MACGILLIVRAY FREEMAN'S
DREAM BIG
ENGINEERING OUR WORLD

GRADE 7:

BUILDING THE PYRAMIDS

Grade level: 7

Lesson length: 140 minutes (can be broken down into multiple class periods)

> Analyzing primary sources, students assess the claims of how ancient Egyptians moved large-scale stones across a desert, as described in hieroglyphic accounts.

In the Film

In *Dream Big*, we see that engineers build their ideas and techniques on the previous work of others. Engineers are fascinated by the past and by the ways humans have been solving problems similar to ours for millennia. Just as engineers study the Roman construction of the aqueducts and the Chinese construction of the Great Wall of China, engineers are still investigating how the ancient Egyptians were capable of moving stones large enough to build the pyramids.

NGSS Disciplinary Core Ideas

MS-PS2.A- Forces and Motion

For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

NGSS Engineering Practices

MS-ETS1.A Defining and Delimiting Engineering Problems

The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will work. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

MS-ETS1.B Developing Possible Solutions

A solution needs to be tested and then modified on the basis of the test results.

There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

Dream Big: Engineering Our World is a film and educational project produced by MacGillivray Freeman Films in partnership with the American Society of Civil Engineers and presented by Bechtel Corporation. The centerpiece of the project is a film for IMAX and other giant screen theaters that takes viewers on a journey of discovery from the world's tallest building to a bridge higher than the clouds and a solar car race across Australia. For a complete suite of *Dream Big* hands-on activities, educational videos, and other materials to support engineering education, visit discovere.org/dreambig. The *Dream Big* Educator Guide was developed by Discovery Place for the American Society of Civil Engineers. ©2017 American Society of Civil Engineers. All rights reserved. Next Generation Science Standards ("NGSS") is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards were involved in the production of this product, and do not endorse it.

Key Words/Vocabulary

Position: The location of an object.

Force: A push or pull on an object in any direction.

Friction: The force causing an object to resist movement or a change in position.

Machine: A tool that makes work easier.

Materials (choose either Option A or B)

Option A: A device that can carry a student across a sand pit outside.

Per whole group:

- ☐ Sand pit
- ☐ Hose or bucket of water
- ☐ Optional: force probe

Per team:

- ☐ 4 feet of wood (scraps, planks, 2 x 4s)
- ☐ 2 yards of rope
- ☐ Hammer
- ☐ Handful of nails

Per student:

- ☐ Examining Ancient Egyptian Hieroglyphs sheet
- ☐ Engineering a Rock Moving Machine sheet

Option B: Small-scale device that can carry a stone across a tub of sand indoors.

Per whole group:

- ☐ Plastic storage bin filled with a layer of sand
- ☐ Heavy object, such as a bag full of rocks
- ☐ Spray bottle filled with water
- ☐ Optional: force probe

Per team:

- ☐ 20 popsicle sticks
- ☐ 1 hot glue gun
- ☐ 1 hot glue stick
- ☐ 1 yard of string

Per student:

- ☐ Examining Ancient Egyptian Hieroglyphs sheet
- ☐ Engineering a Rock Moving Machine sheet

Teacher Prep Notes

Decide whether you want to do Option A or Option B. Note: The ideal team size for Option A (the student-sized device) is three or four students. This activity has to be tested outside in a sand pit. The ideal team size for Option B (small-scale device) is two students.

Notify parents that students will be using a hammer and nails for an engineering activity.

Teach students how to use a hammer and nails safely. If you choose Option B, students need to know how to handle a hot glue gun safely.

Prepare to teach students about force, friction, and the kinds of systems and simple machines people have used throughout history to move heavy objects over long distances. Examples relevant to this activity include slickening a surface and using an inclined plane.

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the film *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they are watching the film:
   - **a.** What are some of the lessons engineers have learned from studying the ancient architecture of Rome and China?
   - **b.** How can we use the information they gained through these studies as we engineer structures for our modern life?
2. Debrief as a whole class after viewing the film. Allow students to verbally reflect on the guiding questions you gave them.
3. Introduce the design challenge. Students will study hieroglyphs recently discovered on the inside of an Egyptian ruin. From these hieroglyphs, engineers think they may have finally identified the mysterious system that Egyptians used to move heavy rocks to build the pyramids. The students' task is to recreate a working model of the system and to test the claim to see if it really does make moving heavy objects easier.

