# Engineering Innovations of Ancient Egypt

**Merry Ostheimer**

## Introduction

I have the privilege of teaching at West Park Place Elementary School (WPP), an elementary school about a mile away from University of Delaware (UD). As you may guess, many students have parents who work for UD or are visiting scholars from other countries. Two great effects of residing on the fringe of academia are that education is highly valued at WPP and there is a transient entity to our population: some of my students are with me for just six months while their families study or teach at UD. My students' immersion into our American culture is intense and will end around February when they return to their home countries. This year, my self-contained 2nd grade classroom consists of 28 students, five of whom are English Language Learners (ELL). My ELL students face many challenges as they progress through our American education system such as learning to speak, understand, and write in English. One way to give equal footing to all my students is to provide fun, hands-on experiences that stimulate conversation, engage senses, and create social bonds.

## Rationale

As a child, I always marveled at the ancient pyramids. How did people more than 4000 years ago sculpt stone into blocks, transport those blocks across great distances, and stack them into colossal tombs of nobility and royalty? And those glorious monoliths are not just found in Egypt: pyramids are found in Nubia, Mexico, Peru, Italy, and Iraq. Just thinking that humans came up with the idea of erecting humongous monuments that celebrate the dead at around the same time in human history blows my mind.

In my unit, students will study why and how the ancient Egyptians built tombs for their dead. In order to understand why these pyramids were built, there is essential background knowledge about how Egyptian mythology in afterlife drove the civilization to erect burial monuments. The Nile River and Egyptian landscape contributed to the unique building components and shape of the pyramids. Ancient engineers refined their tools and techniques over trials of error and time as they developed simple machines to render them. Students will play with, build, and create pyramids with a variety of materials to recreate the pyramid building process. Finally, simple machines that were used in ancient Egypt are still essential tools for us today.

## Objectives

This integrated unit will feature Engineering, English Language Arts, Math, and Social Studies. My students will use the Engineering Design Process to create their own pyramid prototypes. Standards will target asking questions, making observations, and gathering information about how ancient Egyptians solved their problem about memorializing their dead. Students will develop physical models of pyramids by making mudbrick blocks and then assembling them in pyramid form. Students will then work to improve the structure of blocks and compare the strengths and weaknesses of their models. After these activities, my students will learn about simple machines and explore how levers, inclined planes, pulleys, wheels and axles, wedges, and screws make work easier.

English Language Arts Common Core State Standards include (RI2.1) Ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text. My students will read a lot of material including the Egyptian Creation Myth and Primary Resources: Carter's Discovery of King Tutankhamun's Tomb (ReadWorks).

Math Common Core State Standards include (2GA.1) recognize and draw shapes having specified attributes such as a given number of angles or a given number of equal faces, and (2GA.2) partition a rectangle into rows and columns of same-size squares and count to find the total number of them. This will came in handy when we planned to make a mudbrick structure that had a foundation of 25 bricks arranged in a 5 x 5 array. A 4 x 4 array is placed on top of that, then a 3 x 3, then a 2 x 2, and finally a single brick at the top. The class adds up the total number of bricks used to make this one pyramid: 25 + 16 + 9 + 4 + 1 = 55 bricks.

As for Social Studies Standards, Delaware Department of Education recommends that students in second grade will understand that documents and artifacts give us information about the past so we will practice the skills of gathering historical data, and examining, analyzing, and interpreting these data (k-3a). Students will also understand that historical accounts are constructed by drawing logical inferences from artifacts and documents. Just by looking at photographs of pyramids throughout the Nile Valley, the students saw these structures are real and have withstood the test of time. By recreating the experience of building pyramids, my students have acknowledged that these structures are feats of hard work and ingenuity.

The ***Enduring Understandings*** that will be realized are: Egyptian mythology and the belief of afterlife drove the ancient Egyptian civilization to erect burial monuments that have a specific pyramid shape. The Nile River and Egyptian landscape contributed to the unique building components. Ancient engineers refined their tools and techniques to make work easier and, in doing so, invented the first simple machines. ***Guiding questions*** to focus the unit include: *Who built the pyramids? How old are the pyramids? Why were the pyramids built? Why are pyramids shaped the way they are? How did these structures evolve? Why was the Nile so important? How were the pyramids built? How long did it take to build a pyramid? What tools were used? What are some ways the Egyptians made their work easier? Did they use simple machines? How can you tell which simple machines were used?*

**Content**

In order to appreciate why pyramids were built, I think it is essential to know the History of Egypt. There are sections for Egypt's Creation Myth, the Evolution of Pyramids, The Nile River and its Influence on Egyptian Civilization, and Ancient Egyptian Belief in the Afterlife. In this section, there will be teacher read aloud selections in addition to student-read selections. Maps will teach the geography of where in the world is Egypt and how does its landscape and climate contribute to pyramid building.

