Freestanding Structures

Design Challenge Learning

The Tech Museum of Innovation

201 S. Market St.
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thetech.org

Students work together to design the tallest structure that can be built utilizing only the materials provided. As they iterate through this design challenge, they gain firsthand experience in the design process.

Grades 3-8
Estimated time: 30 minutes

Student Outcomes:

1. Students will be able to design and build a stable structure utilizing limited materials.
2. Students will be able to discuss their design considerations based on concepts of elasticity, tension, torque, compression, force, and shape.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

Next Generation Science Standards
Grade 3-5: *Engineering Design* 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
Grade 6-8: *Engineering Design* MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4

Common Core Language Arts-Speaking and Listening
Grade 4: SL.4.1b-d, SL.4.4a
Grade 5: SL.5.1b-d, SL.5.4
Grade 6: SL.6.1b-d
Grade 7: SL.7.1b-d
Grade 8: SL.8.1b-d

Vocabulary:

Familiarity with these terms and concepts will enhance students' experience in the activity

- Buckling: When a material bends under compression.
- Compression: When a force pushes materials together.
- Elasticity: The property of a material to bend or deflect, and then return to its original shape.
- Force: Any influence that tends to accelerate an object; a push or a pull.
- Load: The weight which a building or structure must carry.
    - Dead Load: The weight of the building itself plus all permanent fixtures; does not change.
    - Live Load: Weight of the objects which move in, out, or shift in the building (people, furniture, etc.); constantly changing.
- Plasticity: The property of a material in which it does not return to its original form after a bend or deflection.
- Shear: When a force slides materials against one another.
- Tension: When a force pulls materials apart.
- Torque: When a force twists materials.

Resources:

- Building Big: A website curated by PBS. It includes information on building large structures, challenges, interactive labs, educator guides, and the shows in the series. While it covers a range of structures, it includes an extensive section specific to skyscrapers. www.pbs.org/wgbh/buildingbig/index.html

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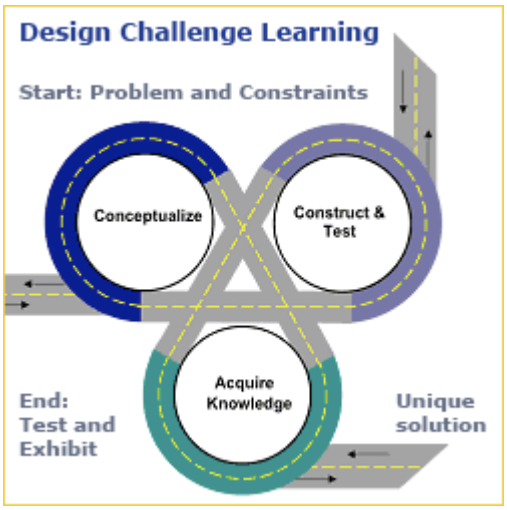
- How Skyscrapers Work: An article by Tom Harris from "How Stuff Works" that describes the history, science, and engineering feats of the tallest structures in the world. http://science.howstuffworks.com/engineering/structural/skyscraper.htm

Design Challenge Process:

The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects.



The process consists of three interconnected steps:

Conceptualize
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

Construct and Test
- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

Acquire Knowledge
- Research
- Share solutions
- Reflect and discuss

Through the try, fail, learn approach, students develop the skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure.

Materials:

Engineering Team Materials (for 2-3 Engineers):
- 20 3/8" x 36" Wood Dowels
- Unlimited Rubber Bands
- Tape Measure

Lesson Plan:

Introduction (3 minutes)
1. Think about the tallest building you have seen. What did it look like? What was it made of? How do you think civil engineers are able to build these tall structures?
2. Today you are in charge of designing a new skyscraper, but the people who have hired you only have limited materials. What would your structure look like? What materials would you use? Can you build the next great structure?

Design Challenge (15 minutes)
1. Introduce the Challenge: Design the tallest structure possible that can stand on its own, using only rubber bands and 20 dowels.

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2. Introduce the Constraints:
    - All 20 dowels must be used in the structure.
    - Only rubber bands may be used to connect the dowels.
    - Height must be measure vertically.
    - The structure must be free standing; it cannot be strapped to another structure or fixed to the ground.
3. Build: Give students about 15 minutes to build and test. The instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker.

Demonstration and Reflection (12 minutes)

1. Demonstration: Have students demonstrate and measure their devices one team at a time. Engineering teams should present from their build station.
2. Reflection: Each team should present on their unique design and why the design was successful (or not successful). The instructor should ask questions to help guide teams toward the teaching points.
    - Teaching Points:
        - Force is a push or a pull; any influence that tends to accelerate an object.
        - Building stability is influenced by: shear, tension, torque, compression, support/reinforcement, shape (use of triangles), weight (heavy at the base, light at the top), and size (wide at the base, narrow at the top).
        - There is more to designing something than building it. You must consider the resources available and the limitations of a design.
        - Brainstorming, testing, and teamwork are important to a successful design process.
    - Questions:
        - Are there different ways to use the rubber bands?
        - What kinds of shapes do you most often see in buildings?
        - Are there other shapes that might work well?
        - How can you make it more stable?
        - What are some ways you can use the materials to provide support for your structures?
        - What do you think might happen to your structure in an earthquake?
        - How would your design change if you were given more or less dowels?
        - What changes would you make if your structure had to support a book on the top?
3. Discussion: Discuss how scientists and engineers go through this Design Challenge process on a daily basis; learning from their mistakes, reflecting and improving upon what they have designed.

Extensions

1. Repeat the design challenge but introduce a load (e.g. a book) to include in the design.
2. Repeat the design challenge, investigating how building on different surfaces influence design choices. Have students investigate different properties of surfaces around the school and then build in these unique locations: grass, sawdust, sand, blacktop, tile, carpet, wood, concrete, rubber, etc.
3. Repeat the design challenge and then have the students test their structures against an earthquake. Produce a large shake table by placing a sheet of plywood on skateboards or on top of balls.