these methods in part 2.

TEACHER NOTE: Depending on which ideas students generate and select to test, the "control" method of water flooding may still need to be done. Some extraction process ideas might be done in place of the initial water flooding method (ex: flooding with hot water), and some might be done after the water flooding (ex: CO_2).

Part Two:
Be sure to gather any additional materials necessary based upon student ideas selected at the end of part 1. You will also need to "reset" the oil recovery model. As much as possible, reuse the same oil and water from the original setup. Since students will not each have their own systems to test, the teacher can encourage engagement by having a different student help with each part of the processes (measuring liquids, holding the bottles, etc.).

1. Say: **"Yesterday, we tested our oil recovery models. We noticed that there was still oil left to be extracted, so we came up with some additional ideas. We decided that today we would test** _____ (name ideas selected in part 1). **"**

2. Decide which method will be tested first, and have students record that on their Oil Recovery Design Challenge worksheets. Say "**In order for us to determine whether or not the ideas we are testing today are really more effective, we need to make sure that the only thing that is changing is the specific method of oil recovery that we are testing. Everything else should be the same. Yesterday I marked the oil level, and I've 'reset' the well to have the same starting amount. Can you think of anything else that needs to stay the same?**" The aspect of the system students are changing for this experiment will change, but all other variables should stay the same, including the rocks used, size of containers, tubing (length and type), amount of liquid used, etc.

3. Conduct a trial with the oil recovery method. Students should record a brief description, results, and other observations on their Oil Recovery Design Challenge worksheets. After completing the trial, discuss whether or not the method was effective. Be sure that students are drawing upon evidence when determining whether or not the model was successful.

In this task, students will be engaged in the higher order thinking skill of application by designing, testing, and experimenting through the use of problem-solving techniques.

TEACHER NOTE: If students pick a method that would "contaminate" the model (ex- soapy water), that should be the last method tested, as it would be very difficult to reset the model after using a contaminant. That may be a discussion opportunity about the precautions taken when putting chemicals into the ground.

4. Repeat the process to conduct a trial with an additional oil recovery method. Again, point out that the well will need to be" reset" so that it is a fair test. Students should again record a brief description, results, and other observations on their worksheets. After completing the trial, use the results to discuss whether or not the method was effective.

TEACHER NOTE: When disposing of the liquids from the lesson, be sure to dispose of the oil properly. It can be poured back into its original bottle or into another sealed container like a milk jug. Make sure it is sealed before disposing of the container.

5. If using CO_2 was not one of the methods selected by the class, at this point the teacher should decide if that model should be done as an additional trial. It is an engaging demonstration, and it is a process that resembles actual enhanced oil recovery methods. Some teachers may opt not to do it, as it is developmentally more complex, and students may not have schema for CO_2, pressurized systems, etc. Additionally, the focus of the lesson is not on that method per say, but on the engineering design process and the idea that engineers have used the process to help the oil industry be better stewards by enhancing their oil recovery methods. Students can meet that goal without conducting a trial using CO_2.

6.  Students can now compare which of the methods was most successful. As they discuss the different methods, be sure that they are evaluating them based on the success criteria and constraints. If any of the methods didn't work, students can discuss why they think that method might have been unsuccessful, and if there are changes they could make that would improve the method.

 In this task, students will be engaged in the higher order thinking skill of evaluation.

7. Discuss the activity. Allow students to respond before moving to the next question. Ask:

- **"What were our results?"**
- **"What did you find engaging?"**
- **"What challenges did we experience?"**
- **"What were some of our successes?"**
- **"If you had more time and/or unlimited resources, what might you like to try?"**

8. Say: **"Energy and fuels are derived from renewable and nonrenewable resources and their uses affect the environment. Oil industries have a responsibility to be good stewards of our land and natural resources. They play an important role in stewardship decisions affecting Wyoming's land. The awareness of being good stewards is evident. Let's watch this quick video about The Environmental Partnership."**
https://www.youtube.com/watch?v=fiWsM8TPzI0

9. Say: "**As you saw in the video, the U.S. Natural Gas and Oil Industries look for ways to improve production processes just like you did in the oil extraction activity**." Discuss how scientists/industry experts might have different/additional approaches when trying to improve our use and production of energy. Possible discussion points are:
    - *innovating existing devices*
    - *developing new ideas for how to use energy sources*
    - *developing ways to minimize the negative impacts of some energy resources*
    - *finding new sources of energy, etc.*

10. Say: "**After completing the experiments and watching the video, what are some ways the oil and gas industries are being good stewards?"** Students may recognize the older wells are being enhanced rather than abandoned (the life of the older wells is extended), the drilling sites and paths of pipelines have been reclaimed putting the landscape back to its previous state, safety procedures are in place to protect the environment, and preventative measures are taken with the pipelines, storage tanks and refineries to protect areas from damage.

11. Say **"Remember, you are our future, and just like scientists in the oil field, you are empowered to solve problems, and create positive change in our world!"**

Assessment: Use the completed student worksheets and discussions at the end of part 2 of the lesson to assess student understanding that scientists use the engineering process to improve upon existing designs or create new solutions to existing problems.

Credits/Sources:

1. The American Petroleum Institute. (2019, March 26). *The Environmental Partnership: Who We Are*. Retrieved June 11, 2020 from https://www.youtube.com/watch?v=fiWsM8TPzI0
2. U.S. Department of Energy (2013, April) Fossil Energy Study Guide: Oil. Retrieved June 6, 2019 from https://www.energy.gov/sites/prod/files/2013/04/f0/HS_Oil_Studyguide_draft2.pdf
3. U.S. Department of Energy (n.d.) *Enhanced Oil Recovery.* Retrieved June 6, 2019 from https://www.energy.gov/fe/science-innovation/oil-gas-research/enhanced-oil-recovery
4. Energy & Environmental Research Center. (2014, April 3). *The Phases of Oil Recovery – So Far*. Retrieved June 4, 2019 from https://www.youtube.com/watch?v=kxBqKY36h7M
5. Wyoming Agriculture in the Classroom. (2019, June 6). *How to: Build an Oil Recovery Model*. Retrieved June 6, 2019 from https://youtu.be/V337sOZLt_4