This historical outlook will set up the next content part: how were the pyramids built? Engineering techniques will be targeted in this section. The Engineering Design Process will be practiced as students make their own mudbricks, quarry their own stone, and shape their blocks into bricks that can fit together to form a level plane. As I inform you how the pyramids may have been build, I will discuss how Simple Machines made these enormous accomplishments possible and include some ideas for using Simple Machines in class investigations.

**Why were the pyramids built? History of Egypt**

*Egypt's Creation Myth*

To the Egyptians, the journey began with the creation of the world and the universe out of darkness and swirling chaos. Once there was nothing but endless dark water without form or purpose. Out of this chaos (`Nu') rose the primordial hill, known as the Ben-Ben, upon which stood the great god Atum (or, in some versions of the myth, Ptah). Atum looked upon the nothingness and recognized his aloneness and so he mated with his own shadow to give birth to two children, Shu (god of air, whom Atum spat out) and Tefnut (goddess of moisture, whom Atum vomited out). Shu gave to the early world the principles of life while Tefnut contributed the principles of order. Leaving their father on the Ben-Ben, they set out to establish the world. In time, Atum became concerned because his children were gone so long and so removed his eye and sent it in search of them. While his eye was gone, Atum sat alone on the hill in the midst of chaos and contemplated eternity. Shu and Tefnut returned with the eye of Atum (later associated with the Udjat eye, the Eye of Ra, or the All-Seeing Eye) and their father, grateful for their safe return, shed tears of joy. These tears, dropping onto the dark, fertile earth of the Benben, gave birth to men and women.[1]

According to the creation myth, as a primeval mound formed by the sun-god when he required a place to stand, the Benben stone was symbolically thought to have the power to raise the dead. This stone is a very important part of the creation myth and takes on two styles throughout the history of Egypt: an obelisk and a pyramid.[2] The Benben stone acts as the capstone, or pyramidion, which is placed on top of the pyramid. I find this myth to be very important in teaching about pyramids since it explains why pyramids are shaped the way they are. After reading this myth with my class, we use made 3-d pyramids and wrote directions.

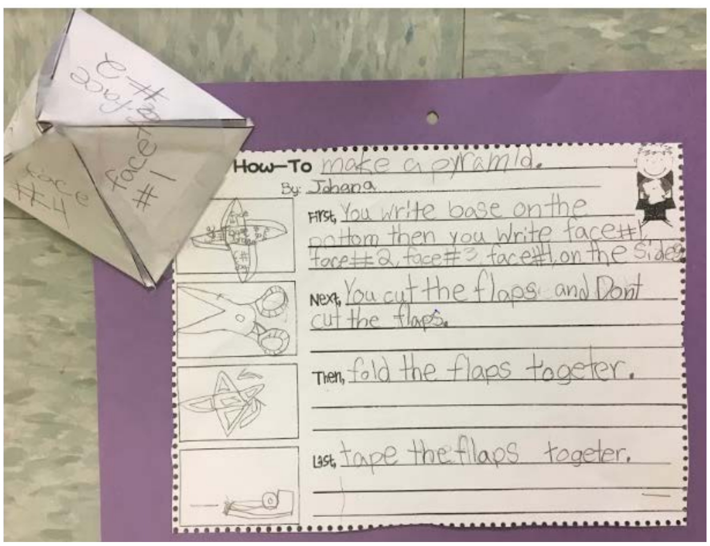


Fig. 1: How to build a pyramid by Johana. Image credit: Merry Ostheimer

*Evolution of Pyramids*

Mastabas were low mounds that covered burial pits in early tombs. As a primeval mound formed by the sun-god, this mound was symbolically thought to have the power to raise the dead.[3] In the First Dynasty, early pharaohs and other wealthy Egyptians had burial tombs made of mud bricks called mastabas, which meant “eternal house.” The mummies were buried underneath the mastabas in a burial chamber. Often, mastabas were built in clusters and were referred to as a “city of the dead.” These mastabas had a basic house plan that included a central room which housed the sarcophagus, and other rooms that served as storage space.

