STEM gems

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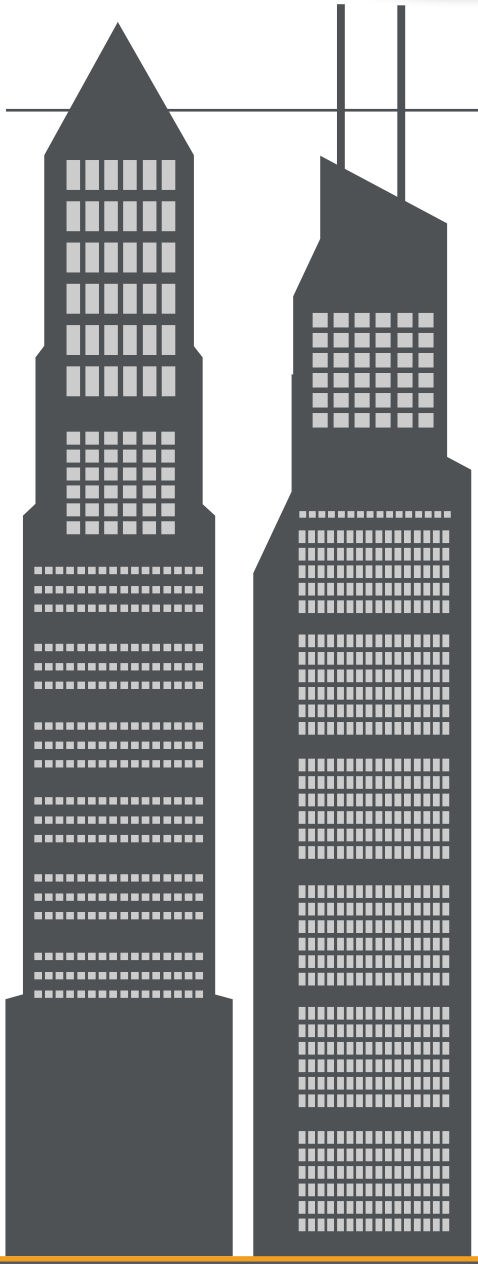
TOWER ENGINEERING CHALLENGE



big IDEAS

THIS STEM GEM IS AN ENGINEERING CHALLENGE THAT IS PERFECT FOR THE HECTIC START OF A SCHOOL YEAR. It is low cost, low stress and extremely easy to implement. Tower building can serve as a great icebreaker and team building exercise for any new faces that have joined in your program.

WHAT IS A STRUCTURAL ENGINEER?

Structural engineers specialize in designing and constructing all types of structures. Along with towers, structural engineers help design bridges, tunnels, ships, airplanes, warehouses, and even houses. When structural engineers design something, they must take into account the technical aspects of construction, environmental concerns and limitations, as well as the aesthetic properties of design. Structural engineers often build small scale models to test their designs, in particular, to test the forces a structure will experience under different conditions. Structural engineers start with an idea, create a design, then organize and oversee the actual building of the project. Throughout the process, they work closely with other engineers who specialize in specific areas, such as electricity and plumbing and with the builders, architects and surveyors.

WHAT IS A TOWER?

A tower is a building or structure that is higher than its length or width. Towers can stand alone or be attached to adjacent structures. The earliest known towers were vertical stone structures without windows. When iron and steel were introduced during the Industrial Revolution, towers became much stronger and taller, and the term “skyscraper” was coined. In addition, the invention of the elevator in 1857 made tall towers more accessible and practical for everyday use.

WHAT FORCES DO STRUCTURAL ENGINEERS HAVE TO CONSIDER WHEN DESIGNING TOWERS?

