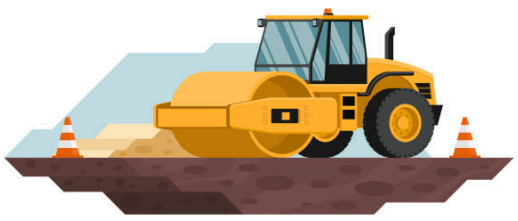
Overview

Name _____ Period _____

Soil Compaction and Vehicle Mobility Lab

Background:

The ground beneath our vehicles is more than just dirt; its soil, a complex and dynamic system vital for life, water filtration, and supporting our infrastructure. However, the very act of driving and building can profoundly change soil's natural properties. When heavy vehicles and constant traffic press down, they cause **soil compaction**, squeezing out vital air and water spaces. Understanding how human actions, particularly those involving vehicles, impact soil is crucial for designing better ways to move across the land and build sustainably.



Purpose:

In this lab, you will investigate the essential properties of soil and explore how human activities, particularly those involving vehicles, lead to soil compaction. Through hands-on experiments, calculations, and an engineering design challenge, you will discover how changes in soil density and porosity affect vehicle mobility and learn to apply scientific principles to design solutions for navigating diverse terrains.

Problem:

How does soil compaction, resulting from human activities and vehicle pressure, impact the ground's properties (like density and porosity), and how can we design a vehicle to effectively traverse both loose and compacted "soil" conditions?

5E Unit Plan:

Day 1: Engage: Soil Coring Activity
Day 2: Explore: Quantifying Soil Properties
Day 3: Explain: The Mechanics of Soil Compaction
Day 4: Elaborate: Human Impact and Engineering Solutions
Day 5: Evaluate: Engineering Design Challenge - The Terrain Traverser

Learning Objectives:

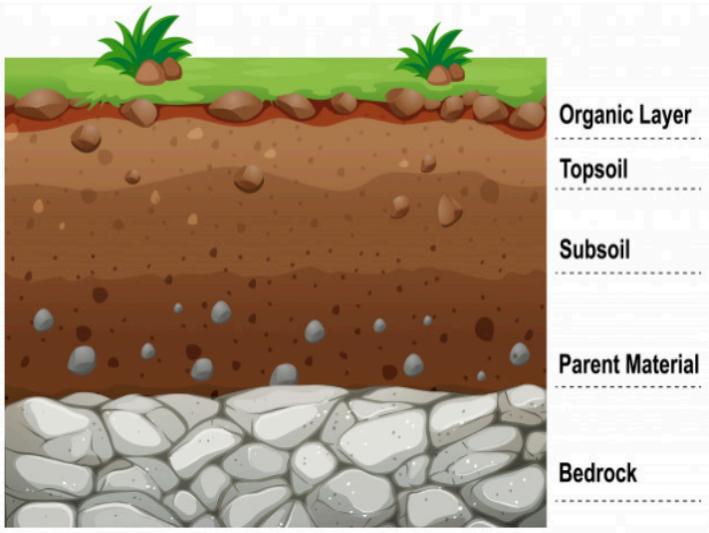
- I will define soil compaction in terms of bulk density, porosity, and permeability.
- I will analyze how human activities contribute to soil compaction and its environmental consequences.
- I will apply mathematical concepts to calculate soil properties and vehicle pressure.
- I will design, build, and iteratively refine a vehicle to optimize its mobility across various "soil" conditions, evaluating solutions based on criteria and constraints.
- I will construct explanations based on evidence regarding the relationship between soil properties and vehicle performance.

Day 1: Engage

Name _____ period _____

Day 1: Engage: Soil Coring Activity

Background:
The earth is made up of several different layers and soil types and when scientists and engineers are trying to determine the makeup of the soil and analyze the area they are interested in they will do a process called soil coring which provides a detailed, visual record of subsurface conditions, allowing scientists and engineers to analyze the composition, properties, and changes in soil over time. This information is essential for making informed decisions related to agriculture, environmental management, and construction projects.



[1] Layers of soil, from the living organic matter on top to the bedrock on the bottom.

Purpose:
In this lab, you will investigate the essential properties of soil and how geologists and engineers use soil coring to find the makeup of the area they are trying to build on.

Problem:
How to core soil for samples to determine what the soil makeup of a certain area might be so the possibilities of the area to be used for road, building or agriculture may be determined.

Learning Objectives:

- I will be able to compare the internal structures of different candy bars based on their core samples.
- I will be able to describe the process of taking core samples, mimicking how geologists/engineers complete this task to sample areas they are interested in using in the future.
- I will be able to observe and describe the layers and components of different candy bars.