*Step Pyramid*

When the mound was formed into a step pyramid, it seems to have acquired a more practical function: that of helping to estimate the yearly cycles of the rising and setting sun.[4] This transition from a single layer mastaba to multiple layers of step pyramids started to resemble the Benben stone, the sacred object used to greet the rising sun.

In the Third Dynasty (2611 BCE), Djoser or Zoser the Pharaoh and Imhotep his architect formed the step pyramid by stacking six mastabas on top of each other. Following this step pyramid, was the Meidum Pyramid by Pharaoh Huni and continued by Pharaoh Sneferu (2613 BCE). It was a step pyramid that was encased to resemble a smooth-sided pyramid. This pyramid marked a transition from “stepped” pyramid structure to that of a “true” pyramid structure in which the sides were made smooth with a layer of limestone. However, there were structural errors which included the outer layer being founded on sand and not rock and the inner step pyramids had been designed as the final stage so the outer surface was polished and the platforms of the steps were not horizontal but fell to the outside. The compromised stability caused a collapse of the Meidum Pyramid while it was still under construction.

The Bent Pyramid was built under Pharaoh Sneferu (2600 BCE) and got its name from the change in angle of its slope. The pyramid rises at a 54 degree inclination, but the top section is built at the shallower angle of 43 degrees. There are two possible reasons for the change in slope. The first is that the structure appeared to be unstable sot the builders adopted a shallower angle to avoid collapse. The second is that at the initial angle of the structure would take too long because Sneferu’s health was nearing.

There are a series of six step pyramids that were constructed by an unknown builder and lacked burial chambers. These pyramids were crudely built with layers of local fieldstone and held together with a mortar of desert clay.[5] Most of these six are carelessly oriented, badly squared, uneven in the length of their sides, and unequal in both thickness of brick and layers. Ramps were left in place. Isler wrote, "This series of small step pyramids of unknown dates and ownership, opens the door to some interesting conjecture concerning their chronologies. All forms of technology have a natural progression that starts with small, tentative steps before a major work can be accomplished. These show the imagination and daring drive to produce greater work.[6]" I wanted my class to experience this process of unending persistence and innovation, so we got to work recreating some of the process the ancient Egyptians took.

In our initial activity, my class worked to quarry stones from pretend stone that I made by combining flour, salt, alum, sand, and water. First I mixed the ingredients in a zip-lock bag and kneaded it. Then I portioned the mixture out on trays and let them bake in the sun. After two weeks, the stone was very hard and ready for my students to plan how to cut them into blocks. We used string to make toothpick holes along in horizontal and vertical line patterns to form a grid.

Fig. 2: Preparing to quarry stones. Image credit: Merry Ostheimer

In quarrying blocks, my students ran into many problems: the pretend stone was very hard and wooden toothpicks could not penetrate them. The class brainstormed solutions and tried running a penny along the string to make a rut. Sometimes this strategy worked, but the pretend stone was so hard and dry that even a penny could not cut through. The class also tried using a nail and mallet to chisel some stone. No matter what they tried, there was more dust than blocks. The class did salvage some stone blocks that sat a couple of days and then students shaped them a nail file and pumice stone.

The next exploration my class performed was making their own mudbricks. There was a mixing station that included clay, humus, sand, flour, and water. One small group of students went up at a time to mix these ingredients in a small plastic cup and then stirred it with a Popsicle stick. The teams then poured their mixture into a mini ice cube tray and let it bake in the sun for about a week. When the cubes popped out, they were ready to use as pyramid building blocks.

Fig. 3: Filling mini ice cube trays with mudbrick mixtures. Image credit: Merry Ostheimer

Fig. 4: Mudbricks are ready for distribution. Image credit: Merry Ostheimer

Fig. 5: Laying the foundation using white glue and an array of 5 x 5 bricks. Image credit: Merry Ostheimer

As my class explored the cutting of stone to make blocks and mixing earth materials to make mudbricks, they found it very difficult. When a batch of mudbricks was overly dry and crumbly, they couldn’t be used so the team had to start over. With a growing pile of rubble, my students were determined to find the perfect mix of ingredients. This trial and error exercise helped my students appreciate that it took ancient Egyptians over twenty years to build the Great Pyramid of Giza.