Structural engineers must consider all the loads a building must bear. The dead load (the weight of the actual structure), the live load (the weight of the objects inside a structure, such as people and furniture), and environmental load (the natural conditions a structure must endure, such as extreme temperatures, high winds, and earthquakes). After all of these calculations have been made, the engineers create designs and select the materials that will support each type of load. When selecting designs and materials the engineers need to consider the balance between the forces of compression and tension. Tension is the pulling force created by stretching a material or pulling it apart. When materials are put under tension they become strong and inflexible. Compression is the opposite of tension. Compression is a pushing force created by pushing or squeezing a material together. Generally, in most structures compression supports most of the load in a building, as gravity is always pulling everything downward. Most materials can bear a lot of compression in one direction end to end but very little in another. If a straw is compressed end to end then it is very strong, but when squeezed on its side the straws cannot support much and folds flat. Engineers need to know how to use the building materials they are given so a balance of tension and compression can support the loads that the structure will be under.

What do engineers do? *Explain that engineers design and build things. (There are many different types of engineers. One type, a structural engineer, designs buildings, roads, bridges, and tall towers.)*

Have you ever been inside a tall tower of any kind? *If yes, where, and what was it like? (Children's choice. Children may have been in skyscrapers or in iconic towers such as the Space Needle in Seattle or the Empire State Building in New York City.)*

Have you ever built a model tower? *If yes, what building materials did you use? (Children's choice. Children may have built towers with unit blocks, Lego® bricks, rocks, K'Nex® building toys, or other building materials.)*

What things do you think engineers have to think about when they are designing and building a tower? *(Some examples include how to reach the required height, how to achieve balance, how to make the base wider than the top, how to make the tower sturdy enough to withstand wind, and what design to use so the tower is good to look at.)*

SCIENCE talk

COMPRESSION: The force of squeezing or pressing something together.

DEAD LOAD: The weight of structural components that remain relatively permanent over time, including the structure itself and immovable fixtures such as walls and carpet.

ENVIRONMENTAL LOAD: The impact of weather, topography, or other natural phenomena on a structure.

FORCE: A push or a pull.

GRAVITY: An invisible force that pulls objects toward the center of Earth.

LIVE LOAD: The weight of structural components that are temporary, of short duration, or movable. Furniture, planters, and people are examples of live loads.

STRUCTURAL ENGINEER: A trained professional who uses math and science to build structures that support or resist loads.

TENSION: The force of stretching or the condition of being stretched.

TOWER: A building or structure that is higher than its length or width.

what YOU WILL NEED & before YOU BEGIN

- **30 Straws per group**
- **30 Paperclips per group**
- **3 Feet of tape per group**
- **Paper bag to hold materials for each group**
- **Drawing paper**
- **Pencils**

Find a flat area for where small groups can build their towers. Bag the supplies each group will have to work with.

EXPLORE & EXPERIMENT

1. **Have the group split** into small engineering teams.

2. **Explain to the following to teams:**

   - ☐ They have just all become structural engineers for the day.
   - ☐ Their design challenge is to build the tallest tower they can with the building supplies that they are given.
   - ☐ The towers must be freestanding and must not use anything but the floor for support.
   - ☐ Each tower must be able to stand up on its own unsupported for at least ten seconds.

3. **Show each team the building supplies that they will have available:** 30 straws, 30 paper clips and 3 feet of tape. Invite the group members to pick up and examine a straw.

4. **Ask the kids what they think the strengths and weaknesses are** of using straws as a building material.

5. **Explain that any structure must support its load** by balancing the forces of tension and compression.

6. **Define and explain compression.** Tell the groups that straw can be compressed two different ways – on its ends and on its sides. Ask the groups which way the straw can hold more weight.

7. **Have the groups bend their straws into an arch and explain tension.** Explain how an arched straw can support more weight on its the sides than a straight straw, because when the sides are under tension they are harder to compress. When a straw is arched the tension in it redirects any downward force along the length of the straw and out to the ends.

8. **Ask the groups what they think is the best way to join their straws together for building?** The straws can simply be taped together, slid together or joined with a paper clip as shown below.