Research and Gather Information: 45 minutes

1. Using the information you have prepared, teach students about force, friction, and simple machines that have been used throughout history to move heavy objects. Engage students in a discussion about how these topics relate to the challenge faced by the ancient Egyptians, who wanted to move large, heavy rocks over the rough and yielding surface of sand.
2. Organize students into teams, if they will be completing Option A, or pairs, if they will be completing Option B.
3. Distribute the worksheet "Engineering a Rock-Moving Machine." Ask students to fill in the answer to the first question based on this discussion.
4. Ask students to look at the Egyptian hieroglyphs image on the "Examining Ancient Egyptian Hieroglyphs" handout and to read the information below it. Ask them to describe the system the Egyptians used to move rocks in as much detail as possible. Tell them to write down their ideas at the bottom of the sheet. Push students to identify the following key components:
   - **a.** Water was poured in front of the sled to reduce friction and therefore the force needed to move the sled.
   - **b.** Multiple people pulled on the rope connected to the device. This shared the pulling force of moving the rock between many people and therefore reduced the force each person had to exert.
   - **c.** The rock/statue was tied to the sled.
   - **d.** The sled had a slight upturn in the front.
5. Important: Remind students that their task is to recreate what they think the hieroglyphs are conveying, not what might be the easiest way to move the sled. For example, since there are no round logs placed beneath the sled to roll it along the desert, the students can't use this method in their own design.
6. Have students determine what materials they will use by looking at the image. Tell them to answer question 2 on their worksheet "Engineering a Rock-Moving Machine" by listing the materials that were present and available to Egyptians. Tell students that they cannot use anything other than these to create their rock-moving device.

Plan a Solution: 20 minutes

Ask students to fill in the "Plan" section of the worksheet "Engineering a Rock-Moving Machine." Students should write a step-by-step process for how their device will be built. Based on their knowledge of machines, force, and friction, they should describe how their device will reduce the amount of force and work that each person on their team will need to do in pulling a heavy object.

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two fundamental ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a whole class brainstorming the criteria and constraints of this particular engineering challenge.

Make It: 30 minutes

Once students have drawn their plan, allow them to begin building their device. As students are building, visit each group, reviewing what they learned about force and motion. Ask students questions about how their system reduces friction and decreases the work needed to be done by each worker. Allow students to make mistakes along the way and to struggle. When they do, ask questions about what they have observed and what they could change to fix the problem. Avoid offering solutions and instead encourage students to test ideas as they build.

Test: 20 minutes

Students will test either Option A or Option B:

Option A: Build a device that can carry a child across the sand pit outside of the school.

Option B: Build a device that is smaller but can carry a stone load across a tub of sand indoors.

1. In either case, students will first test the amount of force required to move their test load across dry sand.
2. Then the teacher will lightly wet the sand with water. If doing this exercise outdoors, use a hose to lightly spray down the sand pit. If doing this on a smaller scale indoors, use a spray bottle to mist water onto the sand.
3. Have the students conduct a secondary test with the same load, this time dragging it across the wet sand to identify if there was a difference in terms of the force required to complete the task.
4. For the third test, heavily wet down the sand so that more than just the top layer is moist. Again, have the students drag their device across the sand and record the force necessary to pull the load.

You can measure the actual amount of force exerted in each case with a force probe held by the students pulling the device. Or, do qualitative assessments as students describe if it "felt easier" to pull. Other good qualitative observations to take are the amount of sand that gathers at the front of the device and the depth the device sinks into the sand.

Evaluate: 10 minutes

Have students assess their device with the questions found on "Engineering a Rock-Moving Machine." As time permits, hold a class discussion about students' thoughts.

Taking It Further

Explore other possibilities: Could that liquid in the hieroglyphs have been something other than water? Obtain other liquids that would have been plentiful in the time of the Egyptians and use them to wet the sand and test the force necessary to pull heavy loads. Options include soapy water, salty water, and tea from marshmallow root.

Extend the impact of your device: Students identify additional ancient cultures and mythologies that they can explore, test, and verify.