*The Nile River and the Egyptian Civilization*

Known as the lifeline of Egypt, the Nile River is located in northern Africa where its source is located in either Burundi or Rwanda and its mouth is the Mediterranean Sea. The Nile River is the longest river in the world at 4,160 miles long. Ancient settlers formed two different kingdoms-- Upper Egypt in the south where the source is., and Lower Egypt, in the north, where the Nile Delta is. Ancient Egyptians lived on the fertile banks of the Nile River which provided water, food, transportation, and excellent soil for growing food.

The Egyptian year was divided into three seasons: flooding, planting, harvesting. Each spring, heavy rains and melted snow sent down torrents of water that overflowed the banks of the Nile. When the floods receded, rich mud remained and became excellent soil for planting. The ancient Egyptians could grow crops only in the mud left behind when the Nile flooded, so planting fields emerged all along the Nile. Egyptians lived in villages on the banks of the Nile since the rest of Egypt was a huge, hot desert. At the harvest time, farmers used strong oxen to gather fruits and vegetables, as well as wheat, barley, and flax. As people learned to raise crops in the rich soil, their settlements grew and refined techniques for farming: they dug ditches and canals to channel the annual floodwaters. The Egyptians used the flooding of the Nile River to their benefit: their irrigation system kept flooding under control and increased the size and richness of their farmland. Trading and agriculture took off.

This information was important to teach my class because it emphasized the power of water and effects of climate. The Nile River was so instrumental to the ancient people because it provided food and transportation. We examined the methods of extracting water from the river with a shaduf, which is a simple machine that uses a large pole balanced on a crossbeam, with a rope and bucket on one end and a heavy counter weight at the other. By pulling the rope, a farmer lowered the bucket into an irrigation canal and raised the bucket full of water by pulling down on the weight and then swinging the pole around to empty the bucket onto the field.

Fig. 6: A wall drawing of a shaduf. Image credit: Ancientvine.com

Our class made models of a shaduf by using sticks, clay, pipe cleaners, and mini-cupcake wrappers. First we planted three sticks in clay on a desk. Then we wrapped the tops with a pipe cleaner so they looked like a wigwam. Next we took another stick and put clay to be a counter weight at one end and the mini-cupcake wrapper attached with on the other end. Finally, we rested the stick on the wigwam which acted as the fulcrum and pushed down the counterweight and saw the wrapper lift up.

*Ancient Egyptian Belief in the Afterlife*

Pyramids were not built for people to live in, but were the tombs for the pharaohs, who the ancient Egyptians believed would live in another world after death. Preparations for death were made carefully and long in advance: tomb chapels and burial chambers were built, grave goods laid aside, and endowment set up to pay the mortuary arrangements set up to pay the mortuary priests who provided for the eternal well-being of the deceased's spirit. The people of ancient Egypt essentially did not fear death because they did not believe that death was an ending.

Egyptians believed that every person was made up of three parts: the body, the ka or life force, and the ba or personality. The Egyptians believed that when a person died, the ba and ka left the body because in order for the person to live in the Next Life, the ba and ka had to come together again. Since the body was the home to the ba and ka, it was essential that the body of a dead person should not be destroyed, so the body was turned into a mummy. The embalming process preserved the bodies so they could be used in the afterlife. As part of their religion, Egyptians believed that the pharaoh needed certain things to succeed in the afterlife. Deep inside the pyramid, the pharaoh would be buried with a variety of items and treasures that he might need in the afterlife. Near the pharaoh's burial chamber, would be other rooms where family members and servants would be buried including small rooms that acted as temples and larger rooms for storage.

**How were the pyramids built? Engineering Techniques**

Over the course of pyramid building, there was a team of workers, each specializing in a specific area. The pharaoh and architect drew up plans that would require thousands of men to come to the area. Stonecutters, masons, surveyors, mortar makers, carpenters, and general laborers were brought to the site. Barracks and workshops were set up at both the quarries and the pyramid site to start organizing the work forces. When the fields flooded and farming was impossible, thousands of farmers were drafted to various teams that would transfer stone from the quarries to the site. Each gang was led by a soldier acting as the foreman. Payment for work was food and clothing.