Open a paperclip up and push a straw on to each of its ends. The ends can be squeezed together or opened to ensure a tight fit.

Two straws can be joined together by pinching the end of one straw and sliding into the other one.

9. **Have each group retrieve** a piece of paper and pencil.

10. **Challenge each team to come up with a design** that they think will enable them to create the tallest tower.

11. **Promote discussion** by going around to each group and asking questions about their designs and how they are going to support the load with compression and tension.

(continued...)

12. **After each team has finalized a design** hand out the bags of building supplies and give an appropriate amount of time for the groups to build their towers. Remind everyone that designs can be tweaked and changed until they are successful.

13. **When time is up, have the engineering teams share their towers with the entire group.** The groups should explain their designs and whether they had to make any changes to their original designs in order for their towers to stand. After each groups shares, have the young people in the group count to ten to make sure the tower meets the freestanding requirement.

14. **Have a competition to determine:**

- ☐ Which tower will stay standing the longest?
- ☐ Which tower is the tallest?
- ☐ Which tower used the least amount of straws?
- ☐ Which tower is the most eye catching?

make THE CONNECTION

Bring in books or photos and description of towers or provide computer and internet access and invite young people to research different designs all over the world have been used to build tall towers. Each team can be challenged to pick a tower to present to the rest of the group.

THE EIFFEL TOWER, one of the most famous towers in the world, was designed by Gustave Eiffel (1832-1923), a French engineer who specialized in metal structures. Revolutionary for its time, the Eiffel Tower was built completely from iron. Eiffel wanted to demonstrate that iron was a viable building material, as strong and as stable as stone, but infinitely lighter. The Eiffel Tower was completed in 1889, and at 986 feet tall, it was the tallest building in the world until the completion of the Chrysler Building in New York City in 1930. For more information about the Eiffel Tower along with photos visit http://www.toureiffel.paris/en.html

The builders of the **LEANING TOWER OF PISA** Italy did not intend for the tower to lean. The tower started out on level ground when construction began in 1173, but by the time the builders reached the third floor in 1178 they realized the tower's foundation was sinking. The foundation's stones had been laid on soft ground containing clay, sand, and shells, which sunk as it was compressed by the tower's weight. Today, the eight-story tower is over five meters off perpendicular. For more information about the Tower of Pisa along with photos visit http://www.towerofpisa.org/

ONE WORLD TRADE CENTER (also known as the Freedom Tower) is the main building of the rebuilt World Trade Center complex in Lower Manhattan, New York City. It is the tallest building in the Western Hemisphere and the sixth-tallest in the world. The building reaches a total height of 1,776 feet. Its height is a deliberate reference to the year when the United States Declaration of Independence was signed. For more information about One World Trade Center along with photos visit https://www.wtc.com/about/buildings/1-world-trade-center

The world's tallest skyscraper is the **BURJ DUBAI** in Dubai, United Arab Emirates. It uses Y-shaped cross sections to support a central tower. This structural design makes the building very rigid. At approximately 2,716 feet tall and containing 162 floors, the building rises nearly one half mile into the sky. As a point of comparison, the Empire State Building in New York City is just over 1,200 feet tall. For more information about Burj Dubai along with photos, visit www.burjdubaiskyscraper.com.

EXTEND & EVALUATE

CHALLENGE THE KIDS TO USE PAPER AND DRAWING TOOLS TO DESIGN A NEW FUTURISTIC TOWER FOR YOUR HOME TOWN. HAVE THE CHILDREN THINK ABOUT NOT ONLY THE STRUCTURAL DESIGN, BUT THE USE FOR THE TOWER AND ITS AESTHETICS:

Is the tower going to be a tourist attraction or a practical building like a school? • How does the design make it strong? • How does light get in? • What is it made from? • How do people get in and out and around the tower? • What will be used to make the tower environmentally friendly? • What design elements could be added so people want to visit or work in the tower?