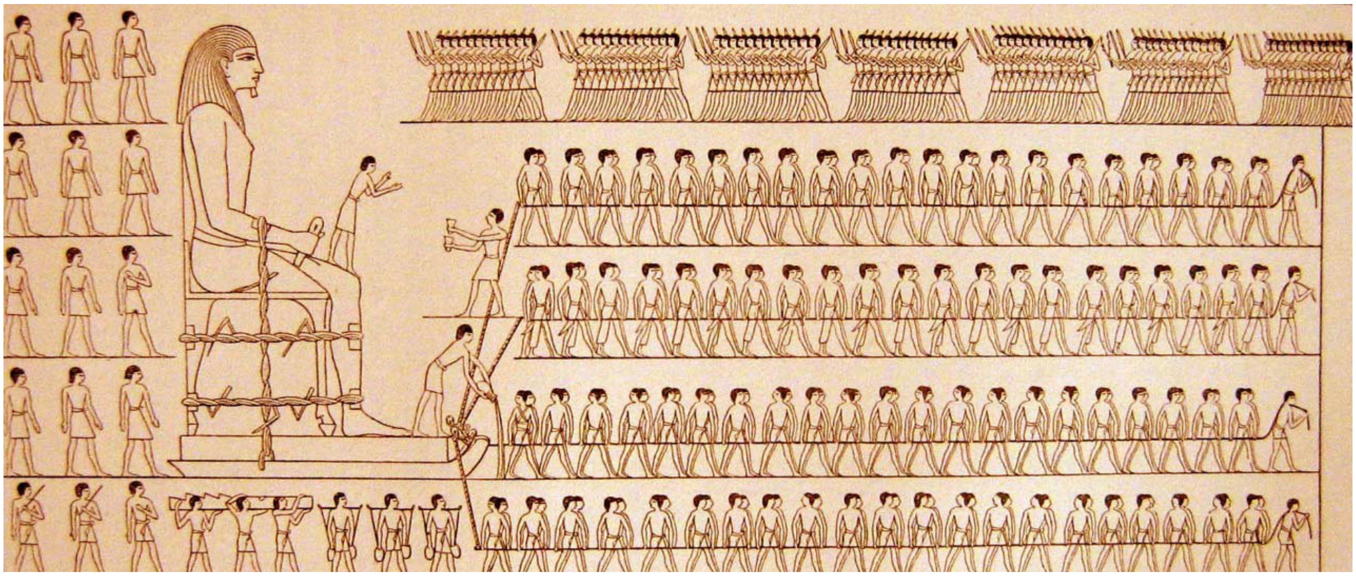
Learn about this engineering in the real world: Engineers can look at ancient technology to uncover secrets of how to create modern structures. For example, Christine Fiori of Virginia Tech is studying the ancient roads of the Incan culture through the Andes mountains to uncover ways we can sustainably build roads in our modern culture. Current road creation involves modifying the landscape by blasting through rock, which often creates landslides. The ancient Inca, however, carefully followed the native landscape and controlled the water flow around it. Because of this, many of their roads still exist today, thousands of years later. Learn about what her team is doing to study these roads and replicate them in today's modern engineering at: mlsoc.vt.edu/articles/students/dr-christine-fiori-leads-expedition

Document your students' work through our social media outlet: #dreambigfilm

EXAMINING ANCIENT EGYPTIAN HIEROGLYPHS

Name: ____

How Were the Pyramids Made?



For years archaeologists and engineers alike have investigated how an ancient culture like the Egyptians could move such large stones miles across the desert floor. The Egyptians built the pyramids over 5,000 years ago, well before the development of advanced machinery or motors. Each stone weighed over 2.5 tons and dragged heavily across the high friction of the desert sand floor. Recently, however, engineers feel they may have discovered the secret to how the Egyptians were able to achieve this incredible feat. An international team of researchers led by the University of Amsterdam investigated the claim that the hieroglyphs found in the tomb of Djehutihotep show the use of water being poured in front of the rock-moving device to reduce the friction of the sand floor. According to the results of the study, the water substantially reduced the amount of force necessary to pull 2.5-ton rocks across sandy terrain.

1. What is the building system present in this text and image?

2. Drawing from the text and the image, describe in as much detail as you can how this system worked and what materials were used:

ENGINEERING A ROCK-MOVING MACHINE

Name: ____

Problem to Be Solved

Recreate a working model of the ancient Egyptian system of moving large stones. Test the model to see if it does indeed make moving heavy objects easier.

Research and Gather Information

1. What do we know about friction and the ways that simple machines can make work easier in areas with heavy friction?

2. Based on the hieroglyphic image, what are our material constraints? What are the materials they used in this image?

Plan

- ☐ The criteria of the engineering and design challenge are:

- ☐ The constraints of the engineering and design challenge are:

- ☐ Draw a picture of what you plan to make.

- ☐ Write a step-by-step process of how to create your design.

- ☐ Describe how your device will reduce the amount of force and work needed to be done by each person pulling the heavy object.

Make It!

Evaluate

Did your device meet the constraints of the engineering challenge?

Did you use only the materials present within the hieroglyphic image?

Did your device meet the criteria of the engineering challenge?

Did it make pulling the rock easier than if it was dragged across the sand alone?

Did it safely move the heavy object without it falling off?

What differences did you observe among the dry sand, lightly moistened sand, and soaking wet sand?

What can you conclude from your class's data about this method of moving rocks across the desert floor? Can you confirm that the Egyptians would have had an easier time of moving the large stones? Can you disprove it with your results? Were your results inconclusive? Why?

DREAM BIG VIDEO SERIES

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