The very first step was surveying to find the location of true north, so that the pyramid could be accurately oriented. The Egyptians built a circular wall approximately in the center of the site. It was built high enough to block a view of the surrounding hills and the top was made level, creating a perfect horizon line. In the evening, a priest stood in the center of the circle and watched for the appearance of a star in the east. The star's position was marked as it rose above the wall and a line was drawn from that point on the wall to the center of the circle. The priest watched the star as it moved in an arc through the sky and finally set in the west. As it dropped behind the wall, its position was marked again and another line was drawn to the center of the circle. The architect and surveyors repeated this process in the presence of the pharaoh for two weeks, during which animals sacrifices and prayers were offered. Finally, metal stakes were driven into the rock at the four corners and the ground was cleared of sand and rubble in order to expose the rock on which the pyramids were leveled.

Fig. 7: Picking the right location. Image credit Q-files: The Great Illustrated Encyclopedia.

Leveling the site involved cutting a network of narrow connecting trenches into the rock. Then they filled the trenches with water until filled. This acted as a level. When the top of the water had been marked on the sides of all the trenches, they were drained. The spaces between the trenches were then cut down to the height of the marks and the trenches were filled with stone.

Fig. 8: Leveling the site. Image credit: Atlantis online

When quarrying rock, most of the rocks used in building pyramids was limestone. To get the best limestone, tunnels were dug into the face of the cliffs from which huge caverns were cut block by block. Columns of stone were left standing in the caverns to support roofs. As each block was cut, it was assigned to a work gang for delivery. Using hemp ropes and heavy timber levers, the men would first roll the block onto a wooden sled and then tie it down. Then they would drag the sled to a boat, where the stones were marked with the name of the work gang that hauled them and checked off the list when they reached the site.

Stonecutters used tools made of copper or a very hard stone called dolerite. Copper chisels and stone mallets were used to break rocks from their parent rock. Dolerite balls were used to make grooves and indentations in rocks. Handles for tools and most of the measuring instruments were made of wood. Metalworkers were kept busy both at the quarry and on the site sharpening worn tools and making new ones. Polishing stones were used to make the surface smooth.

Huge stones of granite and limestone were dragged on sleds up a causeway to work areas and transferred onto more easily movable wooden rockers. After the tops and ends were chiseled smooth, each stone was numbered in the order that it would be laid. Then a thin coat of mortar was smeared on the ends and bottom of the stone block and the rocker was removed. The stone block was pushed into place among other stones which made up rows and rows of carefully cut limestone paving stones which made up the base line of the pyramid. After that, granite casing blocks were pushed into place along a line inscribed on the paving stones. This foundation was applied over inner burial rooms that were constructed underground. The rest of the pyramid was built all around the burial chambers.

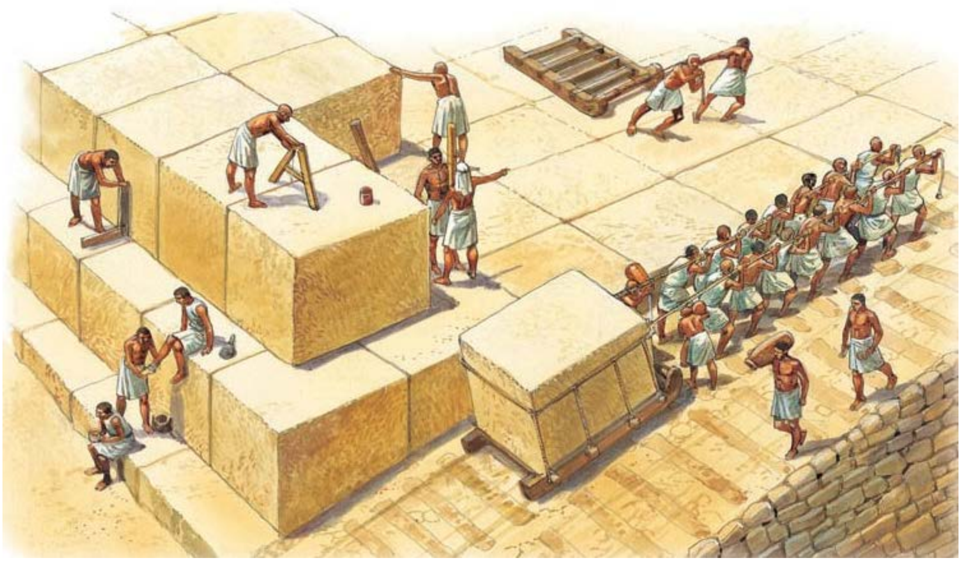

Fig. 9: How ancient Egyptians used ramps, sledges, plumb bob levels, and squares. Image credit Q-files: The Great Illustrated Encyclopedia.