Day 1: Engage: Soil Coring

Learning Goals:

- I will be able to use the process of "drilling" into candy bars and characterizing the "sample," which will mirror how geologists/engineers take core samples of the Earth.
- I will learn what core samples are and how scientists use them to study the Earth's layers.



Dilema:

You are going to be given samples of the earth and you will have to take core samples of the samples and identify what the makeup of the samples is and what part of the ground did those samples come from.

Lab activity:

1. Cut your straw into 3 pieces.

2. Place your thumb over the straw and “drill into one of the candy bars in front of you.

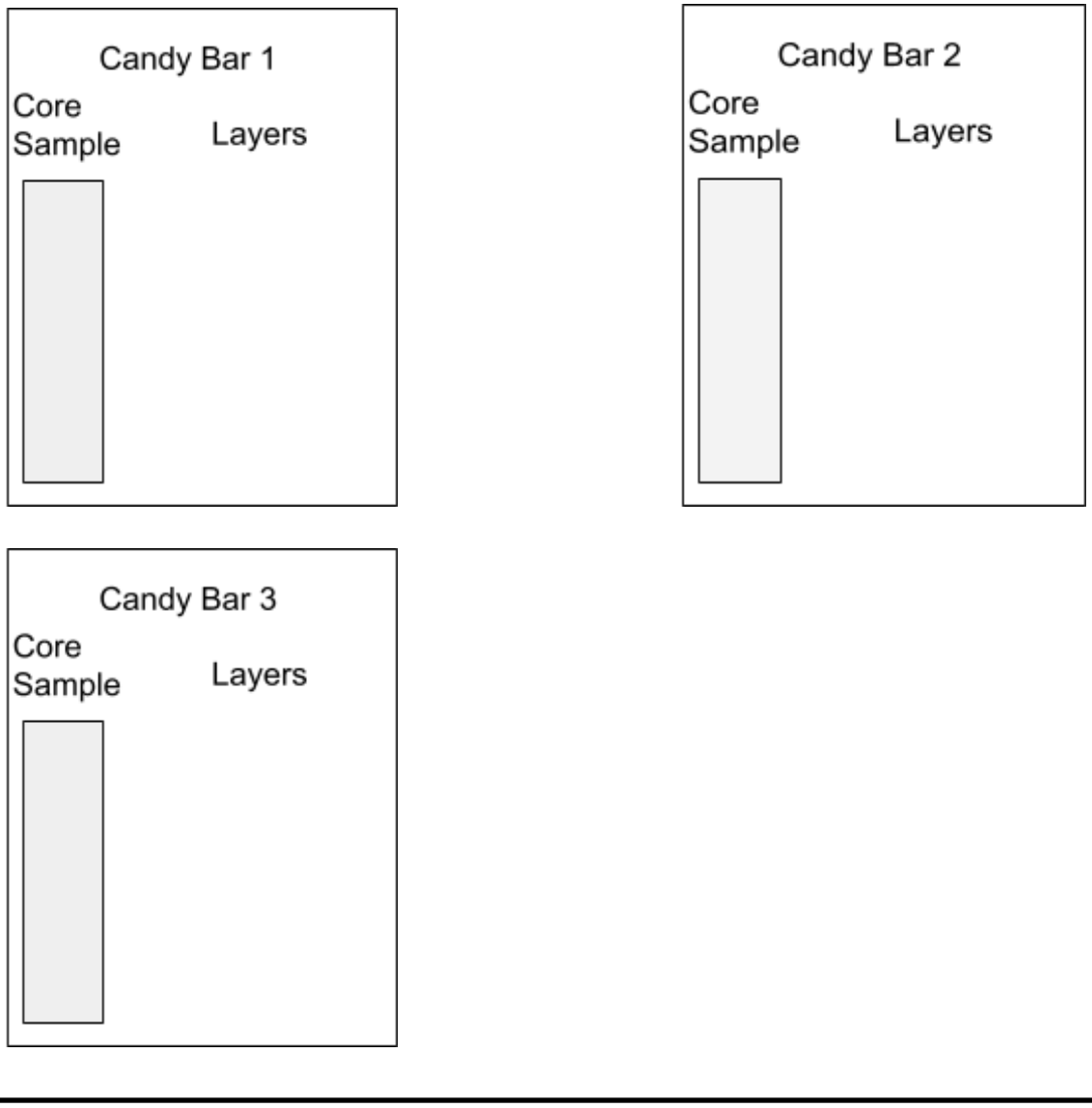
3. Draw and color what the layers of your core look like. What are the soil layers that would be represented by the core sample you took?