Ramps were formed by mixing piles of rubble with Nile mud and placing timbers to give traction for the sleds. The ramps would wrap around one side of the foundation and rise gradually to enable workers to place more stone layers. Trowels were used to apply mortar, squares were used to set materials to right angles, and plumb bobs were used to make sure that stones were placed evenly. When ramps were not required, levers were used to raise heavy stones. A wooden beam was wedged under the stone and over a fulcrum. The workers would push down on the end of the beam opposite to the stone and were able to raise the stone more easily. Sleds or sledges could be used to haul heavy loads up the ramp, but there was another system used.

Boning rods were a set of three wooden rods, two of which are connected by a string from the tops. The rods were placed vertically on opposite sides of the area of the stone which was to be cut. With the string taut, the third rod was slid vertically under or next to the string. If the string rose above the rod, the stone was not level and needed to be chiseled down to perfection. A plumb line was used to be sure that stones were vertical. A weighted string hung from two wooden sticks joined at a right angle. When the wood frame was placed on a stone, the weight at the edge of the string should hang perfectly vertical.

For years, work gangs went back and forth from quarry to the pyramid site, ferrying stones, hauling them up ramps, and placing them to build the pyramid. One of the final steps was placing the Benben stone. This large block cut roughly in the shape of a pyramid would rest on the topmost layer. Prayers and offerings followed the workers hauling the capstone up the ramps that wrapped around the pyramid. As the stone was placed on top, there were more prayers and ceremony led by priests to thank the gods. When the ceremonies were completed, workers polished the casement stones from the top of the pyramid to the bottom. As they finished each layer, laborers began dismantled remaining construction ramps that were comprised of rubble, wooden scaffolding, and mud.

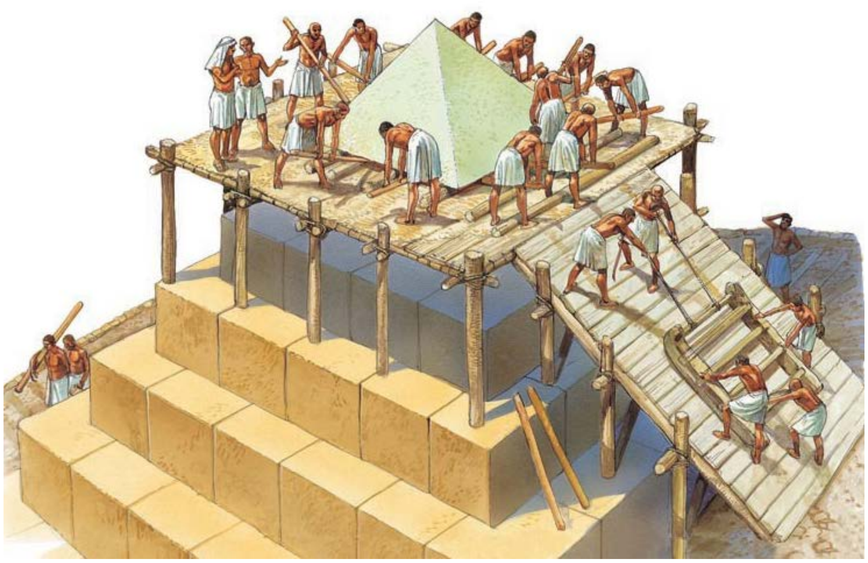

Fig. 10: How ancient Egyptians placed the pyramidion, or capstone, into place. Image credit Q-files: The Great Illustrated Encyclopedia.

## Implementation Strategies

### *Cooperative Learning Teams*

Cooperative Learning Teams is a strategy I use in my classroom daily for every subject. Students work in teams of four students who learn at varied levels. The four students sit shoulder to shoulder and face to face. The goal is to actively engage each student through activities that shift between direct-instruction, teamwork, and pair-work. I instruct my class to "Make sure that everyone knows…", "Work with your face-partner", and "Turn to your shoulder-partner". This friendly atmosphere helps students learn to be good speakers and listeners. An inherent benefit is students are continually practicing effective leadership skills by checking each other's understanding.

This year, I have used Colleges and Universities to name my teams so there is University of Delaware, Yale, Bowdoin, Haverford, University of Chicago, Princeton, and Harvard. This exposure to higher education institutions helps my second graders believe that college is in their future. My students really have thought of themselves in a different light than in past years when I used the colors of the rainbow to name their teams. Team Red is not as inspiring as Team University of Delaware.