4. Repeat this process for the other 2 candy bars you have on your plate.

5. Fill in the chart below as you finish your coring of each candy bar.

Day 1: Engage: Soil Coring

Candy Bar Design Coring Observations:



Day 1: Engage: Soil Coring

Observations of the coring activity:

1. Lay your candy core samples side by side keeping track of which one is which. Observe the samples.

How are your samples similar? _____

_____

How are they different? _____

_____

2. Are individual layers visible in your sample? _____

_____

3. Are you able to identify what type each candy bar is? What bar do you have?

_____

_____

4. Are some of the bars easier to identify than others? _____

_____

What makes the bars easier or more difficult to identify?

_____

_____

5. What layer would each of the candy bar layers represent in a real soil sample? _____

_____

6. How was this activity similar to what a scientist would do to take a core sample? _____

_____

Career Links

Geoscientist - studies the physical aspects of the Earth's composition, including the atmosphere, water, soil, and the Earth's crust.

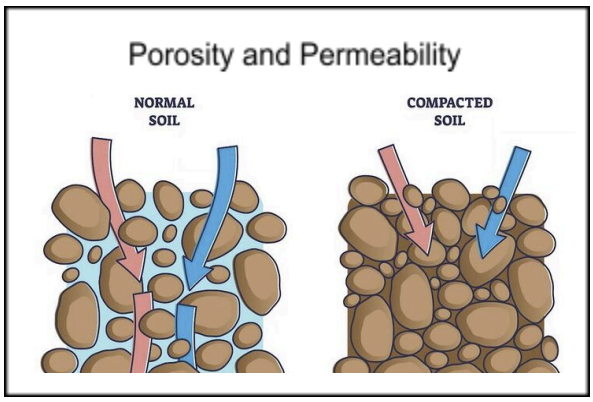
Soil Scientist - The field of soil science is the study, analysis, and recommendation of soils for appropriate land use.

Day 2: Explore

Day 2: Quantifying Soil Properties

Background:

Porosity is all about the tiny holes or spaces found in materials like soil. In dirt, these spaces tell us a lot about what kind of soil it is, what it's made of, and how big its pieces are. While porosity is how much liquid a material can hold, permeability is about how easily liquids can move through it. Together, porosity and permeability help us understand how well water drains through soil, rocks, and other surfaces.



Purpose:

Today, we're going to investigate the hidden properties of soil and how human actions can profoundly change them, impacting everything from water cycles to our ability to move across the land.

Problem:

Look around our environment and think about construction sites, dirt roads and ORV (off road vehicles) routes, or even frequently walked paths.

What do you observe about the ground in these areas compared to an undisturbed forest floor or garden bed? Consider how water drains, or how plants grow.

Learning Objectives:

- I will be able to use the term quantify, describe the procedures scientist use to quantify the properties of soil and conduct test on soil samples
- I will be able to measure soil density and porosity
- I will be able to predict the porosity of soil samples

The word "quantifying" is made up of three parts:

	What other words have these “parts" in them?	What do you predict the parts of this word mean?
quant		
i		
fy		

Day 2: Quantifying Soil Properties

Prediction: What does Quantify mean?

Observations- Quantifying soil:

What are the visible components of your soil sample? e.g., mineral particles, living matter, pore spaces	Draw some of the components below
Describe the texture and color. How do these properties relate to the soil's composition?	Use colored pencils to create the colors and textures you see in the soil below.
Predict: Which soil sample might have the largest proportion of empty spaces (pores)?	Why do you think that?
Consider the phrase 'ecosystem services'. How does healthy soil provide benefits to living things and the environment?	

Day 2: Quantifying Soil Properties

Science meets Math - Measuring Soil Density and Porosity

Mass of dry soil:

- Measure and record the mass of an empty graduated cylinder. _____
    - Add a measured volume (e.g., 100 cm3) of dry soil to the cylinder.
    - Gently tap to settle, but do not compact heavily.
- Measure and record the mass of the cylinder with soil. _____

Record your observations, what happened to your soil as you tapped on the cylinder.

Calculate the mass of the dry soil. Show your work.

Bulk Density Calculation:

$$Bulk\ Density(g/cm3) = \frac{Mass\ of\ Dry\ Soil(g)}{Volume\ of\ Soil(cm3)}$$

Calculate the bulk density of your soil sample. Show your work.

Day 2: Quantifying Soil Properties

Water Absorption (Porosity Estimation):

- Slowly add a measured volume of water (mL) to the 100 cm3 soil sample until the soil surface is saturated (water no longer readily drains).
- Record the volume of water absorbed. _____

Sketch what it looked like when you completed this step:

Putting it all together:

If a soil sample has a total volume of 100 cm3 and absorbed 45 mL of water, what is the *approximate* porosity of this soil sample as a percentage? (Assume 1 mL=1 cm3).

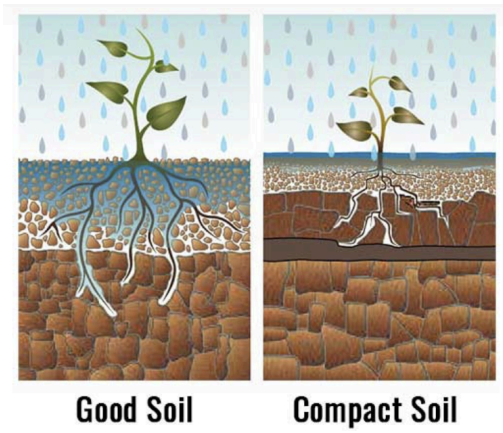
What does a higher porosity value tell you about the soil's structure?

Day 3: Explain

Day 3: Explore: The Mechanics of Soil Compaction

Background:

We've seen that soil has vital pore spaces that allow for water, air, and root growth. Now, we're going to investigate what happens when these spaces are physically removed. This process is called soil compaction. Soil compaction happens when dirt gets squished, making it harder and denser. This squeezes out the tiny spaces where air and water usually are. When soil is compacted, it's tough for plant roots to grow and for water to soak in, which isn't good for plants or the critters living in the soil.



Purpose:

Today, we're going to investigate soil compaction impact on our ability to move across the land. Soil compaction can be a significant environmental issue. As you complete your activities today, keep a mental list of how it could impact plants and animals.

Problem:

Now, instead of construction sites, think only of the different roads you have driven across on your bike, scooter or when riding in a car. Brainstorm the difference in a vehicles ability to move over dirt roads on a ORV (off road vehicles) routes, versus riding your bike after a rain storm, across a freshly watered field of grass and the difference when riding on a bike path.

What is different about the ground in these areas compared to an undisturbed forest floor or garden bed? Consider how vehicles may be designed to make their way on these different types of roads.

Learning Objectives:

- I will be able to model and measure soil compaction
- I will be able to test the effects of a compacted road vs an uncompacted road on a vehicle
- I will measure and calculate- volume, density and compaction

Day 3: Explore: The Mechanics of Soil Compaction

Prediction: How does compaction affect a vehicle's ability to move across a surface?

Modeling Compaction with Cloud Dough	**A model for soil**
1. In a large mixing bowl, have pairs combine 1 cup all-purpose flour and ¼ cup baby oil. 2. Mix until it forms a moldable, crumbly consistency.	This dough serves as an *analogy* or *model* for soil particles and their arrangement, allowing us to manipulate and observe compaction more easily.
Describe the texture and color. How do these properties relate to a soil's composition?	**In what ways could this model be inaccurate?**
Does this soil sample have a large or small proportion of empty spaces (pores)?	**Why do you think that?**

Cloud Dough Initial testing (as a model for soil)

1. Take one handful of cloud dough, spread it over the bottom of the container.
2. Use a hot wheel to drive the car through the sample.

Sketch and record in words your observations about how the cloud dough soil and car move.

Day 3: Explore: The Mechanics of Soil Compaction

3. Compact cloud dough to form a solid layer on the bottom, now drive the car over it.
Record your observations about how the cloud dough soil and car move.

4. Now, add another fluffy, loose layer over the solid layer, test your car
Record the data.

5. Compact the layer again, and test again.
Record the data.

Day 3: Explore: The Mechanics of Soil Compaction

5. Your container should now be half way filled, add another handful of dough, but this time, just compact it.

6. Add the remaining dough to the container and compact it a final time, now test the car and **record your observation.**

What changed about the dough as you added each new layer?

Why do you think it changed and became more “road like” at the end?

7. Return your dough to the bowl and loosen, fluff it back up. Then return the bowl to your teacher.

Science meets Math - Compaction Calculations

Initial Volume & Density: Take a section of loose cloud dough.

- Mold it into a precise rectangular prism (10 cm×5 cm×4 cm).
- Measure its mass.