*Engineering Design Process*

According to the Next Generation Science Standards website, “Science and Engineering Practices describe what scientists do to investigate the natural world and what engineers do to design and build systems.” Through this inquiry-based practice, my students engage in activities that build, deepen, and apply their knowledge of core ideas and cross-cutting concepts.

The first step in the Engineering Design Process is to ask “What is the problem?” In this phase. We kept a journal of our inquiry using this chart that I adapted from Explorations in Nonfiction Writing. The second step is to imagine what are some solutions of the problem? We will research to find out more about our topic. Then the team brainstorms methods to solve the problem. The third step is to plan by drawing a picture of the solution. The teams need to include what supplies are needed and who will do which job. Finally, the team makes a list of the steps they will take to make the solution. The fourth step is to create a device by following the team’s plan. Collaboration is necessary as the team works steadily and manages their time. The great part of this is testing the design because the teams are very interested in taking turns so that everyone has a chance to test out their device. The fifth step is to improve the design by learning from mistakes. The team makes their design even better and retests it. The final step is to present their devices to the class. A lot of times, the teams want to “go back to the old drawing board” once they see each team’s solutions.

**Activities**

Where in the world is Egypt?

The objective of this lesson is to learn where Egypt is in relationship to where we are in Delaware. This lesson will review cardinal directions and teach where the equator, Tropic of Cancer, and Tropic of Capricorn are. Other geographical terms include delta, river, sea, mountain, valley, desert, river source, and floodplain. Teams will use maps to answer questions about Egypt and its neighboring countries. Then teams will discuss advantages and disadvantages to being located in a desert and beside a river.

Egyptian art and Bastet, the cat goddess

The objective of this lesson is to investigate what you might find inside an Egyptian tomb. Ancient Egyptians held cats sacred and even protected them by law. Cats were seen as embodiments of the goddess Bastet, who was portrayed as a woman with the head of a cat. Bastet was the bringer of good fortune and health and was believed to be the protector of women, children, and cats. The ancient Egyptians greatly respected and loved cats and often mummified them in the same way as humans. In this art activity, students will draw designs on a cat outline.

Introduction to levers

The objective of this lesson is to introduce levers. Principle vocabulary includes fulcrum (pivot point), bar (a long beam placed on the fulcrum), and force. Students start this activity with a highlighter, ruler, and cotton ball. First, the students will secure their highlighter on the edge of their desk. Then, they will place their ruler on the highlighter which is the fulcrum. Next, they will put a cotton ball on the end of the ruler that is on the desk. Then, they will launch the cotton ball by pressing down on the other end of the ruler. The class investigates what will happen if the lever is longer and by shifting the fulcrum.

Catapults!

The objective of this lesson is to use ten Popsicle sticks, five rubber bands, a spoon, and cotton balls to build a catapult. Teams will use one rubber band to join two sticks on one side. Then they will create the fulcrum by stacking the remaining eight sticks with two rubber bands, one on each side. Then they will slide the fulcrum between the two sticks that were previously banded. They will carefully use the fourth rubber band by making an x at the center and securing all the sticks together. Finally, use the fifth rubber band to connect the spoon to the top stick. This will serve as the launching pad for flinging cotton balls.

**Appendix A**

This unit will integrate the Next Generation Science Standards for Kindergarten through second grade. Students will be able to ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool. They will develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem. Students will also analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

History Common Core Standards will also apply where students gather, examine, and analyze historical data and use artifacts and documents to gather information about the past.

The Common Core State Standards in Reading Informational Text will also be targeted.

**Appendix B**

Pretend Rock Recipe

| **Ingredients** | **Materials** |
|---|---|
| 1 cup flour<br>½ cup salt<br>2 tsp alum<br>1 cup sand<br>½ cup water | Large zip lock bag<br>Measuring tools<br>Tray<br>Paper towels |

**Procedure**

1. Mix flour, salt, and alum in the large zip lock bag.
2. Add water.
3. Knead the bag until the mixture no longer sticks to the sides of the bag.
4. Add sand.
5. Knead until the mixture is well-mixed.
6. Divide the mixture into 18 balls.
7. Flatten the balls to form rocks of varying shapes.
8. Place the rocks on the tray.
9. Let the rocks dry for two weeks.

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3 Isler. p. 111.
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6 Isler. p. 103.