Day 3: Explore: The Mechanics of Soil Compaction

Compaction: Using a flat block or another rectangular container, apply significant pressure to compact the dough.

- Measure the new dimensions (length, width, height) of the compacted dough.

- Remeasure its mass (should be the same).

You started with a cloud dough sample that measured 10 cm long, 5 cm wide, and 4 cm high. *Calculate its initial volume in cm3.*

If the mass of the dough was _____grams, calculate its initial bulk density (mass/volume) in g/cm3.

After compaction, the dough now measures _____ cm long, _____ cm wide, and____ cm high. *Calculate its final (compacted) volume in cm3.*

Calculate its final (compacted) bulk density in g/cm3

Calculate the percentage decrease in volume due to compaction.

Discussion Questions:

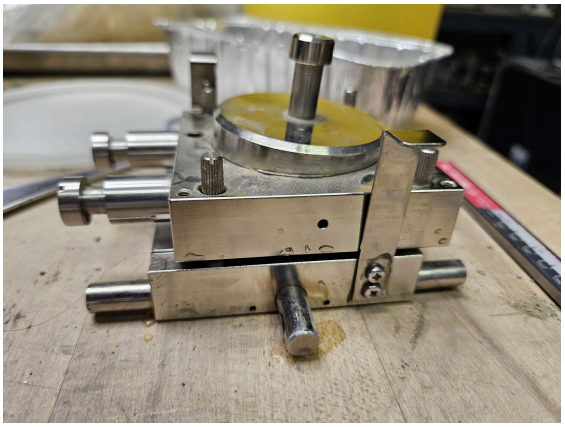
- What does this tell you about the reduction of pore spaces?
- What is the percentage increase in bulk density due to compaction?
- How does this relate to the concept of soil health?

Day 3: Explore: The Mechanics of Soil Compaction

Extension: Background:

The Direct Shear Test is like a special "strength test" for soil. Engineers take a sample of soil and then push on it in a specific way, trying to make one part of the soil slide past another. By doing this, they can figure out how much pushing force the soil can handle before it starts to break or move.

Direct Shear device after test is complete.



Purpose:

This "shear strength" is super important because it helps engineers design roads and buildings that will stay stable and strong, even when lots of weight and pressure are put on the ground.

Problem:

What is happening when the soil compresses - Imagine you're trying to build a road on top of dirt. You need to know if the dirt is strong enough to hold the road and all the cars and trucks that will drive on it without it pushing apart or crumbling.

Learning Objectives:

- I will be able to model and measure the direct shear of a soil sample using a simulation

1. Go to the Direct Shear Test Simulation site
2. Follow the directions at the top of the screen to set up and run the test
3. Based on your observations and calculations, what physically happened to the 'pores' in the cloud dough when it was compacted?
4. Relate this back to real soil. What human activities cause soil compaction?
5. What are the direct consequences of soil compaction for water infiltration, root growth, and soil organisms?

Day 4: Elaborate

Day 4: Elaborate: Human Impact and Engineering Solutions

Learning Goals:

- I will design, build, and iteratively refine a vehicle to optimize its mobility across various "soil" conditions, evaluating solutions based on criteria and constraints.
- I will construct explanations based on evidence regarding the relationship between soil properties and vehicle performance.

Dilema:

You are going to be taking a road trip and need to design a vehicle to use that will effectively transverse all roadways you encounter.

Sketch:	Design:
	Design a vehicle for your road trip and sketch it to the left. Next, drive your vehicle online, then answer the following questions.

Design Questions:

1. What was your vehicles top speed: _____mph
2. What was the distance your vehicle travels: _____ miles.
3. Which “soils” from the lab would your vehicle be best suited to travel?
   _____
4. Could you change your vehicle to transverse all lab soil types?
   _____
5. Now consider the real-world. Do you think there is one tire that could drive all road types? Consider vehicle performance on loose, high-porosity soil versus dense, compacted soil. Explain. _____
   _____
   _____
6. Why do some vehicles have specialized tires (e.g., wide, low-pressure tires; tracks)?
   _____
   _____

Day 4: Elaborate: Human Impact and Engineering Solutions

Science meets Math:

Engineers designing vehicles for varying terrains must consider the pressure a vehicle exerts on the ground. Pressure is calculated as Force/Area. The force exerted by a vehicle is its weight.

Vehicle A (e.g., a truck) has a mass of 5000 kg and its tires have a total contact area with the ground of 2 m2.

Vehicle B (e.g., a tracked bulldozer) has a mass of 10000 kg but its tracks have a total contact area of 10 m2.

1. Assuming the force of gravity is approximately 9.8 N/kg, calculate the weight (force) each vehicle exerts on the ground in Newtons ($F=m \times g$).
   _____
   _____
   _____

2. Calculate the pressure (in Pascals, or N/m2) each vehicle exerts on the ground.
   _____
   _____
   _____

3. Based on your calculations, which vehicle would likely cause more compaction on soft soil? Explain why using the concept of pressure.
   _____
   _____
   _____

4. How does this relate to the engineering challenge of designing vehicles for different soil conditions?
   _____
   _____
   _____

Day 5: Evaluate

Day 5: Evaluate: Engineering Design Challenge - The Terrain Traverser



Background:
Vehicles that have the ability to traverse in different types of terrain have been around in different forms since the early 1900's. The militaries all over the world have used these vehicles to help move troops, equipment and other vehicles.

Learning Goals:

- I will design, build, and iteratively refine a vehicle to optimize its mobility across various "soil" conditions, evaluating solutions based on criteria and constraints.
- I will construct explanations based on evidence regarding the relationship between soil properties and vehicle performance.

Problem:
You are a team of environmental engineers tasked with designing a prototype vehicle capable of efficiently traversing diverse 'soil' conditions, specifically loose and compacted surfaces. Your design must minimize negative impact (e.g., sinking, getting stuck) while maximizing mobility.

Criteria and Constraints:

Criteria: Vehicle must move effectively across both loose and compacted surfaces.

Constraints: Use only available materials (recycled), time limit, size restrictions should fit completely on a 3x5 index card (so it will fit on testing surfaces), non-motorized

Research

1. What did you and your teammates find were important features in an all terrain vehicle when you researched the vehicles?

2. What do you remember from our previous lessons on soil that might help you with your car design?

Day 5: Evaluate: Engineering Design Challenge - The Terrain Traverser

Brainstorm

Sketch proposed designs, and discuss how different wheel/track designs might interact with varied surfaces based on the modeling they completed in the previous lesson.

Final Design ideas:

(place your sketches with dimensions and materials here.)

Day 5: Evaluate: Engineering Design Challenge - The Terrain Traverser

Construct Prototype:

You will have _____ of time to construct your prototype vehicle. Add a picture of your vehicle here.

Test your vehicle:

How did your vehicle perform?

What could you do to optimize your vehicle?

Rebuild and Retest your vehicle

Now that you have rebuilt your vehicle, how did it perform?

Present Your Solution

You and your teammates should prepare a short presentation to share your solution to this problem to the other students in your class.

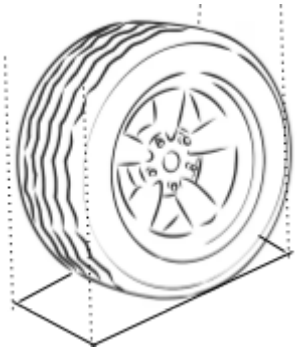
How did you and your teammates solve the problem, why did you design your vehicle the way you did? How did your vehicle perform? What would you change if you redesigned again?

Day 5: Evaluate: Engineering Design Challenge - The Terrain Traverser

Science meets Math:

Today you will use the same math from yesterday to apply it to your vehicle.

1. The name of your vehicle: _____
2. What is the mass of your vehicle? _____
3. Trace your wheel base, measure the length and width in centimeters, then calculate the contact area.

Example:	
	Length:_____cm divide by 100 = _____m Width:_____cm divide by 100 = _____m Calculate your contact area ($length \times width$):

4. Assuming the force of gravity is approximately 9.8 N/kg, calculate the weight (force) each vehicle exerts on the ground in Newtons (F=m×g).
   _____
   _____
   _____
   _____
5. Calculate the pressure (in Pascals, or N/m2) your vehicle exerts on the ground.
   _____
   _____
   _____
   _____
6. Based on your calculations and knowledge, hypothesis if you think your vehicle will be able to cross all three soils in the experiment to come.
   _____
   _____
   _____
   _____

Day 5: Evaluate: Engineering Design Challenge - The Terrain Traverser

7. How does this relate to the engineering challenge of designing vehicles for different soil conditions?
   _____
   _____
   _____

Conclusion questions:

1. How did this activity simulate what engineers might do to design, build and test an off road vehicle?

2. Why is understanding the conditions of the soil your vehicle is going to traverse important?

3. How did your team work together to come up with your solution ideas?

4. How do all aspects of STEM work together?